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

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## Abstract

Currently, Peruvian textile companies have played a very important role in the national economy, therefore, they are constantly seeking to implement production design strategies that allow them to obtain optimum efficiency. Accordingly, this scientific paper aims to increase efficiency in the finishing area by implementing a production model based on Lean-TPM. The results obtained can be of great value for textile industries, especially for those who wish to improve the efficiency of their operations, avoid waste and increase productivity. Therefore, the commitment to adopt new ways of working starts from the highest levels of management down to the operators, and it is important to integrate all members of the production team, because it will lead to achieve great economic benefits and be more competitive in the textile market. This article refers to the implementation of autonomous maintenance based on lean six sigma in a fabric production company where an increase from 78% to 80% in the efficiency of the finishing area was achieved.

## Keywords
Textiles, TPM, machine downtime, time study, efficiency

## 1. Introduction
Internationally, China is considered the world's largest textile manufacturer with a global share of 39.2% in 2019, being the sixth largest energy consumer and the third largest discharger of wastewater, where the economic growth of textile industry is achieved by competing for energy consumption as well as ecological depletion (Gai et al., 2022). The textile industries in China consider the availability of machinery, the availability of manpower, and the willingness of labour to minimise costs as fundamental capital for the development of operations (Dong et al., 2022). As well as the managers of textile industries in Honduras are reluctant to maintain adequate knowledge of the methods that guarantee the order of industrial procedures, since employees share a mentality that working without any rules makes them more efficient (Mohan et al., 2020). Also, industries in the Americas face great challenges in minimising operating costs due to market inconsistency, competition and external demands (Mbogo, 2019). At the national level, the textile sector is a highly competitive market and is considered one of the main economic engines of the country, providing more than 463 thousand jobs represented by 7.4% of GDP (Barzola et al., 2021). Therefore, the economic challenges it faces are based on the increasing global competition in the perspective of production, management and technological processes, as well as consumer expectations (Sourav et al., 2020).

It is of great importance to consider the Lean methodology in the production processes of the textile sector, since many of the companies lack specialised human resources that allow a correct performance in the main processes (Vieria et al., 2018). The development of textile industries has allowed competition to become more acute, due to the fact that, in order to maintain a competitive position, it is necessary to keep their production effectiveness at the highest level (Sakti et al., 2019). On the other hand, to increase efficiency in textile industries, it is required to reduce manufacturing defects and the time to manufacture the product, highlighting the Lean methodology for the reduction of waste generated in the manufacturing process, so as to reduce the cost and value added to the product (Yashini, 2020). In such a way, autonomous maintenance allows overcoming economic losses, generated by machinery breakdowns, based on performance indicators, availability and their effectiveness. (Nurprihatin et al., 2019). The growing competitiveness generated in the textile sector industries is causing slow growth since it leads to losses represented in the last 2 years, pointing out that it is necessary to analyse the current production system based on the Lean methodology (Huamaní & Álvarez, 2020). Therefore, globally, 86% of textile industries have integrated Lean thinking in order to overcome low production levels (Dong et al., 2022). There is also a need for automation of material handling within the production unit in order to gain benefits in terms of increased production with automated handling management processes as well as reel transport (Shree et al., 2018). Textile industries often employ Lean manufacturing strategies because they have highly flexible automated machinery with high volume of low product variety (Mohan et al., 2020).

According to the research reviewed, there is little information on Lean-TPM working models applied in the textile industries in Latin America. For this reason, the need to develop the present study arises. The aim of the research is to demonstrate that applying the Lean - TPM based production method increases the efficiency of the finishing process in textile companies.

The scientific article is structured as follows: literature review, in which the theoretical framework of the problem to be studied is reviewed by means of studies carried out by other researchers. Method shows the type of study, through the analysis of the model and its detailed description by indicators; followed by the validation section, which details the results of the evaluations carried out, the implementation and finally the conclusions regarding the stated objectives.

### 1.1 Objectives

The study aims to demonstrate that applying the production method based on Lean - TPM increases the efficiency of the finishing process in textile companies, firstly, the unproductive times and reprocesses generated in the finishing process will be identified through the time study; secondly, TPM and the 5's will be applied on the fabric finishing process and finally the technical and operational feasibility of the implementation of these will be identified.

## 2. Literature Review

### 2.1. Lean Model - TPM

The Lean - TPM model comprises a methodology that ensures the expected availability and reliability of operations, equipment and the system by applying concepts for prevention, zero defects, zero accidents and full participation in all operations (Waqar et al., 2019). Full participation is based on traditional preventive maintenance activities, where it is carried out not only by maintenance personnel, but also by trained and multi-skilled production personnel (Ince et al., 2018). The periodic planning of maintenance work is incorporated under the concept of equipment improvement, with the aim of counteracting the occurrence of failures, taking advantage of the operator's knowledge (Flores et al., 2019).

### 2.2. Lean Manufacturing in the textile industry

The Lean Manufacturing methodology is based on a systematic approach to achieve the shortest possible cycle time by eliminating process waste through continuous improvement, thus making the operation highly efficient and only consisting of value-added steps from start to finish (Shalini et al., 2018). Furthermore, such a methodology seeks to ensure lean and productive production, providing an increasingly competitive scenario to remain active in the market (Mohan et al., 2020). However, it enables organisations to utilise the maximum resource by reducing waste, making the activity value-added (Deshmukh et al., 2022).

### 2.3. TPM

Total Productive Maintenance allows reducing the main losses that are considered significant in production processes, these include losses due to equipment failures, configuration losses, as well as adjustments due to high downtime losses, start-up losses and losses due to defects (Peralta et al., 2020). At the same time, it has fundamental pillars such as autonomous and preventive maintenance, which are key to achieving an increase in the efficiency of equipment in any production process, as well as other pillars such as planned maintenance, quality maintenance, education and training, safety, health and environment, office TPM and development management (Tortorella et al., 2021). In this way, it is based on a Lean tool that promises continuous and rapid improvement in the manufacturing process, involving workers by training them in the use of preventive methods with maintenance concepts (Dennis et al., 2018).

### 2.4. Standardised work in the textiles sector

The implementation of standardised work with information systems improves the effectiveness and accuracy of standardised times, making the method suitable for waste reduction in the textile industry (Hin & Cheng, 2022). In another study, the authors suggest that textile companies should follow a methodology aimed at counteracting situations such as process variability, the lack of a detailed sequence of work procedure as well as the great diversity of products by using the standardised working method (Meca & Camello, 2020).

### 2.5. Methodology 5'S

The 5's, is considered the most qualified Lean tool for use in companies that follow known standards, with the purpose of obtaining an international qualification, based on Seiri, Seiton, Seiso, Seiketsu and Shitsuke, which facilitate the development of work because it creates an orderly and clean working environment within the organisation (Palange & Dhatrak, 2021). The 5's tool is useful in the implementation of sorting, organising, cleaning and other basic requirements required at the ground level for the improvement of the work environment, which in turn improves the level (Kumar et al., 2022).

The 5's comprises of the initials of five Japanese words, which represent each of the five component stages, such as Seiri, which is based on removing all unnecessary tools and parts. Seiton, allows to organise work, labour, equipment, parts and instructions in such a way as to work without inefficiencies. Seiso involves cleaning the workspace and all equipment (Gai et al., 2022). Seiketsu ensures that procedures and settings throughout operations promote interchangeability. Shitsuke becomes a way of life, as it ensures disciplined compliance with rules and procedures (Jimenez et al., 2018).

## 3. Methods

The current study is a case study, because it is based on a specific topic, in this case a textile industry, and mixed methods are used to analyse the textile industry. According to Hernández (2018) points out that a case study focuses on analysing in depth the nature of a given situation or case, under various study techniques.

With respect to the diagnosis of the fabric production process, a high unproductive time can be identified, of which the time for cleaning and maintenance in the finishing area is the most considerable, this was managed to be closely related to the time of the activities, the designation of the activities to the personnel involved and the use of the material resources employed. Therefore, the diagnosis of the situation of the finishing area of the company, a tree diagram was elaborated with the purpose of identifying the different causes, as well as the consequences of the main problem which would be the efficiency of the area.

According to the analysis of the problem tree in the diagnostic phase, it was identified that the main causes are the lack of a cleaning and preventive maintenance plan, the low participation of the machine operator in these activities, the lack of standardised procedures, and the fact that there is no programme and planning schedule for carrying out these activities, Therefore, the operators were not informed and there is no established timetable. Likewise, there are processes that are carried out consecutively when they could be done simultaneously, in order to optimise time, counteracting the lack of tools and necessary material resources that imply inefficient management in the study process.

Once the main causes and problems had been identified, it was possible to analyse solutions and tools to be applied to improve the indicators that have a significant impact on the process, where it is hoped that the application of these will reduce downtime and thus improve the efficiency of the study area. The variables that have been directly identified with the efficiency of the process are the time of the activities, the capacity of the operator to carry out each activity, reduce downtime, increase production capacity and reduce costs. In view of this, Figure 1 shows the model proposed for the development of the implementation proposal.

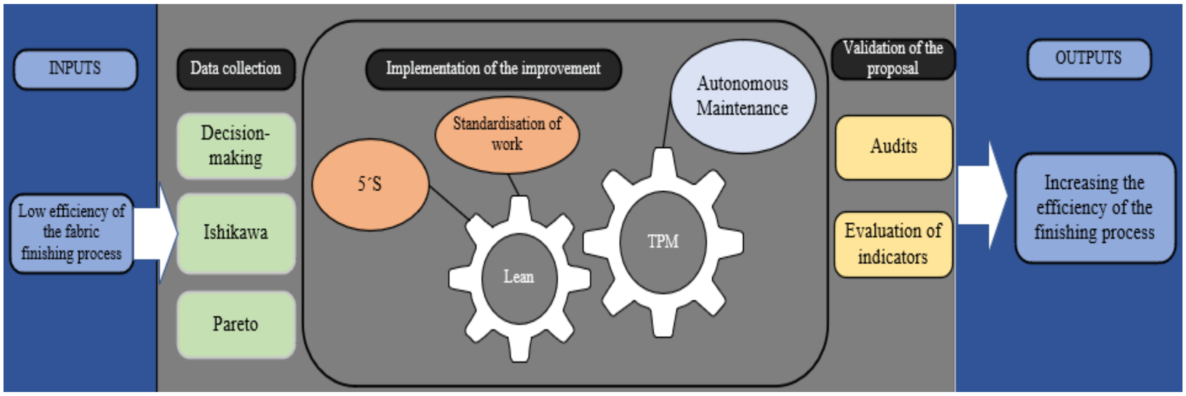


Figure 1. Proposed model

### 3.1. Information on the study process

The finishing process, in the textile industries, is the last process of fabric manufacturing before storage, where machines called branches are used. In this process the drying and finishing of the fabric is carried out, and according to the programming of the parameters gives it certain characteristics such as appearance to the touch and behaviour.

## 4. Data collection

The data collection consisted of obtaining and measuring information from various sources that will allow a complete evaluation, where a series of tools such as surveys and interviews were used to receive information on the activities and techniques carried out in the fabric production area, as well as the Pareto to determine the most critical problems in the area and the problem tree to identify the main causes. Once the information was collected, it was determined that it was feasible to use tools such as autonomous maintenance concerning a pillar of TPM, 5's, standardised work and within it the time study. Figure 2 shows the step-by-step process to obtain the results of this research.

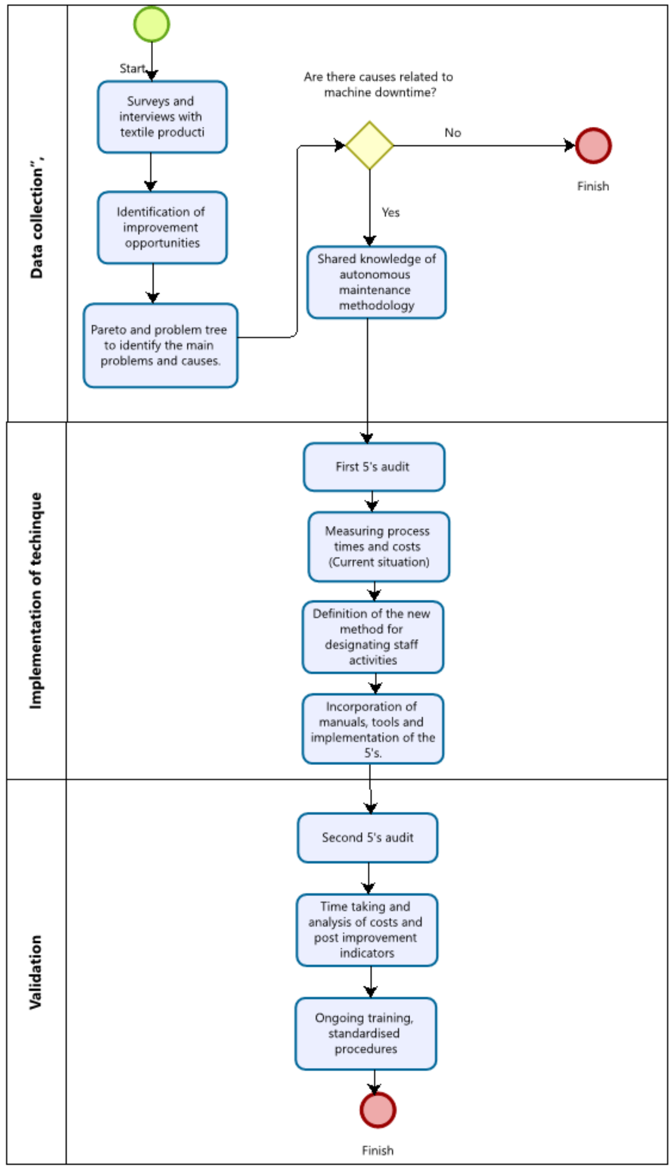


Figure 2. Diagram of the results

### 4.1. Implementation of 5S, Autonomous Maintenance and Standardisation of Work

The 5S's consist of five steps: sorting, ordering, cleaning, standardising and discipline. For this project, we will combine autonomous maintenance in the third phase and standardisation of work in the fourth phase.

a. Sorting: Unnecessary items in the work area such as worn out rags, worn out blades, bad cables, plastic bags, defective parihuelas and fabric scraps were removed.
b. Tidying up: Visual controls were used for the correct location of the elements, in order to order and identify all the materials in the work area and the correct preparation for the cleaning and preventive maintenance process.
c. Cleaning and autonomous maintenance: This phase is combined with autonomous maintenance, since, according to Lean Manufacturing theory, cleaning is synonymous with inspection.

According to the time recording system of the finishing machine, the average downtime for cleaning and preventive maintenance, i.e. from the time the machine is empty until it is reloaded with production, is 9 hours and 53 minutes. For the analysis of the activities, a time study was carried out in which, by means of the relevant calculations, the standard time for each activity was obtained. With this, the analysis of activities that could be eliminated, combined, ordered and simplified could be carried out. With the aim of applying autonomous maintenance, which involves training the operators in the maintenance and cleaning activities of the machines, reducing machine downtime and making the personnel more efficient and trained.

Table 1 shows the cleaning and preventive maintenance programme in a branch with the standard time for each activity before the improvement. The people involved are a mechanical technician, cleaning staff and machine operators, with the latter having almost no involvement.

Table 1. Standard time for cleaning and preventive maintenance activities before upgrading.

| No | Operation | Start time | Standard T. before upgrading | Time end | Activity manager |
|---|---|---|---|---|---|
| 1 | Machine without load | 6:00 | 0:45 | 6:45 | Branch Operator |
| 2 | Switching off burners | 6:45 | 0:05 | 6:50 | |
| 3 | Machine cooling | 6:45 | 1:30 | 8:15 | Branch Operator |
| 4 | Foulard cleaning | 6:51 | 0:20 | 7:11 | Branch Operator |
| 5 | Removing nozzles | 8:25 | 0:42 | 9:07 | Maintenance technician |
| 6 | Dismantling of extractors and dampers | 8:32 | 1:03 | 9:35 | Cleaning operator |
| 7 | Removing and cleaning filters | 8:45 | 0:35 | 9:20 | Cleaning operator |
| 8 | External cleaning of roof and fields | 9:21 | 1:38 | 10:59 | Maintenance technician |
| 9 | Cleaning of gumming machines | 9:36 | 1:28 | 11:04 | Cleaning operator |
| 10 | Internal cleaning of nozzles | 11:00 | 0:58 | 11:58 | Maintenance technician |
| 11 | Assembly of extractors and dampers | 11:30 | 0:44 | 12:14 | Cleaning operator |
| 12 | Internal cleaning of fields | 11:59 | 1:02 | 13:01 | Maintenance technician |
| 13 | Final technical overhaul | 12:15 | 0:16 | 12:31 | Branch operator |
| 14 | Fitting filters | 13:05 | 0:26 | 13:31 | Branch operator |
| 15 | Installation of nozzles | 13:32 | 1:15 | 14:47 | Branch Operator |
| 16 | Heating | 14:48 | 1:05 | 15:53 | |

On the other hand, in order to be able to carry out cleaning and preventive maintenance in a safe way, the sources of dirt, places of difficult access and risk areas will be identified in order to have informed and trained personnel.

d. Standardisation of work: With regard to safety, the symbols of the EPPS, implements necessary for the cleaning and preventive maintenance of the machine will be placed.
   Another standardisation is the creation of Lessons at a Point (LUP), which are graphic procedures that help to streamline operations and avoid errors, as well as having a standard for operations.
e. Discipline: In the last phase, emphasis will be placed on ensuring that employees are able to comply with the previous 4 phases, through constant training over time and recognition of employees who promote the 5Ss in their work area. Periodically, an internal audit will be carried out to ensure that this tool is complied with.

**Numerical time and cost analysis**
The following has been considered to define the quantity produced before upgrading:

1. The average downtime for cleaning and initial preventive maintenance according to the machine records is 9 hours and 53 minutes. This process is carried out twice a month in each branch as a preventive measure.
2. There are 3 working days of 21 effective hours in total.

Given these conditions, we proceed to calculate the indicators for a day of cleaning and preventive maintenance.
Effective time = 21 h/day x 60 min/hour = 1,260 min/day
Branch availability = Effective time - Time for cleaning and preventive maintenance = 1260 min/day - 593 min/day = 667 min/day.

Production of one branch = 18 m/min x 667 min/day = 12,006 m/day
Efficiency of the finishing area = 78%.
Table 2 below shows the costs in sols involved in downtime for cleaning and preventive maintenance prior to upgrading.

Table 2. Cost per cleaning stoppage - preventive maintenance

| Material / Personnel | Quantity | Unit | Cost (S/.) | Unit cost (S/.) | Quantity | Requirement per process | Unit | Cost per requirement (S/.) |
|---|---|---|---|---|---|---|---|---|
| Wipes | 20 | unit | 18,9 | 0,95 | | 5 | unit | 4,73 |
| Electricity | 1 | KWh | 0,8 | 0,80 | 4 | 4,6 | hour | 14,72 |
| Compressed air | 1 | Kg/h | 0,2 | 0,20 | 4 | 4,6 | hour | 3,68 |
| Cleaning personnel | 1 | hour | 5,5 | 5,50 | 4 | 4,2 | hour | 92,40 |
| Mechanical personnel | 1 | hour | 8 | 8,00 | 2 | 3,5 | hour | 56,00 |
| Operating personnel | 1 | hour | 5,6 | 5,60 | 3 | 2,8 | hour | 47,04 |
| | | | | | | | | 218,57 |

## 5. Results and discussion

The application of the improvement for the reduction of non-productive time in the fabric finishing process was carried out for 1 month, during which time the guidelines and work techniques for each activity were provided, considering that the quality of production is equal or superior, and it is important to emphasise that the personnel received training and manuals for carrying out the new designated activities. The results of the pilot test are shown in table 3, where it can be seen that downtime was reduced to 6 hours, i.e. by 39%.

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

| No | Operation | Start time | T. standard after upgrading | Time end | Activity manager |
|---|---|---|---|---|---|
| 1 | Shutting down burners | 6:00 | 0:05 | 6:05 | Branch operator |
| 2 | Machine cooling | 6:05 | 1:30 | 7:35 | |
| 3 | Foulard cleaning | 6:06 | 0:19 | 6:25 | Branch operator |
| 4 | Removing and cleaning filters | 6:26 | 0:25 | 6:51 | Branch Operator |
| 5 | Gumming machine cleaning | 6:52 | 1:25 | 8:17 | Branch Operator |
| 6 | External cleaning of roof and fields | 8:17 | 1:15 | 9:32 | Cleaning Operator |
| 7 | Nozzle removal and overhaul | 8:18 | 0:36 | 8:54 | Branch Operator |
| 8 | Dismantling of extractors and gates | 8:30 | 1:00 | 9:30 | Maintenance Technician |
| 9 | Internal cleaning of nozzles | 8:55 | 0:49 | 9:44 | Branch Operator |
| 10 | Internal cleaning of fields | 9:31 | 0:59 | 10:30 | Cleaning Operator |
| 11 | Installing filters | 9:45 | 0:15 | 10:00 | Branch Operator |
| 12 | Assembly of extractors and dampers | 10:04 | 0:44 | 10:48 | Maintenance Technician |
| 13 | Assembly of nozzles | 10:02 | 0:55 | 10:57 | Branch operator |
| 14 | Final technical check | 10:49 | 0:10 | 10:59 | Maintenance Technician |
| 15 | Machine heating | 11:00 | 1:00 | 12:00 | Activity manager |

With the new times found, after the proposed improvement to the textile factory under study, we can calculate the new efficiency and production capacity, remembering that the following must be considered:

1. The average downtime for cleaning and preventive maintenance after upgrading is 6 hours. This process is carried out twice a month in each branch as a preventive measure.
2. There are 3 daily shifts of 21 effective hours in total.

Given these conditions, we proceed to calculate the indicators after the improvement in one day of cleaning and preventive maintenance.

Effective time = 21 h/day x 60 min/hour = 1260 min/day

Branch availability = Effective time - Time for cleaning and preventive maintenance = 1260 min/day - 360 min/day = 900 min/day.

Production of a branch = 18 m/min x 900 min/day = 16,200 m/day

The calculations show an improvement in the reduction of downtime, higher machine utilisation and a higher production of fabric, since considering the 4 branches available, up to 33,552 metres more can be produced in a month, i.e. an additional income of 306,761 soles per month or 3,681,134 soles per year.

The indicators were recalculated to corroborate the impact of the reduced stoppage on the efficiency of the area. In the fourth quarter of 2021 it was estimated that 4,800,00 metres were produced, of which 3,749,583 metres were produced, but with the proposed improvement it would be 3,850,239 metres in the same period.

At the end of the pilot test of applying the 5S, it can be seen in Figure 3 that the company obtained a result that is not far from the expected ideal situation, since with the evaluation that we initially carried out, the workers were not trained for the new tasks, they were not organised with the engineering and maintenance area, they wasted materials and sometimes their tools were incomplete or defective. Therefore, we conducted training and informed the supervisor and workers of this methodology and other engineering tools.

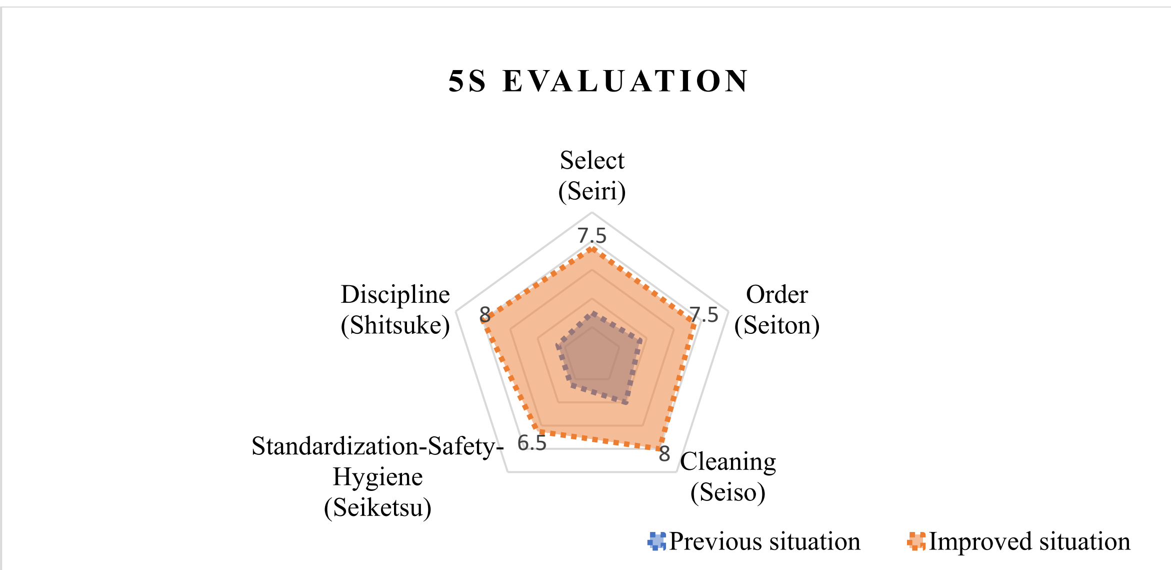


Figure 3. Assessment of the 5's

Table 4 shows the costs in soles involved in downtime for cleaning and preventive maintenance after the upgrade.

Table 4. Cost of downtime for cleaning - preventive maintenance

| **Material / Personnel** | **Quantity** | **Unit** | **Cost (S/.)** | **Unit cost (S/.)** | **Quantity** | **Requirement per process** | **Unit** | **Cost per requirement (S/.)** |
|---|---|---|---|---|---|---|---|---|
| Wipes | 20 | unit | 18,9 | 0,95 | | 5 | unit | 4,73 |
| Electricity | 1 | KWh | 0,8 | 0,80 | 4 | 3,5 | hour | 11,20 |
| Compressed air | 1 | Kg/h | 0,2 | 0,20 | 4 | 3,5 | hour | 2,80 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Cleaning personnel | 1 | hour | 5,5 | 5,50 | 3 | 2,2 | hour | 36,30 |
| Mechanical personnel | 1 | hour | 8 | 8,00 | 1 | 1,9 | hour | 15,20 |
| Operating personnel | 1 | hour | 5,6 | 5,60 | 3 | 4,8 | hour | 80,64 |
| | | | | | | | | 150,87 |

## 5.1. Cost analysis

With the analysis of the data obtained, the cost benefit is 541.60 soles for cleaning and preventive maintenance per month. This result is considerable, as the proposed investment for the necessary changes in the process is low compared to the additional profits that the organisation would have annually. The investment is 9,538 soles, this amount refers to the purchase of tools and personnel that will facilitate our work at each stage of the 5S implementation and autonomous maintenance. These tools are hoovers, electrical extensions, head torch, protective gloves, hand torch, hand spatula, tapes, pencils, steel shelf to organise machine accessories, symbolised tool panel, highlighting labels and filing cabinets. Finally, the use of man hours in the implementation of tools and signage in the work area, training and audits.

## 5.2. Validation

The proposed model was validated through the implementation of a pilot test lasting 1 month, analysing a total of 8 cleaning and preventive maintenance processes between February and March 2022. With the new data obtained after the implementation, the proposed indicators were calculated, resulting in the following percentages:

Table 5 shows the current vs. improved indicators, indicating that at the end of the implementation, results were obtained regarding machine availability, production of a branch and efficiency, surpassing the objectives set by the organization.

Table 5. Comparison of indicators between scenarios

| **Indicators** | **Initial situation** | **Objective** | **Improved situation** |
|---|---|---|---|
| Machine availability | 667 min/day | | 900 min/day |
| Machine availability | 53% | 70% | 71% |
| Production of a branch | 12,006 m/day | | 16,200 m/day |
| Efficiency | 78% | 80% | 80% |

Efficiency: Efficiency increased from 78% to 80% due to the increase in metres of fabrics processed over the estimated metres of fabrics processed by the fourth quarter of 2021. The proposed target was achieved and there is room for further improvement with the help of different engineering tools.

Downtime for cleaning and preventive maintenance: This decreased by 39%, from 9 hours 53 minutes to 6 hours with the 5S methodology and autonomous maintenance. With this indicator we came very close to our target and a significant amount of downtime was transformed into production time.

# 6. Conclusions

The analysis carried out in a Peruvian textile company fulfilled the general objective that we had set at the beginning of this study, which was to reduce the unproductive times that were generated during the fabric finishing process and thus improve the efficiency of the fabric finishing area. The commitment to adopting new ways of working starts from the highest levels of management down to the operators, and it is important to be clear and integrate the whole team, as it will achieve great benefits and be more competitive in the textile market.

It is important to have the historical information of the machine, in order to re-evaluate the indicators and in this way propose the integration of engineering tools to be adapted as a model that can be replicated and contribute to maintenance management.

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**Martín Collao-Diaz** 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 nationaland multinational companies in industrial, hydrocarbon, and mass consumption sectors. Broad experience in supply chain management (purchasing, inventory, suppliers and supply sources management, logistics: transport, distributionand warehouse management), operations (planning and control of production and maintenance), and integrated systemmanagement (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).

**Juan Carlos Quiroz-Flores** holds an MBA from Universidad ESAN. Industrial Engineer from Universidad de Lima. PhD. in Industrial Engineering from Universidad Nacional Mayor de San Marcos, Black Belt in Lean Six Sigma. He is currently an undergraduate professor and researcher at the University of Lima. Expert in Lean Supply Chain and Operations with more than 20 years of professional experience in the direction and management of operations, process improvement, and productivity; specialist in implementing Continuous Improvement Projects, PDCA, TOC, and Lean Six Sigma. Leader of transformation, productivity, and change generation projects. Able to form high-performance teams aligned with the company's "Continuous Improvement" strategies and programs. He has published articles in journals and conferences indexed in Scopus and Web of Science. His research interests include supply chain and logistics management, lean manufacturing, lean six sigma, business process management, agribusiness, design work, facility layout design, systematic distribution planning, quality management, Industry 4.0, Digital Transformation, and Lean Manufacturing. He is a classified researcher by the National Council of Science, Technology and Technological Innovation of Peru (CONCYTEC) and a member of IEOM, IISE, ASQ, IEEE, and CIP (College of Engineers of Peru).