

Improvement Proposal to Reduce Preventive Maintenance Time of Electric Hoists Using 5S and Standardized Work

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Abstract

This study proposes the implementation of 5S and Standardized Work tools under the Lean Manufacturing approach to reduce the preventive maintenance cycle time of electric hoists in a Peruvian metalworking SME. The process was executed empirically, averaging 8.87 hours per equipment with a standard deviation of 13.30 minutes, generating annual labor cost overruns of USD 8,451. A four-phase continuous improvement model was designed and implemented as a pilot test conducted over approximately 3 months on non-consecutive days, applied to electric hoists with a maximum of 2 lifting chains and load capacities between 125 and 2,500 kilograms. Results showed a cycle time reduction from 531.93 to 387.10 minutes (27.23%), a decrease in standard deviation from 13.30 to 4.18 minutes (68.57%), and an improvement in 5S compliance from 45.8% to 64.0%. Statistical validation through an Anderson-Darling normality test and a paired T-Student test yielded $T = 53.83$ and $p = 0.000$, confirming the significance of the improvements. The findings demonstrate that the combined application of 5S and Standardized Work constitutes a viable and low-cost alternative to reduce operational variability and standardize maintenance processes in SMEs of the metalworking sector.

Keywords

Lean Manufacturing, 5S, Standardized Work, Cycle Time, Preventive Maintenance.

1. Introduction

The lack of standardization in the preventive maintenance process represents a critical issue affecting the operational efficiency of the metalworking sector in Peru. This sector demonstrated notable performance, contributing 9.4% of the Manufacturing Gross Value Added and representing 1.2% of national GDP by the end of 2024 (PRODUCE 2025). Furthermore, it recorded a 0.7% increase in manufacturing-related services, driven by an 8.2% growth in machinery repair services and a 14.6% increase in electrical equipment repair (Ministerio de la Producción 2025), highlighting the importance of standardizing industrial maintenance services.

In the company under study, it was identified that the maintenance process was carried out empirically, based solely on the technician's own judgment. This lack of standards generated an excessive total cycle time averaging 8.87 hours per unit, with variability reflected in a standard deviation of 13.30 minutes, generating estimated annual labor cost overruns of USD 8,451.

Lean Manufacturing offers a set of tools aimed at eliminating waste and standardizing processes, among which 5S and Standardized Work stand out for their applicability in industrial maintenance environments. 5S enables the creation of orderly and predictable physical conditions in the workplace, while Standardized Work defines precise execution sequences that reduce variability and operational errors. The combination of both tools has demonstrated significant results in manufacturing SMEs. Herrera-Carhuanina et al. (2024) successfully reduced defects and unproductive time through workplace reorganization. Diaz-Cornejo et al. (2024) demonstrated that standardization reduces operational variability and increases efficiency. Kikushima and Cervantes (2023) validated in a Peruvian SME that 5S implementation reduces material transfer times by up to 8.75% and travel distance by 43.77%. Therefore, this study proposes the implementation of these tools to reduce the preventive maintenance cycle time of electric hoists in a Peruvian metalworking company.

This study is structured in six sections: the Introduction presents the problem and its context; the Literature Review supports the tools employed; the Methods describe the proposed model and indicators; the Data Collection details the instruments used; the Results and Discussion present the values obtained and their comparison with the literature; and the Conclusions summarize the study's findings.

1.1 Objectives

The main objective of this study is to reduce the total preventive maintenance cycle time of electric hoists through the implementation of 5S and Standardized Work tools. The specific objectives are: to reduce process variability by 40%; to raise the 5S compliance level above 90%, measured through a structured audit checklist evaluating the degree of implementation of each of the five stages in the work area; and to reduce the average time of critical Assembly and Electrical Replacement operations by 20%.

2. Literature Review

2.1 5S

5S is the foundation of all improvements and is the key component for establishing a visual workplace (Senthil Kumar et al. 2022). It is considered an efficient management tool useful for eliminating non-value-added processes (Senthil Kumar et al. 2022); it also reduces waste and increases worker safety (Shahriar et al. 2022), achieving improvements in productivity, employee engagement, and the company's competitive market position (Worthington et al. 2021).

The 5S compliance level is measured through periodic audits based on structured checklists, evaluating the degree of implementation of each of the five stages: Sort (Seiri), Set in Order (Seiton), Shine (Seiso), Standardize (Seiketsu), and Sustain (Shitsuke). Each stage receives a score according to predefined criteria, and the final result is expressed as a percentage of the total possible score (Shahriar et al. 2022). This methodology enables the identification of compliance gaps, the establishment of baselines prior to intervention, and the measurement of actual progress after implementation (Senthil Kumar et al. 2022). In the context of this study, 5S was applied to organize the hoist maintenance area, labeling tools and establishing cleaning and inspection routines that reduced unnecessary movements during the process.

2.2 Standardized Work

Standardized Work is a central element of lean manufacturing, whose main objective is to convey to workers how to perform their tasks efficiently; its implementation includes time studies, video analysis, and work study (Vijay and Gomathi Prabha 2021). It has become the common paradigm in Operations Management (Frangeskou et al. 2024). Cycle time reduction is achieved because Standardized Work eliminates randomness in task execution: by defining a precise sequence of steps, target times, and quality criteria for each operation, technicians can perform maintenance without improvisation or procedural uncertainty. This directly reduces execution errors, internal rework, and consultation time between operators (Vijay and Gomathi Prabha 2021). In this study, Standardized Work was implemented by defining an optimal operational sequence for each maintenance stage of the hoists, including target times and quality criteria per operation.

2.3 Lean Manufacturing

Lean Manufacturing is the methodological framework that groups tools aimed at eliminating waste and increasing operational productivity, offering customers greater value through resource optimization (Veseli et al. 2024). In this study, the 5S and Standardized Work tools are employed as components of the Lean approach, since their combined

implementation allows the simultaneous elimination of motion, time, and operational variability waste. Florez-Cáceres et al. (2024) implemented Lean tools in a Peruvian metalworking SME and achieved a 10% increase in productivity and 23.8% improvement in efficiency. Pawlak (2024) confirmed that Lean techniques reduced operational delays related to failures and human errors by an average of 26 hours per week.

2.4 Cycle Time

Cycle time is defined as the total interval required to execute an operation, establishing itself as a critical KPI for monitoring operational efficiency and response agility (Santos et al. 2025). Tripathi and Bhadauria (2026) achieved a 9.36% reduction in total production cycle time through the elimination of idle activities. Sahin and Kologlu (2022) reduced total setup time by 34.41%, demonstrating that technical intervention in downtime has a direct effect on line availability (Table 1).

Table 1. Comparative matrix of tolos

Authors	Cause 1: Disorder / Search	Cause 2: Lack of Procedures	Cause 3: Rework / Quality
Kikushima and Cervantes (2023)	5S and SLP		
Rishi et al. (2018)	5S	SOP	
Pawlak (2024)	5S	Standardized Work	Standardized Work
Quiroz-Flores et al. (2024)		Standardized Work	Standardized Work
Florez-Cáceres et al. (2024)	5S	SMED	TPM
Proposed Study	5S	Standardized Work	Standardized Work

3. Methods

3.1 Proposed Model

The proposed model (Figure 1) is structured in four continuous improvement phases. Phase 1 corresponds to the Technical Analysis, where root causes are identified through problem trees, Ishikawa diagrams, Pareto analysis, and DOP, DAP, and DDR process diagrams. Phase 2 establishes Standardized Work through the definition of the optimal operational sequence, cycle time calculation, and line balancing. Phase 3 implements 5S and strategic organization, arranging the physical environment through classification, standardized cleaning, and operational discipline. Finally, Phase 4 consolidates Knowledge Management and Control through visual documentation, process control requirements, and continuous improvement.

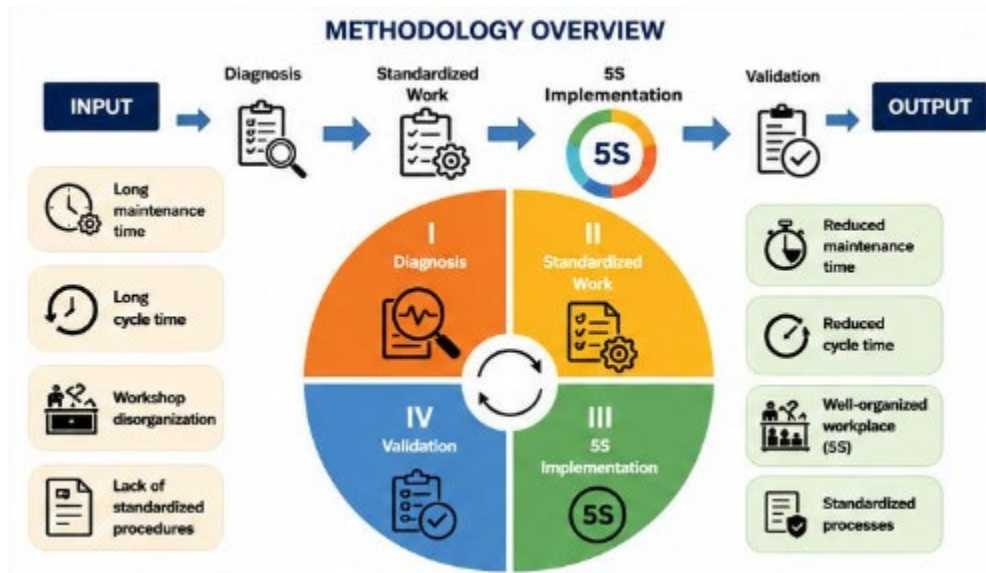


Figure 1. Proposed Model — Continuous Improvement Process Diagram

3.2 Components

3.2.1 Component 0 — Diagnosis

In the initial diagnosis, a problem tree was used to structure the causes and effects of inefficiency, focused on method and environment. Pareto analysis prioritized these causes, confirming that the lack of standardization and disorder accounted for more than 65% of the negative impact. Flow mapping through DOP and DAP diagrams revealed waiting times and unnecessary movements. Four critical indicators were identified: total maintenance cycle time, 5S compliance level, average time of critical operations, and maintenance variability.

3.2.2 Component 1 — Standardized Work

This component established the optimal operational sequence for each maintenance stage. The cycle time was calculated and line balancing was performed to equitably distribute the workload. Process requirements and controls were defined, specifying quality standards and operational parameters. Everything was consolidated into visual documentation and integrated into a knowledge management system (Flores-Pérez et al. 2023).

Figure 2 presents the implementation block diagram of Component 1, illustrating the methodological sequence followed from current process analysis to statistical validation.

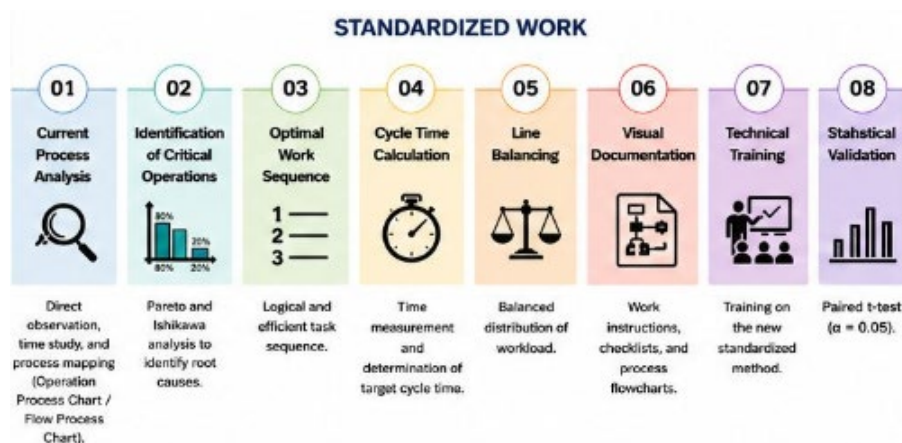


Figure 2. Implementation block diagram — Component Standardized Work

3.2.3 Component 2 — 5S

The 5S methodology was applied with the objective of ordering and organizing the work environment, creating optimal physical conditions for maintenance. The Sort and Set in Order stage (Seiri and Seiton) eliminated unnecessary items and organized tools in designated and labeled locations. Standardized Cleaning (Seiso) established preventive inspection routines through checklists. Finally, Discipline and Continuous Improvement (Seiketsu and Shitsuke) was implemented through rules and periodic audits. This workshop reorganization minimized unnecessary movements (Kikushima and Cervantes 2023) and facilitated the smooth execution of Standardized Work (Pawlak 2024). The application of 5S increases operational efficiency (Collao-Díaz et al. 2024).

Figure 3 presents the implementation block diagram of Component 2, detailing the complete 5S application cycle from initial diagnosis to the final compliance audit.



Figure 3. Implementation block diagram — Component 5S

3.3 Indicators

The pilot test was conducted over approximately 3 months on non-consecutive days, applied only on those working days when electric hoists with characteristics similar to the defined sample were received: equipment with a maximum of 2 lifting chains and load capacities between 125 and 2,500 kilograms. This selection criterion ensured sample homogeneity and the comparability of recorded times across the 30 observations (Table 2).

Table 2. Indicators of the proposed model

Indicator	Definition	Target	Formula
Total maintenance cycle time	Time from work order initiation to equipment operational delivery.	Reduce by 30% the current average time of 8.87 hours.	$\text{Cycle Time} = (\text{Final Time} - \text{Start Time})$
5S compliance level	Percentage of 5S standard implementation, measured through a structured audit checklist.	Achieve a score above 90%.	$\text{5S Level} = 100 \times (\text{Points Obtained} / \text{Total Points})$
Average time of critical operations	Average time of Assembly and Replacement operations, those with the highest operational variability in the maintenance cycle.	Reduce by 20% the current average of 97.65 minutes, achieving a value equal to or below 78.0 minutes.	$\text{T. Crit. Ops} = (\text{T. Assembly} + \text{T. Replacement}) / 2$ Where: <i>T. Assembly</i> = time in mechanical assembly; <i>T. Replacement</i> = time in replacement and electrical connections.

Maintenance variability	Operational fluctuation relative to the average maintenance time.	Reduce by 40% the current standard deviation of 13.30 min.	$\sigma = \sqrt{[\sum(x_i - \bar{x})^2 / (n-1)]}$ Where: σ = standard deviation; x_i = individual time; $\bar{x}$ = average time; n = number of records.
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4. Data Collection

For field data collection, the time study technique was applied using chronometric recording forms during the preventive maintenance process of the hoists, allowing the measurement of total cycle time and its variability. In addition, a structured checklist was used to audit the initial 5S compliance level in the workshop. For activity mapping and analysis, Process Operation Diagrams (POD), Process Analysis Diagrams (PAD), and block diagrams were developed.

5. Results and Discussion

5.1 Numerical Results

The results obtained after the implementation of the improvement proposal are presented in Table 3, comparing initial and final values for each indicator. As a pilot test, the recorded progress constitutes sufficient evidence to validate the operational effectiveness of the implemented tools.

Table 3. Results of the proposed model

Indicator	Initial Value	Final Value	Improvement
Total maintenance cycle time	8.87 h (531.93 min)	6.45 h (387.10 min)	27.23%
5S compliance level	45.8%	64.0%	39.7%
Average time of critical operations	97.65 min	75.0 min	23.2%
Maintenance variability (σ)	13.30 min	4.18 min	68.57%

5.2 Graphical Results

Figure 4 presents comparative histograms of cycle times before and after implementation. The initial histogram shows a distribution with a mean of 531.93 minutes and a standard deviation of 13.30 minutes, reflecting the variability inherent to an empirical process. The post-implementation histogram evidences a notable compression of the distribution, with a mean of 387.10 minutes and a standard deviation of 4.18 minutes, confirming that the process became stable and predictable after standardization.

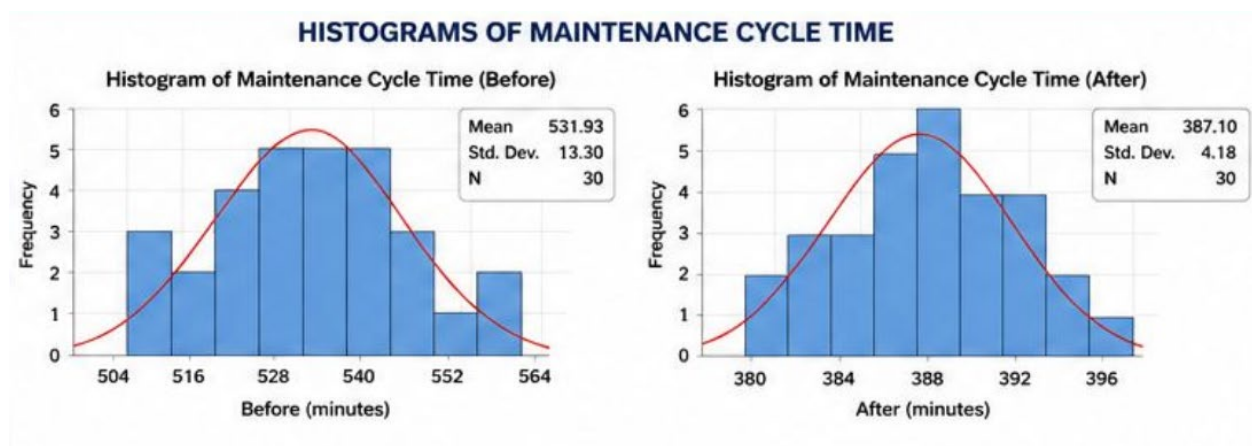


Figure 4. Comparative histograms — before and after implementation

Figure 5 presents the comparative box plot of cycle times before and after implementation, along with the differences plot. It is observed that the entire distribution of differences is located far from the $H_0 = 0$ value, visually demonstrating

that the reduction in times is not a product of chance. The post-implementation box is significantly narrower, reflecting the achieved reduction in operational variability.

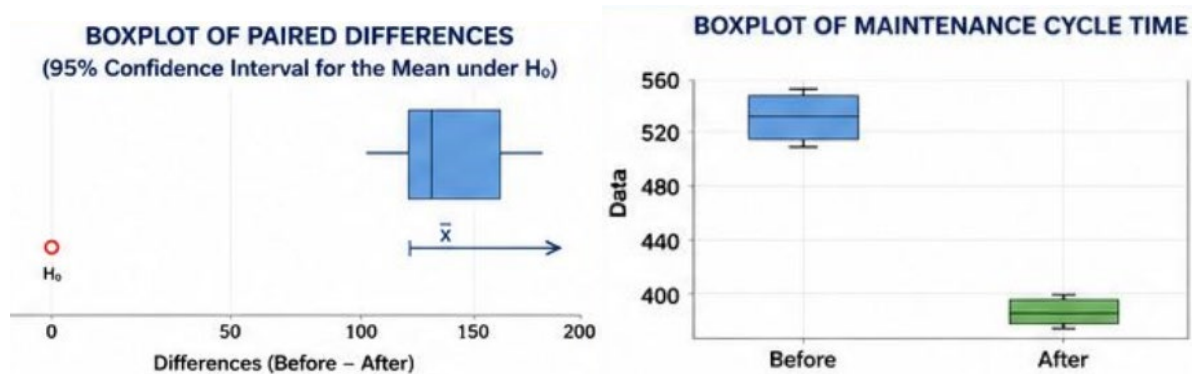


Figure 5. Box plot of differences and comparative cycle time (Before – After)

5.3 Proposed Improvements

The implementation of Standardized Work established an optimal operational sequence for each preventive maintenance stage, eliminating randomness in task execution and equitably distributing the workload through line balancing. The application of 5S physically reorganized the work environment, classifying tools and spare parts in fixed and labeled locations, and integrating cleaning and preventive inspection routines. Both tools acted in a complementary manner: 5S created the physical conditions necessary for Standardized Work to be executed smoothly and consistently, reducing the times of critical Assembly (110.2 → 80.0 min) and Replacement (85.1 → 70.0 min) operations, which concentrated the greatest process variability.

The total cycle time was reduced from 531.93 to 387.10 minutes, achieving a 27.23% improvement. This result surpasses that obtained by Vijay and Gomathi Prabha (2021), who achieved a 17% cycle time reduction through Standardized Work and line balancing in a gear manufacturing cell. The difference is explained by the fact that the present study combined Standardized Work with 5S, enhancing the impact of both tools by simultaneously eliminating randomness in the operational sequence and motion waste in the work area.

The 5S compliance level increased from 45.8% to 64.0%, improving by 39.7%. This progress is consistent with Shahriar et al. (2022), who reported reductions of between 8% and 18% in operating time by eliminating motion waste through 5S, confirming that visual workplace organization directly impacts process efficiency. The level achieved, below the 90% target, reflects the barriers identified: staff resistance to change and lack of sustained discipline in the early stages of implementation.

Process variance fell from 176.82 to 17.47, a reduction of 90.12%, with standard deviation decreasing from 13.30 to 4.18 minutes. This result surpasses the 8.75% reduction in transfer time reported by Kikushima and Cervantes (2023) through 5S implementation in a Peruvian SME. The difference is due to the fact that in the present study, variability reduction came not only from physical reorganization, but also from the standardization of the operational sequence and the use of audit checklists that sustained the achieved conditions throughout the 30 observations.

Among the study's limitations, the pilot test was conducted over approximately 3 months on 30 records from a single equipment type on non-consecutive days, which restricts the generalization of results to other operational contexts. For future research, it is suggested to integrate Total Productive Maintenance (TPM) as a complementary tool, as it would extend standardization toward preventive and predictive equipment management, reducing the root causes of rework in the critical Assembly and Replacement operations (Santos et al. 2025; Collao-Díaz et al. 2024). Additionally, it is recommended to expand the observation sample to validate long-term sustainability and evaluate the replicability of the model in other lifting equipment in the Peruvian metalworking sector.

5.4 Validation

Prior to applying the T-Student test, the normality assumption of both samples was verified using the Anderson-Darling test, with a significance level of 5% ($\alpha = 0.05$). The null hypothesis (H_0) states that the data follow a normal distribution, and is rejected only if $p < 0.05$ (Figure 6).

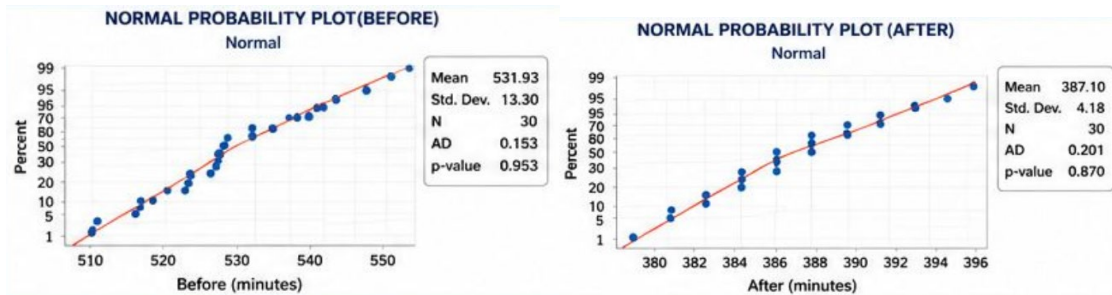


Figure 6. Anderson-Darling normality test — Before (left) and After (right) implementation

Table 4. Normality test results — Anderson-Darling ($\alpha = 0.05$)

Test	Sample	Statistic	p-value	Distribution
Anderson-Darling	Before	AD = 0.153	0.953	Normal ✓
Anderson-Darling	After	AD = 0.201	0.870	

The results show that both samples present p-values above 0.05 (Before: AD = 0.153, $p = 0.953$; After: AD = 0.201, $p = 0.870$), so H_0 is not rejected and both distributions are confirmed to be normal. This result is consistent with the homogeneous nature of the sample: since all hoists share similar characteristics (maximum 2 lifting chains, capacity between 125 and 2,500 kg), each maintenance cycle follows the same process with small and predictable variations, naturally generating a normal distribution. Additionally, with $n = 30$ observations, the Central Limit Theorem criterion is met, guaranteeing the validity of parametric tests. With the normality assumption verified, the paired T-Student test was applied as the statistical validation method (Table 4).

To statistically verify the effectiveness of the proposal, a paired T-Student test was applied to the 30 cycle time records obtained before and after implementation, using a significance level of 5% ($\alpha = 0.05$) (Figure 7).

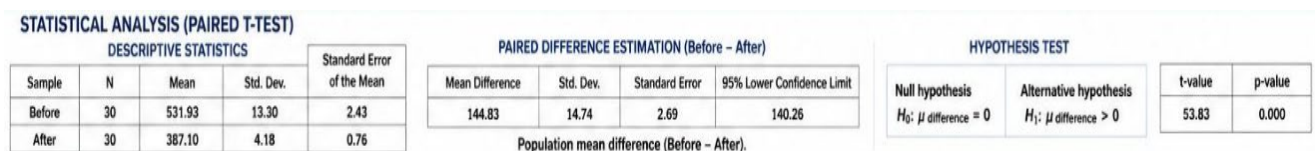


Figure 7. T-Student results for paired samples (Minitab)

The results yielded a T statistic of 53.83 with 29 degrees of freedom and a p-value = 0.000, strictly below the established significance level ($\alpha = 0.05$). Consequently, the null hypothesis (H_0 : difference _{μ} = 0) is rejected, confirming that the reduction in maintenance cycle time is statistically significant and not attributable to chance. The 95% confidence interval establishes a lower limit of 140.26 minutes for the mean difference, indicating that the implementation generated a real and consistent reduction across all records. The most relevant impact is observed in the variance reduction from 176.82 to 17.47 (90.12%), evidencing that the process evolved from an empirical and highly variable operation to a stable, predictable, and statistically controlled one.

6. Conclusions

The most relevant impact was the transformation of the process from an empirical and highly variable operation to a stable and predictable one. Standardized Work eliminated randomness in the task sequence, reducing execution errors

in the critical Assembly and Replacement operations. 5S, in turn, created the physical conditions necessary to sustain this standardization, as evidenced by the 90.12% drop in variance.

The 64% 5S compliance level indicates that operational discipline requires further maturation time. It is recommended to continue with periodic audits to consolidate order habits, extend the proposed model to other lifting equipment in the sector, and integrate Total Productive Maintenance (TPM) as the next step to address preventive equipment management, reduce the root causes of identified rework, and consolidate the long-term benefits achieved.

The implementation of 5S and Standardized Work tools in the preventive maintenance process of electric hoists proved effective in reducing operational variability and standardizing task execution in the workshop. Total cycle time was reduced from 531.93 to 387.10 minutes (27.23%), standard deviation decreased from 13.30 to 4.18 minutes (68.57%), and 5S compliance advanced from 45.8% to 64.0%, generating a potential annual saving of USD 8,451 in labor cost overruns. All results were statistically validated through the Anderson-Darling normality test and the T-Student test with $T = 53.83$ and $p = 0.000$.

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