

# **Safety Model based on 5S, TPM and Work Standardization to Reduce the Accident Rate in an SME in the Construction Sector**

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## **Abstract**

The construction sector is an important driver of the economy and a generator of employment, but it has high occupational accident rates each year. In Peru, small construction companies lack an occupational health and safety management system, which is reflected in the number of accidents reported each year, which is as high as 3,000. Therefore, it is important to look after the welfare of the most valuable asset of each company: the worker. This paper presents a proposal for a safety model based on Lean tools: 5S and TPM, and work standardization to reduce the accident rate in a Peruvian construction SME. The proposed model is divided into three components that represent the application of each of the tools. It also consists of four phases and a duration of two months divided into four fortnights. Finally, the results obtained were favorable, reducing the accident rate by 75% with respect to the initial situation.

## **Keywords**

Security Model, Construction Sector, 5S, TPM, Work Standardization

## **1. Introduction**

At a global level, "the construction sector is a natural dynamizer of the economy, since it makes it possible to close existing infrastructure gaps throughout [a] country, and thus raise the productivity of people and their living standards" (ComexPerú 2022). In Peru, "the construction sector is very important for the economy [due to] its relationship with productive activities in other industries. It is a direct [and] important source of employment and brings together important infrastructure projects" (ComexPerú 2022). The construction sector ended 2022 with a growth of 3% compared to the previous year (-8.9%), this due to the increase in the progress of public works (15.2%) and a lower reduction in cement consumption (-6.7%). with respect to the estimate (CAPECO 2023). Likewise, the companies in the sector interviewed indicated that their levels of operation increased by 1.7%, although infrastructure builders experienced a contraction of 3.3% (CAPECO 2023). Likewise, according to data obtained by the Ministry of Labor and Employment Promotion, in Peru, more than 3,000 accidents occur per year in the construction sector, which shows a high accident rate in companies in the sector.

Carrillo Ayala (2020) explains based on his study that among the main causes are "exposure to long working hours, deficiencies in training and training programs in safety and health at work, non-use of the elements of personal protection and non-compliance with safety guidelines" (p.70). Some case studies in Peru are summarized below. In Lima, a safety model based on Lean Construction and Behavior-Based Safety was developed to reduce the number of accidents and implement a safety culture within a company in the construction sector through the analysis of indicators and as a result, the reduction of the accident rate of 35.37%. (González & Morocho 2022). In Arequipa, a study was carried out with the objective of reducing the accident rate of a local construction company, through the implementation of the occupational health and safety plan based on the G.050 standard, as a result the frequency rate decreased by 529.25 to 366.25 and the severity index from 719.04 to 405.49, reducing the accident rate by 23.37% (Quispe 2021).

In this context, it is necessary for Peruvian construction companies to follow certain guidelines and promote a culture of safety and health at work. Therefore, a case study was chosen that reflects the problems of the sector on a high accident rate due to poor or no system management. The causes identified are the lack of training and security measures, deteriorated tools and equipment in poor condition, non-use or improper use of protective equipment, generating a loss of 1.5% of the net profit of the case study. To solve this problem, a model based on the Lean tools such as 5S and TPM, in addition to the standardization of work to mitigate the factors that affect the high accident rate. This research seeks to reduce the accident rate and promote a culture of occupational safety in each operation of construction companies in the country.

### **1.1 Objectives**

The objective of this research is to demonstrate that the implementation and application of the 5S and TPM tools together with the standardization of work helps to reduce the accident rate, as well as to improve the productivity of the operations and activities of the workers. Thus, eliminating unsafe actions and the risk of accidents due to machinery failures.

## **2. Literature Review**

### **Safety model to reduce accidents in the construction sector**

"The construction industry is considered one of the riskiest activities, due to the high incidence of occupational accidents, affecting personnel, equipment and materials" Aguilar (2019), similarly, González et al (2021) in their study on the construction sector, "considered as one of the economic activities with the highest accident rate, hardship and danger, concludes that the existing safety and health plans have major deficiencies, which puts at risk the management of prevention at work".

Patiño and Zambrano (2020) highlight that "workers are a fundamental capital for the realization of construction projects, since they contribute with knowledge, effort and dedication, that is why employers are in the obligation to provide a safe workspace", therefore, it is essential to have an Occupational Health and Safety Management System to control risks, hazards and accident costs in a company. For this reason, with the study of Pimentel (2021) on the implementation of an OSHMS in a construction company in Trujillo, results in a reduction of 41% compared to the previous year, which indicates that the implementation of this system "is a profitable investment since not only economic benefits will be obtained but also a social impact both internally and externally by improving the company's image in front of the company's stakeholders."

### **5S applications in the construction sector**

In the first place, Silva (2022) tells us that the tools "5s is positively linked with moderate intensity with the productivity variable in the workers of a construction company [just as] it is positively linked with high intensity with the efficiency and effectiveness dimension in the workers", also, Aguirre et al. (2021) comments that "the application of the 5s methodology can be really taken advantage of when we focus it on a cultural change of the application environment since it strengthens in the organization the sense of care for the environment."

With their work, Flores and Malgarejo (2022) corroborated the influence of this 5s tool in the productivity of a company in the construction sector, obtaining as a result that the application of this tool "improved productivity from 46.67% to 71.31%, achieving an increase of 24.64%; efficiency from 63.40% to 79.91%, achieving an increase of 16.51%; and; effectiveness from 73.62% to 89.25%, achieving an increase of 15.63%." In the same way, Hurtado (2021) proposes the implementation of the 5s methodology in a construction company, with an initial situation of 32% of total application, each of the pillars: sorting, order, cleaning, standardization and discipline, obtained a compliance of 31%, 33%, 48%, 48%, 24% and 24%, respectively; with the implementation of this methodology they obtained a compliance of 86%, 83%, 86%, 76%, 92% and 82%, respectively; increasing compliance up to 85%.

### **TPM applications in the construction sector**

According to Condezo (2019), "Industrial companies in Peru have used TPM as one of the tools for the improvement of their production processes, obtaining satisfactory results in the reduction of downtime, and improvement in efficiency and effectiveness". Furthermore, Garay and Villegas (2022) found that the implementation of TPM in a construction company in Huánuco increased productivity by 20.63% in the construction area "Because initially the company presented a productivity of 63.5% and after the implementation the company presented a productivity of

76.6%". On the other hand, Muñoz (2020) through his research work makes reference that there are construction companies that have as main problem the lack of a maintenance plan which generates unplanned stops of the equipment, decrease of the useful life; is for this reason that he has a "proposal of the maintenance plan based on TPM to improve the availability of heavy equipment, have a positive influence on the maintenance management, allowing to quantify the improvement achieved and the greater availability of the equipment" having as a result an improvement of availability of the machinery from 81.40% to 92%. Likewise, Cortez (2021) shows with his TPM research that there is an improvement in maintenance management, having as a result "an improvement in availability of 18.72% increasing from 69.55% to 88.27% and an improvement in performance of 11.08% increasing from 67.80 to 78.88%".

### **Work Standardization applications in the construction sector**

Fazinga et al. (2019) developed a study on work standardization which "seeks the reduction of variability and waste based on three conceptual elements: takt-time, sequence of operations and work in process". Adapting the elements to the construction industry, focusing the standardization on the activities performed by workers, thus obtaining positive results in the stability of operations.

### **3. Methods**

There are a variety of methodologies to mitigate the factors that can cause workplace accidents. Among them are 5S, TPM and work standardization, which promote safe conditions and an organizational culture of continuous improvement. Together, these tools can reduce the accident rate, reduce the costs involved and increase productivity in a company's operations. For the realization of the safety model, previous research on the different tools applied in companies of the construction sector was taken as a reference, as detailed in Table 1.

Table 1. Comparative matrix of the objectives of the problem vs. the state of the art

Scientific articles	Objectives of the problem			
	Safety culture	Optimize work methods	Secure infrastructure	Maintenance management
Silva (2022)		5S	5S	
Aguirre et al. (2021)		5S	5S	
Flores and Malgarejo (2022)		5S	5S	
Hurtado (2021)		5S	5S	
Condezo (2019)				TPM
Garay and Villegas (2022)				TPM
Muñoz (2020)				TPM
Cortez (2021)				TPM
Fazinga et al. (2019)	work standardization	work standardization		
<b>Proposal</b>	<b>Security plan</b>	<b>Standardization</b>	<b>5S Audits</b>	<b>Preventive maintenance program</b>

The components comprising the proposed safety model: 5S, TPM and work standardization; and the proposed model are described below.

#### **5S**

The 5S methodology is a tool focused on order and safety, consisting of the elimination of unnecessary elements within the work area, promoting a continuous and safe workflow. Each "S" represents a Japanese word that describes a stage of the organization and cleaning process. The first stage, seiri (sorting), consists of removing all unnecessary items from the work area, identifying what is essential and discarding what is not needed. Second, seiton (order), this stage involves properly organizing the necessary elements, assigning a specific place for each of them. Third, seiso (cleanliness), which consists of keeping the work area clean and tidy. Fourth stage, seiketsu (standardization), in this

phase rules and procedures are established to keep the three previous stages constant. Finally, shitsuke (discipline), this stage consists of creating habits for the development of a culture of responsibility and safety.

### **Total Productive Maintenance**

Total Productive Maintenance is a methodology focused on continuous improvement and prevention of risk factors. It maximizes the efficiency of the equipment and minimizes losses associated with industrial accidents. The principles of this methodology include training workers to perform basic maintenance tasks such as cleaning, inspection and calibration; establishing preventive and predictive maintenance plans based on data analysis and equipment monitoring; implementing improvements to existing equipment and processes to increase their efficiency, reliability and capacity; and, finally, training and development of personnel to improve their technical skills and promote a culture of safety and responsibility.

### **Work Standardization**

This methodology consists of establishing clear methods and procedures to perform a specific task efficiently and safely. Work standards are created through observation and analysis of best practices. First, a task must be broken down into small, detailed steps to identify the key steps. Second, the most efficient sequence of steps is determined and the most appropriate methods and techniques for performing each step are established. Third, time estimates are assigned for each step and performance standards are established. Fourth, work standards are recorded in manuals or instructions that are accessible and understandable to all team members. Finally, work standards are periodically reviewed for improvement opportunities to optimize existing methods and processes.

### **Proposal safety model**

The proposed model shown in Figure 1 comprises the implementation of 5S, TPM and work standardization. The input is the company's historical data on work accidents. The output is the result of the application of the methodologies in the company. The model consists of 4 phases: preparation and awareness of the personnel, application of the 5S, application of the TPM and finally, standardization of the work.

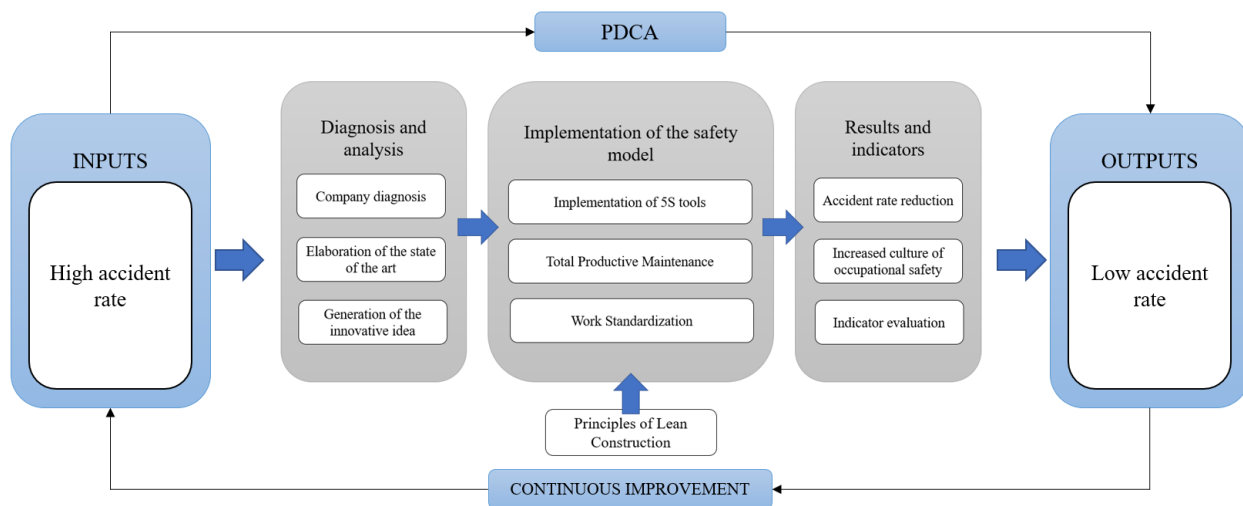


Figure 1. Security model

### **Indicators**

The effectiveness of the improvement proposal will be evaluated through the following indicators:

Accident rate indicator (ARI): This indicator makes it possible to measure the rate of accidents that occurred for every 200 workers. Objective: Achieve the industry standard.

$$ARI = \frac{FI \times SI}{200}$$

Frequency indicator (FI): This indicator allows calculating the number of work accidents for every 200,000-man hours worked. Objective: Achieve a frequency of less than 5 accidents.

$$FI = \frac{\text{Number of occupational accidents}}{\text{Total worked hours}} \times 200000$$

Severity indicator (SI): This indicator allows calculating the total hours lost due to the absence of personnel due to an accident at work. Objective: Achieve an index of less than 100 lost hours.

$$SI = \frac{\text{Total hours lost per day}}{\text{Total worked hours}} \times 200000$$

Standardization indicator (STDI): This indicator allows calculating the percentage of activities carried out according to the established procedures. Objective: Achieve that the standardized activities rate is greater than 90%.

$$\%STDI = \frac{\text{Number of standardized activities}}{\text{Total number of activities}} * 100$$

5S audit indicator (AI): Measures the score obtained in each 5s audit session. Objective: Achieve a 90% compliance rate.

$$\%AI = \frac{\text{5S Audit Score Obtained}}{\text{5S Audit Score Total}} * 100$$

Indicator of correct use of PPEs (PPEI): Measures the percentage of personnel who properly use personal protective equipment. Objective: The percent of adequate use of PPE must be greater than 90%

$$\%PPEI = \frac{\text{Number of workers correctly protected}}{\text{Total number of workers}} * 100$$

TPM indicator (TPMI): Measures the percentage of machines that have not presented any failure or caused any accident during the period. Objective: The percent must be greater than 90%

$$\%TPMI = \frac{\text{Number of machines worked correctly}}{\text{Total number of machines}} * 100$$

#### 4. Data collection

The technique used for the collection of qualitative data was the systematic literature review. According to García Peñalvo (2022), the systematic literature review is a systematic method to identify, evaluate and interpret the work of academics and professionals in a chosen field. Its purpose is to identify gaps in knowledge and research needs in a specific field.

#### 5. Results and Discussion

##### 5.1 Numerical results

This section will detail the numerical results obtained from the implementation of the proposed safety model. First, the results of the 5S audits applied during the project execution time are shown, as well as the score obtained in each "S". Table 2 shows the evolution of the company in each of the phases that comprise this methodology.

Table 2. Results of 5S Audits

	Initial situation	First fortnight	Second fortnight	Third fortnight	Fourth fortnight
Category	Percent	Percent	Percent	Percent	Percent
Seiri (Sorting)	4	6	8	10	10
Seiton (Order)	3	5	7	9	10
Seiso (Cleanliness)	2	4	6	7	9
Seiketsu (Standardization)	4	6	7	9	9
Shitsuke (Discipline)	3	5	7	8	9
<b>Score</b>	<b>16</b>	<b>26</b>	<b>35</b>	<b>43</b>	<b>47</b>
<b>5S audit percent</b>	<b>32%</b>	<b>52%</b>	<b>70%</b>	<b>86%</b>	<b>94%</b>

As a result, a large increase can be observed in the first fortnight, which decreases as the audits go by, achieving and even surpassing the established goal, which was 90%.

Finally, Table 3 compares the results obtained during the 4 fortnights of application of the safety model in the construction company vs. the initial situation prior to the application of the methodologies.

Table 3. Initial situation vs. every week

Indicator	Initial situation	First fortnight	Second fortnight	Third fortnight	Fourth fortnight	Expected result
Accident rate	5.56				1.39	2.08
Frequency index	8.33				4.17	4.17
Severity index	133.33				66.67	100.00
Percentage of correct use of PPEs	65%	75%	85%	95%	100%	95%
Standardized activities	60%	70%	80%	90%	100%	95%
5S audits	32%	52%	70%	86%	94%	90%
Machines worked correctly	75%	80%	85%	90%	95%	95%

It is possible to evidence an overcoming of the expected expectations on the application of the safety model. The frequency index was reduced by 49.94% in accordance with expectations and the severity index by 49.99%, far exceeding the estimate, so it is thanks to the latter that the reduction in the accident rate was greater than predicted.

## 5.2 Graphic Results

This section will detail the graphic results obtained from the implementation of the proposed safety model. First, the evolution of workers using personal protective equipment correctly from the beginning to the end of the workday is shown in Figure 2.

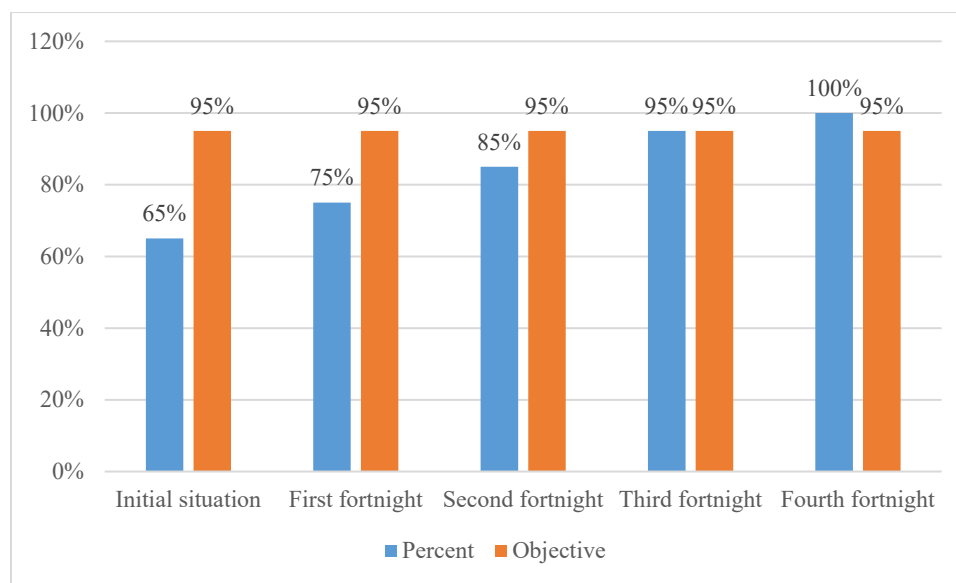


Figure 2. Correct use of PPEs

This graph indicates the proportion of workers who during a full day had no observations or faults described by the supervisor in charge.

Second, Figure 3 shows the increase in standardized activities during the project execution period. The objective was exceeded at the end of the period. It can be concluded that all the company's activities have been standardized.

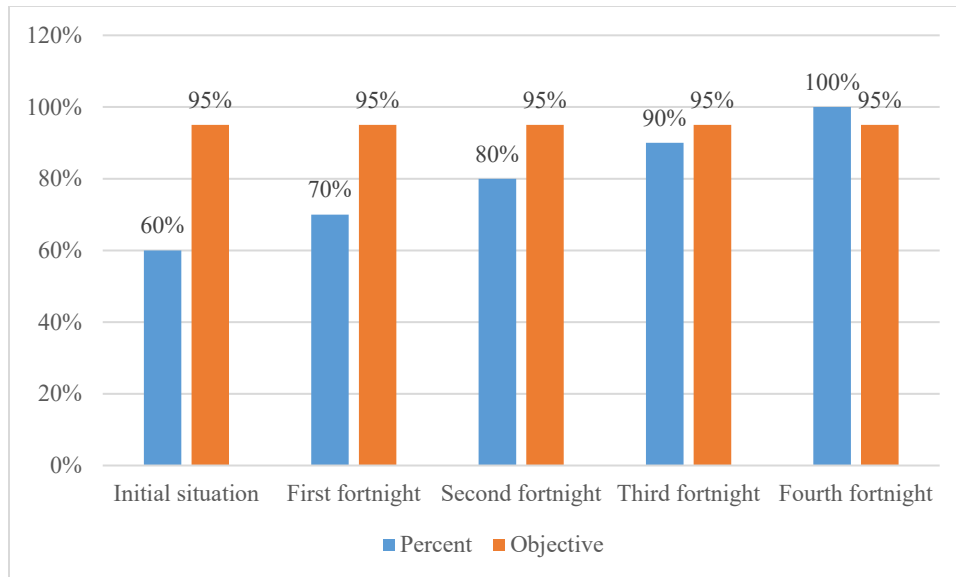


Figure 3. Standardized activities

Finally, the Figure 4 represents the percent of machines that worked correctly without any exception. demonstrating the efficiency of the correct application of the methodology TPM to prevent risk factors and create a safe environment for operators.

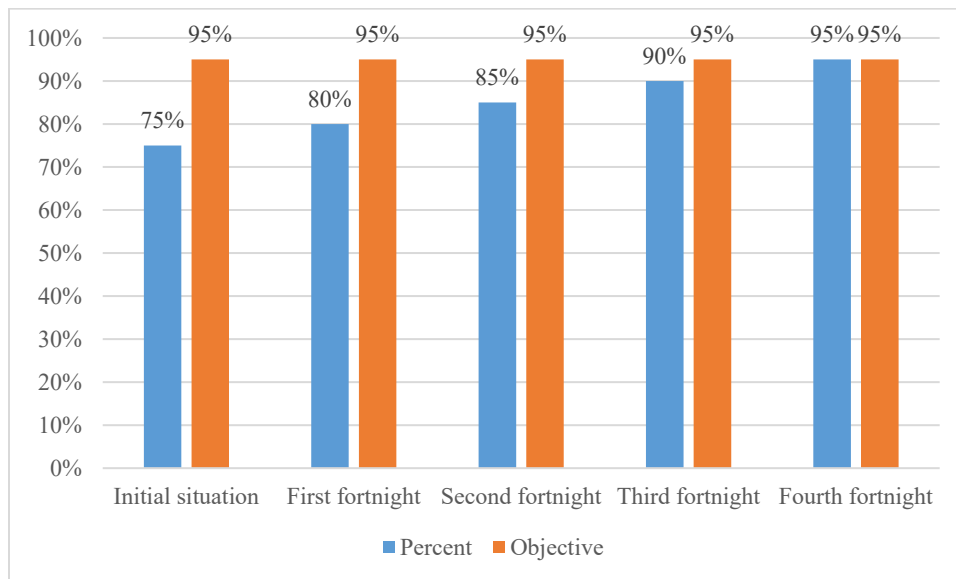


Figure 4. Machines worked correctly

### 5.3 Proposed improvements

It is necessary to highlight that the proposed model has its limitations since the validation and the results were analyzed in an SME in the construction sector with a lower workers per project. Therefore, depending on the number of personnel, initial situation and characteristics of the company, the results of your application may vary.

In addition, it is recommended to carry out a training program for all personnel involved in the process to guarantee the adequate development of the proposed model, in addition to promoting a culture of safety and health at work, allows understanding of the importance of the role within the organization.

## **5.4 Validation**

The implementation of the security model was carried out in 4 phases that are described below.

### **First phase - Induction**

A presentation was made as an induction on safety and health at work with the aim of raising awareness among workers about the importance of prevention measures, safe practices and the correct use of personal protective equipment. This presentation was given by qualified personnel in the subject, in addition, the necessary material was provided to the workers, as well as a brief detail of the tools to be used during the execution of the model.

### **Second phase – 5S**

In this phase, the 5S methodology was implemented, with the aim of being able to guarantee an adequate and safe environment for the operator. A previous audit was carried out to identify opportunities for improvement.

1. Seiri (Sorting): The different types of materials to be used in the work were classified, for which a supervisor was appointed in charge of validating this activity. In addition, different signs were used, such as signs and yellow lines on the ground to be able to locate the materials in the corresponding areas. Also, red cards were implemented to mark unnecessary, defective or obsolete material and thus be able to take corrective actions. Unnecessary materials are transferred to their corresponding areas, defective materials are removed from the work area, and obsolete materials are discarded.
2. Seiton (Order): To have a better order, each area in which the different materials and elements to be used in the work were placed was marked. Also, an area was designated for the workers to leave their personal belongings and not interfere with their activities during the execution of the work. A supervisor was appointed in charge of verifying and enforcing the regulations based on the order.
3. Seiso (cleanliness): A supervisor was appointed in charge of verifying that each worker cleans his work area once his shift is over, transfers the remaining materials to their corresponding classification areas and disposes of the waste materials used in the places assigned by the company. In addition, toilet areas, cleaning elements and areas for waste waste or segregated garbage were implemented.
4. Seiketsu (Standardization): After the first 3S, the new values and behavior patterns for the workers are established. Labels, control panels and shelves were implemented to be able to classify and order the elements used in an appropriate manner, creating regulations for daily activities during a work. Similarly, a supervisor was assigned to ensure compliance with the new work model.
5. Shitsuke (Discipline): Finally, daily evaluations were established to be able to constantly monitor the application of the methodology, as well as conducting daily talks prior to the start of the activities, in order to make the worker aware of the importance of safety during the execution of their duties.

### **Third phase - TPM**

Total Productive Maintenance was implemented to reduce work accidents in the company. The following steps were followed for the implementation of this tool:

1. A team was created to lead the implementation; This team is made up of people in charge of different areas such as maintenance, production, security and human resources.
2. Initial evaluation: the safety situation in the workplace was analyzed, the possible risks and the most frequent accidents were identified
3. Training and awareness: safety training was carried out for all workers, including risk identification, proper use of EPPS and best safety practices. A culture of safety and awareness was encouraged for all staff
4. A preventive maintenance program was implemented to ensure that the machines and work equipment are in good condition, regular checks were carried out and faulty equipment was replaced
5. The participation of workers was promoted with respect to the identification of risks and the search for solutions.
6. Finally, a follow-up was carried out in which key indicators were established, in relation to safety, in order to evaluate their progress.

### **Fourth phase - Standardization of work**



Finally, work standardization was implemented, as it allows workers to perform a task in the fastest and most effective way. The following steps were followed for the implementation of this methodology:

1. A group was created in charge of breaking down the different activities into small steps for their subsequent analysis.
2. The optimal sequence in each activity was determined and the most efficient methods of carrying it out were defined.
3. Times were established in each step to guarantee good performance and work efficiency
4. These standards were recorded in documents accessible to all personnel within the facility.
5. Finally, a weekly inspection was carried out to guarantee compliance with the standards and identify opportunities for improvement.

## **6. Conclusion**

Due to the implementation of the proposed model in which the three methodologies are applied: 5s, TPM and work standardization, a reduction in the accident rate from 5.56 to 1.39 was obtained, exceeding the expected value; These results were significant for the analysis, since with this the correct functioning of the model could be verified. In addition, it managed to improve 100% in the correct use of PPEs and standardized activities, which allows the worker to feel safe, motivated and committed to their work. In addition, accident prevention reduces time lost due to sick leave, avoids delays in projects, prevents damage to company assets and avoids interruptions within work.

Safety and health at work is a relevant issue within a construction company due to the need to protect workers and guarantee their well-being. The implementation of this type of safety model can help take appropriate safety measures and form occupational risk prevention to reduce the accident rate, protecting not only the physical and mental integrity of employees, but also reducing the costs associated with accidents. such as medical expenses and compensation for work disabilities.

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## **Biographies**

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