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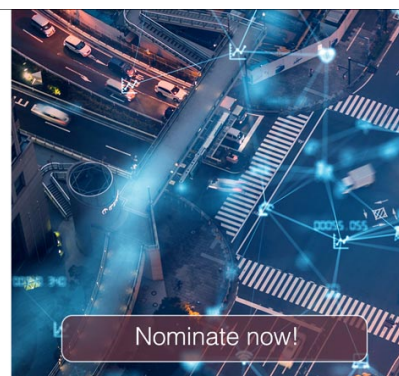


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LEAN maintenance model based on change management allowing the reduction of delays in the production line of textile SMEs in Peru

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Abstract. This article examines the problem of production line delays in a textile small- and medium-sized enterprise (SME) that produces polyester fibre from recycled bottles, based on orders. Factors that have resulted in production line delays include prolonged unscheduled maintenance time, and preparations and adjustments prior to operating the equipment. To address the problem, a model was developed applying lean manufacturing tools through change management, with the aim of increasing equipment availability and useful life. To validate the model, a pilot was developed to determine how the increase in equipment availability helps reduce delays in the production line, which eventually improves completion of customer orders.

1. Introduction

The 2009 global economic crisis originated in the United States and had a significant impact worldwide. Peru was no stranger to this situation, and thus, in the following years, the country went through a process of readjustment. Over the last three years, Peru has remained in the 50th place in terms of gross domestic product, and in Latin America, it is in the 6th place. [1] The textile industry in Peru is not properly developed, owing to reasons such as the lack of innovation in its products and processes or the scarce support from the state for small- and medium-sized enterprises (SMEs). [2] The percentage of participation in textile manufacturing has decreased from 3.72% to 3.31% [3], which suggests that the Peruvian textile industry does not have a strong presence in the international market [4]. These types of companies, which use automated machinery, frequently have problems completing their orders on time, resulting in customers seeking other alternatives, mainly abroad.

For this reason, adequate maintenance management based on lean manufacturing tools will benefit production in such a way that it increases the availability of the machines to start the productive process, thus optimizing associated costs.

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2. State of The Art

2.1. Change Management

People's behaviour is an integral part in any process a company wants to execute or improve. The ADKAR Model serves as an objective-oriented change management model, which can be applied to a personal or organizational context. The model can be applicable to make a successful change for 1 person, 20 persons, 1,000 persons, or for the entire organization, which contributes to standardization. Change management makes a great contribution, close to 80%, to the completion of a project, since it focuses on reducing resistance to change and makes the transition to the new culture smooth and not an imposition. [5] [6]

2.2. Maintenance Management using Lean Manufacturing

Production improvement begins with a good analysis of the production process, and for this purpose, we use lean manufacturing tools, which aim at reducing the delivery time of finished products without significantly affecting the current work systems in the manufacturing industry. [7] [8]

There are several diagnostic tools, which are as follows:

- Value stream mapping (VSM), through which data is collected to know the current state of the industries, identifying the waste that could be eliminated. [9]
- Overall equipment effectiveness (OEE), which depends on process stability and equipment performance, can improve production by identifying unwanted machine downtime and adopting corrective actions at different points in the production cycle. [10]
- However, there are also lean manufacturing tools that help provide a solution to the problem, which are as follows:
- The 5S methodology enables the adoption of new forms of work integrating self-discipline, order, cleanliness, and safety. [11] [12]
- Total productive maintenance (TPM) is a plant improvement methodology that allows for continuous and rapid improvement in the manufacturing process using employee participation, incorporating preventive methods, and maintenance concepts. [13]

The Single-minute Die change of die (SMED) technique aims at reducing waste in the production system. This includes certain improvements to reduce the time required for changing machines, reducing allocated resources, or both. [14]

3. Contribution

3.1. Model Proposed

The model proposed was developed for a textile company for reducing production line delays. This model will be detailed through a design, which was conducted based on the concepts obtained from the literature review and on the designs found in other scientific articles. It encompasses the use of lean manufacturing tools for optimal maintenance and the proposed model is described in Figure 1.

3.1.1. Analysis of the current situation and goals

- Takt Time: Considering the demand, the time necessary to meet such demand will be identified.
- Value Stream Mapping (VSM): All the waste and times that do not add value to the production will be identified. Thus, it will be possible to identify the company's real manufacturing time.
- Ishikawa: It helps find out where the problem is focused and then helps provide a solution.
- Overall Equipment Effectiveness (OEE): It will provide details on the company's production management level through the machines, which will give way to making improvements in the

maintenance area. This will eventually lead to an improvement in the processes along the production line.

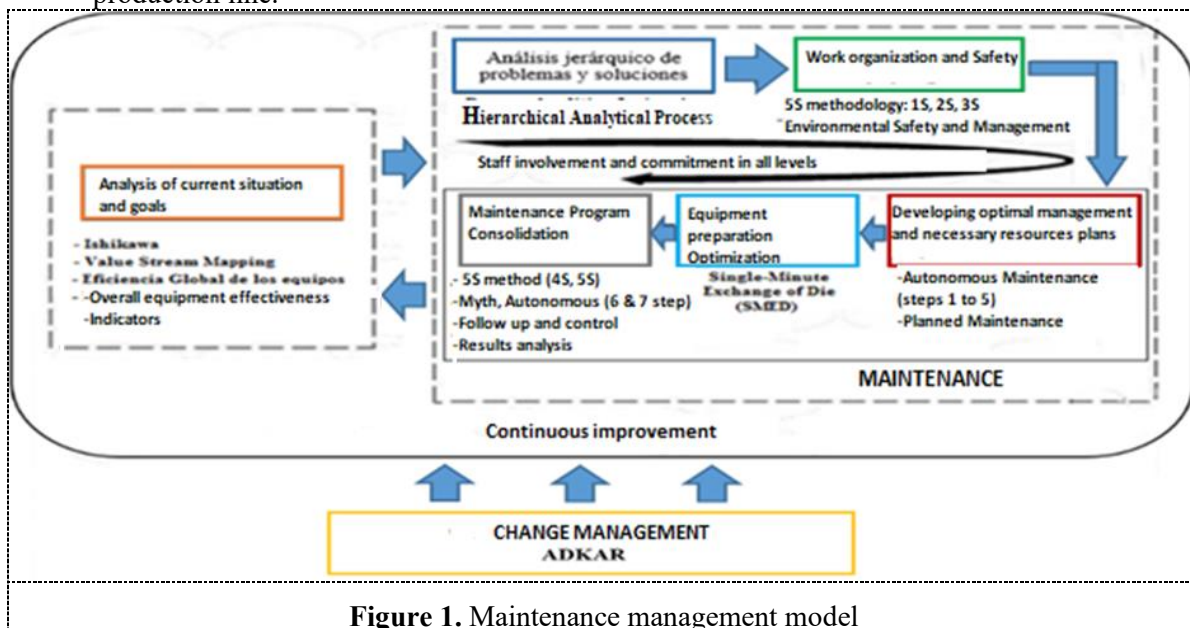


Figure 1. Maintenance management model

3.1.2. Hierarchical analysis of problems and solutions. Analytical Hierarchical Process (AHP Matrix): It will identify the root problems and search for the most effective solutions to these problems associated with maintenance, which will then be presented to management at the start of change management. During this procedure, 6 steps are taken into account, which are decomposition of the problem, weighting of the criteria matrix, normalization of the criteria matrix, comparison of alternatives, decision of the best alternative and, finally, consistency evaluation.

Table 1. Consistency assessment by selected criteria

Alternatives	Sol. 1	Sol. 2	Sol. 3	Sol. n	Average vector	Vector λ max.
Sol. 1					Research data zone	
Sol. 2					Research data zone	
Sol. 3					Research data zone	
Sol. n					Research data zone	
TOTAL					Research data zone	

3.1.3. Work organization and safety

3.1.4. 5S Methodology. Work organization is essentially linked to the development of the 5S, mainly the first three. However, before starting with the implementation of this methodology, it is necessary and extremely important to conduct an audit to see the current company level and the level after the implementation.

- Classify: It consists of categorizing any unnecessary items by means of a list and red cards to be able to remove them more easily.
- Organize: Location of materials by frequency of use, as well as signalling of corridors for the transit of machinery and waste location. This way they will be more easily identified by all company personnel.
- Clean: In this activity, the cleaning will be arranged, the cleaning plan will be prepared along with any elements necessary, and, finally, an evaluation will be conducted.

3.1.5. *Safety Pillar.* Safety is related to safe work by operators, following written procedures for safe work, receiving periodic training on hazards identification and risk assessment in their jobs, and training in the use and management of personal protective equipment, among others.

3.1.6. *Development of optimal management and necessary resources plans*

- Autonomous Maintenance (AM): The first five steps of AM will be developed, starting with initial cleaning, removal of pollution sources, inspection and cleaning standards, general inspection, and autonomous inspection. The purpose of this maintenance is to detect and deal promptly with abnormalities in the equipment, which is precisely the objective of good maintenance.
- Planned Maintenance (PM): The purpose of PM is to maximize the lifespan of equipment, project the maintenance frequency to the equipment, and at the same time, introduce all the available data such as technical sheets and fault control sheets.

3.1.7. *Optimizing the preparation of equipment. Single-Minute Exchange of Die (SMED):* First, internal activities should be analyzed and separated from external activities. Second, internal activities should be converted into external activities, and third, internal activities should be reduced.

3.1.8. *Consolidating the maintenance program.* Finally, consolidation of the maintenance program focuses on performing the 4th and 5th “S” (i.e., standardize and discipline) for the work areas, along with the 6th and 7th steps of the autonomous maintenance plan for equipment in general, supported by follow-ups and controls by management, as well as the operators in charge, to ensure the activities are executed in the most optimal manner.

3.2. *Proposed Method*

The proposed method to be followed for the successful implementation of the model includes five phases in addition to a preliminary analysis, as shown in Figure 2, which must be applicable to all companies that meet certain considerable criteria, starting from whether they belong to the textile sector to whether they have delays in their production line.

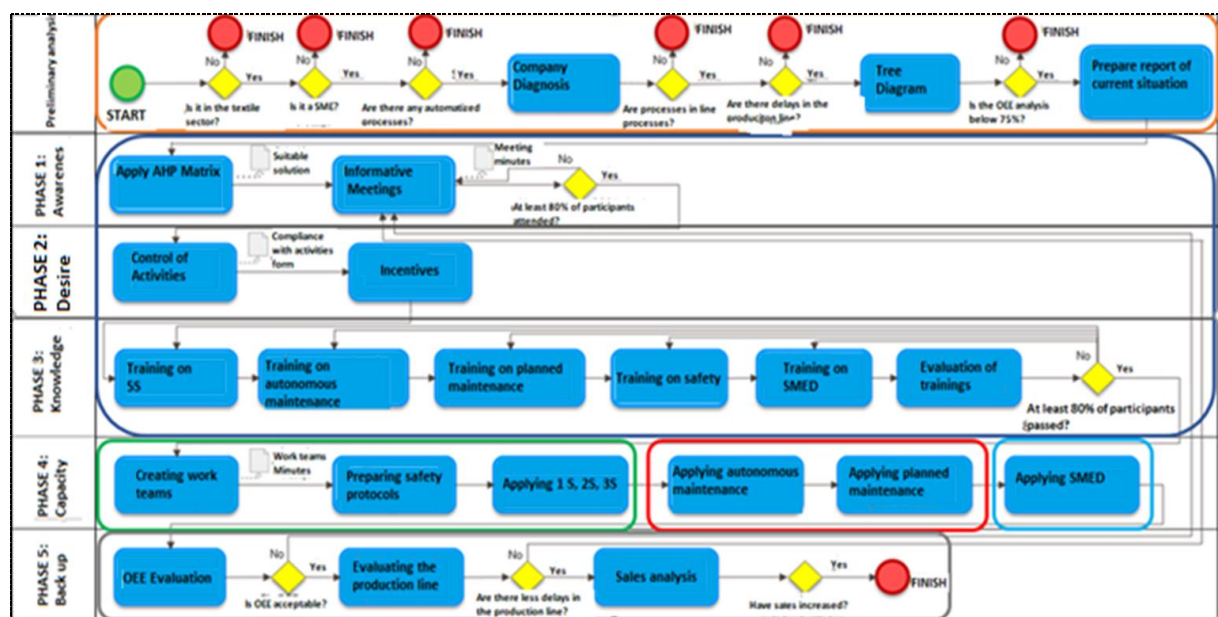


Figure 2. Implementation flowchart

3.3. Indicators

3.3.1. *Availability of equipment.* It seeks to measure a level based on the time in which equipment is at the service of the company to be operated, which represents the main problem to be solved.

$$\text{Availability} = \frac{\text{Operating Time}}{\text{Total available Time}} \quad (1)$$

Unacceptable: Less than 70%, **Intermediate:** Between 70% and 90%, **Acceptable:** More than 90%

3.3.2. *Overall equipment effectiveness (OEE).* It will make it possible to know the level at which the company is with respect to the global indicator and to evaluate the balance sheet or the economic losses incurred.

$$\text{Availability (A)} \times \text{Effectiveness (n)} \times \text{Quality (q)} \quad (2)$$

Unacceptable: Less than 65%, **Intermediate:** Between 65% and 75%, **Acceptable:** More than 75%

3.3.3. *Products delivered on time.* It will provide data of the level at which the company has improved with respect to the arrival of products to the customer.

$$\frac{\text{\# of products delivered on time}}{\text{Total orders}} * 100 \quad (3)$$

Unacceptable: Less than 60%, **Intermediate:** Between 60% and 85%, **Acceptable:** More than 85%

4. Validation

4.1. Case Study

The maintenance management model based on change management to reduce production line delays was implemented in a SME in the textile sector, dedicated to the production and marketing of polyester fiber based on 100% recycled PET bottles. The company is located at Av. Tomas Alva Edison No. 215, district of Ate, in Lima, Peru, and it has participated in the national and international markets for more than 15 years. During validation, the artefacts of the proposed model, included in each phase of the implementation guide, were analysed.

4.2. Initial Diagnosis

The company in question operates under the make-to-order model, in other words, at a customer's request. According to an analysis of sales, the company had a decrease in the last five years. This is due to the delay in orders, as only 83% are delivered on time.

Takt Time was calculated according to demand, which turned out to be 68.58 min per bundle. However, the production rate obtained from the VSM performed is 82.65 min per bundle, which is not enough to meet the required demand. The result of the OEE analysis was 61.48%, with availability being the main factor contributing to the problem, which was 65%.

4.3. Implementation

4.3.1. *Phase 1: Raising Awareness.* Meetings were scheduled with the plant and operations managers to show them the problems and the solution that will be chosen. For this purpose, the AHP matrix was used as support to justify the reason for this decision.

4.3.2. Hierarchical analysis of problems and solutions. The AHP analysis was performed, where the problem was broken down, the criteria matrix was weighted and normalized, the solution alternatives were compared, the best option was taken, and the consistency matrix was evaluated. In this way, the most viable option is proposed. In this case, the 5S and TPM tools are proposed, in addition to SMED. Then, it is presented to management.

4.3.3. Phase 2: Desire. This phase, which belongs to ADKAR change management, was carried out with the aim of motivating operators, who were offered compensation for their good performance. It should be noted that these compensations were previously discussed with management, since they must make the decision to execute it or not.

4.3.4. Phase 3: Knowledge. Once the worker was motivated to participate in the project, training began based on industrial engineering tools. At the end of the training, workers were evaluated to measure their acquired knowledge.

4.3.5. Phase 4: Capacity. Activities for managing proper maintenance began.

4.3.6. Work Organization and Safety. A 5S audit was conducted to obtain the current level of the company. The result was 51%. Then, we started with the implementation of each S.

- Seiri–Classify: Using the red cards to identify dirty pits, an action plan was drafted for these elements.
- Seiton–Sort: The materials were classified by frequency of use, and the work area was organized depending on that classification.
- Seiso–Cleaning: Cleaning plans were implemented, and at the end, the before and after was compared.



Figure 3. Before and after the implementation

Regarding workers' safety activities, safe work procedures were established, and hazards and risk in the company were identified.

4.3.7. Development of optimal plans and necessary resources. Autonomous maintenance (AM): The equipment was cleaned by the operators to recognize any pollution sources and inspect the machine in depth. This is implemented so that the operator has a standard cleaning process and distinguishes between normal and irregular operation of the machine.

Planned Maintenance (PM): The equipment was coded according to the area of work (an abbreviation of name and the position in which they are with respect to the production line), and the technical file of the equipment as well as a maintenance plan were created.

4.3.8. Optimization of equipment preparation. Single-minute Exchange of die (SMED): The activities performed when the machine is stopped were evaluated, and it was proposed that they should be converted to activities with the machine in operation following the safety guidelines. Finally, a comparison was made between the current method and the proposed one, whose improvement is reflected in the optimized time that went from 58.86 to 38.69 min.

4.3.9. Phase 5: Reinforcement

4.3.10. Consolidating the maintenance program. We continued with the steps of the 5S methodology for the work areas as well as the steps of the AM for the equipment, in such a way that it becomes a habit within the company, standardizing the activities and disciplining the workers, with the help of supervisors, as well as with the participation of management.

4.4. Results

The scenario 3 corresponds to the third work shift of the day, which is between 00:00 and 08:00 hours. There are no raw material inputs and inputs, as well as outputs of finished products to the customer. First, from a time taken, an operating time of 25314.24 minutes was obtained, of a total available time of 33600 min. (10 weeks). This operating time represents the availability of the equipment during this turn.

$$\text{Availability} = \frac{25314.24 \text{ min}}{33600 \text{ min}} \times 100\% = 75.34\%$$

Second, the analysis of the overall efficiency of the equipment for this scenario was as follows:

$$\text{OEE} = 75.34\% \times 96.17\% \times 98.01\% = 71.01\%$$

Thirdly, the quantity of products made based on the improvement made, which are placed in the warehouse of finished products and which are dispatched during the first corresponding shift between 08:00 - 16:00 hours, was analysed.

$$\% \text{ Products delivered on time} = \frac{537 \text{ fardos}}{624 \text{ fardos}} * 100 = 86.06\%$$

Table 2. Summary of indicators

Indicator	Traffic Light			Base Line	Improvement
% Availability	< 70%	70% - 90%	>90%	65%	75.34 %
% OEE	< 65%	65% - 75%	>75%	61.48%	71.01 %
% Products delivered on time	< 60%	60% - 85%	>85%	83%	86.06 %

Table 3. Summary of indicators by scenario

Indicator	Scenario 1	Scenario 2	Scenario 3
% Availability	78.40 %	75.80 %	75.34 %
% OEE	73.88 %	71.59%	71.01 %
% Products delivered on time	89.72 %	86.38 %	86.06 %

The study reported benefits in all the points addressed; however, not all of them achieved the expected result because the time available for implementation was limited.

5. Conclusions

It was possible to reduce the production time per bundle, achieving an increase from 524 to 567 bales. This increase of 43 bales during each month reduced the delays in the production line, which was the company's main problem, increasing the percentage of delivery to customers from 83% to 89.72%.

Once the model is implemented, and assuming demand from previous years persists, an 8.206% increase in sales is projected.

Despite not reaching the expected results with respect to the availability and OEE indicators, a significant improvement was achieved considering the time available to execute it. It should be noted that this is an implementation process and the adaptation time varies from company to company and usually takes more time when it comes to tools such as lean manufacturing. However, the model emphasizes continuous improvement, and thus, if application is ongoing, the results will be much better.

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