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Maintenance Management Analysis to Improve the Effectiveness of Single Needle Sewing Machines at PT Alendros Global Production

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Abstract

The operational efficiency of production machinery is essential for improving productivity and competitiveness in garment manufacturing. PT Alendros Global Production faces operational challenges in Single Needle sewing machines, including high downtime, declining production targets, and increasing defect rates. This study evaluates maintenance management, measures machine efficiency using Overall Equipment Effectiveness (OEE)—an indicator combining equipment availability, operating performance, and product quality—identifies major production losses using the Six Big Losses framework, and develops improvement strategies based on Total Productive Maintenance (TPM) principles. A qualitative case study supported by quantitative operational data was conducted using observations, structured interviews, company documents, and operational records from July to December 2025. The findings indicate that maintenance activities remain predominantly reactive, characterized by delayed preventive maintenance, fragmented records, and ineffective spare parts inventory control. These weaknesses resulted in average downtime of 22.80% and an OEE score of 57.63%, below the 85% World Class benchmark. The Six Big Losses analysis identified sudden mechanical breakdowns and spare parts delays as the main sources of equipment losses. Recommended improvements include strengthening preventive maintenance, implementing autonomous maintenance training for operators, establishing safety stock levels, digitizing maintenance records, and improving production–maintenance communication. These measures provide a practical framework for reducing downtime, stabilizing machine performance, minimizing defects, and improving production efficiency.

Keywords:
Maintenance Management; Total Productive Maintenance; Overall Equipment Effectiveness; Sewing Machine; Six Big Losses; Garment Industry.

1. INTRODUCTION

Global Competition and the Role of Maintenance in ManufacturingThe contemporary manufacturing sector is characterized by aggressive global competition, compelling industrial firms to continuously optimize operational efficiency, product quality, and manufacturing flexibility to secure market viability. Within this competitive landscape, production machinery serves a vital strategic role, as equipment reliability directly dictates operational continuity, shop-floor expenditures, and customer satisfaction metrics. Consequently, the execution of an efficient maintenance management framework has surfaced as a mandatory element of industrial operations, allowing manufacturing enterprises to minimize unexpected downtime, elevate machinery reliability, and maximize factory output. Recent empirical literature highlights that structured and systematic maintenance programs are core pillars for securing long-term operational excellence and sustaining robust industrial performance (Gomaa, 2025; Zineb, Maryam, Safae, Aziz, & Mario, 2025).

The Garment Sector and Sewing Machine ReliabilityAs a cornerstone of Indonesia's manufacturing economy, the garment and textile industry contributes substantially to national workforce employment and macroeconomic development. Nevertheless, shifting consumer preferences, shrinking product life cycles, and increasingly rigorous quality assurance standards have intensified the necessity for lean and highly reliable production setups. Within garment manufacturing facilities, sewing machines represent the most critical assets since their operational performance directly dictates the final volume of output and product compliance. Recurrent mechanical disruptions, protracted periods of downtime, and fragmented upkeep procedures heavily undermine floor efficiency and inflate overhead costs, thereby eroding the firm's market competitiveness. To counter these systemic issues, garment manufacturers must establish disciplined maintenance protocols to sustain seamless, uninterrupted production workflows (Fani, Bucci, Bandinelli, & Rossi, 2025; Koç & Eryürük, 2025; Sheel, 2025).

Operational Challenges at PT Alendros Global Production, an established garment manufacturing entity situated in West Bandung Regency, currently grapples with severe operational vulnerabilities tied to the performance of its Single Needle sewing machine fleets. Internal engineering logs from the company reveal that between July and december 2024, average machine downtime escalated to 22.80%, which severely disrupted assembly runs and caused the average production volume to plummet to just 77.74% of the predetermined factory targets. Furthermore, the simultaneous rise in sudden mechanical breakdowns and product defect rates indicates that the existing maintenance infrastructure is underperforming. This operational bottleneck has severely degraded overall asset utility and compromised manufacturing throughput, establishing an urgent requirement for an objective, comprehensive evaluation of the facility's asset preservation strategies.Core Tenets of Maintenance ManagementFundamentally, maintenance management revolves around the methodical planning, execution, supervision, and auditing of technical upkeep tasks to ensure that capital equipment operates at peak efficiency throughout its lifecycle. A fully mature maintenance architecture encompasses strict preventive schedules, targeted corrective interventions, optimized spare parts logistics, routine machinery audits, and centralized documentation practices. Industrial operations that successfully embed such disciplined structures typically benefit from lowered downtime metrics, elevated equipment availability, and enhanced manufacturing yields. Thus, the implementation of organized maintenance serves as a strategic lever for maximizing industrial asset longevity and strengthening manufacturing capacity (Holgado, Macchi, & Evans, 2020; Karim, 2025; Velmurugan, Dhingra, & Velmurugan, 2021). Total Productive Maintenance TPM and the OEE FrameworkAmong contemporary industrial methodologies, Total Productive Maintenance TPM is widely acknowledged as an excellent approach for optimizing asset performance through cross-functional, company-wide accountability and continuous improvement philosophies. Within the TPM paradigm, Overall Equipment Effectiveness OEE serves as the primary metric to grade asset productivity by evaluating three core vectors: Availability, Performance, and Quality. According to benchmarks established by the Japan Institute of Plant Maintenance JIPM, a facility must hit an OEE score of 85% or higher to be certified as a world-class manufacturing operation. In tandem with OEE, the Six Big Losses diagnostic tool provides plants with a granular view to identify the root causes of efficiency leaks and systematically rank corrective measures (Peng, Wang, Wang, Liu, & Wang, 2021; Samal, Sahoo, & Badavath, 2023; Syahid, Guritno, & Raharjo, 2026). Research Gaps in E-Commerce and Garment Maintenance LiteratureWhile extensive research proves that TPM and OEE frameworks significantly curb equipment failure rates and maximize floor utilization, existing literature contains clear empirical limitations. Most past studies focus primarily on calculating baseline OEE data or assessing isolated upkeep actions, without adequately mapping the direct interplay between strategic planning, real-world execution, and dominant productivity drains inside garment manufacturing plants. Consequently, there remains a distinct shortage of empirical evidence detailing how comprehensive maintenance management workflows govern asset effectiveness within the specific context of Indonesia's garment industry (Amengual, Distelhorst, & Tobin, 2020; Annamalah, Aravindan, & Ahmed, 2025; Limon, 2023).

Research Novelty and Study ObjectivesThe structural novelty of this research lies in its integrated methodology, which simultaneously links maintenance management evaluation, empirical OEE measurement, and Six Big Losses diagnostics within a unified case study at PT Alendros Global Production. Moving past traditional studies that rely solely on quantitative data modeling, this inquiry evaluates the alignment between scheduled maintenance blueprints and their actual execution before isolating the primary drivers of factory losses to build practical, TPM-aligned solutions.Driven by this background, this study aims to:Auditing the existing maintenance management setup for Single Needle sewing machines at PT Alendros Global Production.Formally evaluating equipment utility using the Overall Equipment Effectiveness OEE metrics.Isolating dominant operational leaks via the Six Big Losses framework.Formulating actionable, TPM-guided upgrade blueprints.Ultimately, these outcomes are intended to enrich academic maintenance management literature and supply garment manufacturing managers with practical strategies to eliminate downtime, optimize asset value, and maximize factory productivity (Arafat, Das, Assiri, & Mia, 2026; Cannas, Ciano, Saltalamacchia, & Secchi, 2024; González-Viralta et al., 2023).

2. RESEARCH METHOD

2.1. Research Design

This study employed a descriptive case study approach to analyze the maintenance management practices of Single Needle sewing machines at PT Alendros Global Production. The research focused on examining maintenance planning, maintenance implementation, and equipment effectiveness. A mixed approach was applied by integrating qualitative information obtained through field observations, interviews, and documentation with quantitative analysis based on operational and production data. The qualitative approach was used to understand the actual maintenance practices and operational problems, while the quantitative analysis was used to measure equipment effectiveness through Overall Equipment Effectiveness (OEE).

The research was conducted at PT Alendros Global Production, with the Single Needle sewing machines serving as the main unit of analysis. The quantitative assessment used operational data from July to December 2024. The integration of qualitative and quantitative evidence enabled the study to provide a comprehensive evaluation of the company's maintenance management practices and their relationship with equipment effectiveness.

2.2. Data Collection

Data were collected through observation, interviews, and documentation. Direct observations were conducted on the production floor to examine the actual implementation of preventive and corrective maintenance activities on Single Needle sewing machines. The observations included machine operating conditions, preventive maintenance activities, machine breakdowns, corrective maintenance responses, spare-parts availability, and maintenance practices during production operations.

Interviews were conducted with personnel involved in machine operation and maintenance activities. The interviews were used to obtain information regarding maintenance procedures, preventive maintenance schedules, corrective maintenance responses, causes of maintenance delays, spare-parts management, and maintenance documentation practices. The information obtained from the interviews was used to clarify and complement the findings from direct observations.

Documentation was used to obtain supporting evidence and quantitative operational data. The documents included maintenance records, downtime records, repair records, production records, and other available maintenance-related documentation. In particular, operational and production records for the period of July to December 2024 were used to calculate Availability Rate, Performance Rate, Quality Rate, and Overall Equipment Effectiveness (OEE).

2.3. Data Triangulation

Data triangulation was applied to ensure the credibility and consistency of the research findings. The triangulation process involved comparing information obtained from observations, interviews, and documentation. Findings from direct observations were compared with statements obtained from interviews to determine whether the reported maintenance practices were consistent with actual conditions in the production area.

The interview findings were further verified using available maintenance and operational documentation. For example, information regarding machine breakdowns and corrective maintenance responses was compared with downtime records, repair records, and direct observations of maintenance activities. Similarly, information regarding preventive maintenance schedules was compared with documented maintenance records and the actual implementation observed on the production floor.

When the information obtained from the three sources showed consistent patterns, the findings were considered to have stronger supporting evidence. When differences were identified, the available evidence was reviewed and compared to determine the most appropriate interpretation of the observed condition. The triangulation process therefore ensured that the analysis was not based solely on interview statements but was supported by direct observations and documented evidence.

The qualitative findings obtained through triangulation were subsequently considered alongside the quantitative OEE results. This integration allowed the study to relate observed maintenance problems, interview findings, and documented operational conditions to measurable equipment effectiveness.

2.4. Quantitative Data Analysis

Quantitative analysis was conducted to measure the effectiveness of Single Needle sewing machines using Overall Equipment Effectiveness (OEE). Operational data collected for the period of July to December 2024 included planned production time, machine downtime, operating time, total production output, ideal production time, and defective products. The collected data were organized according to the observation period and used to calculate the three principal OEE components: Availability Rate, Performance Rate, and Quality Rate.

Availability Rate was calculated to determine the proportion of planned production time during which the equipment was available for operation. Operating Time was obtained by subtracting machine downtime from Planned Production Time. The formula used was:

Availability Rate (%) = (Operating Time / Planned Production Time) × 100

Performance Rate was calculated to measure whether the machine operated at its expected production speed. The calculation compared the ideal production time with the actual operating time and total units produced:

Performance Rate (%) = (Ideal Cycle Time × Total Units Produced / Operating Time) × 100

Quality Rate was calculated to determine the proportion of total production that met the required quality standards. The formula used was:

Quality Rate (%) = ((Total Units Produced − Defective Units) / Total Units Produced) × 100

After the three components were calculated, the overall OEE value was determined by multiplying Availability Rate, Performance Rate, and Quality Rate:

OEE (%) = Availability Rate × Performance Rate × Quality Rate

The calculated OEE values were analyzed for the July–December 2024 period to identify the level of equipment effectiveness and the component contributing most significantly to production losses. The resulting OEE was then compared with the 85% benchmark adopted in this study to evaluate the effectiveness of the company's maintenance management system. The quantitative findings were subsequently interpreted together with the qualitative findings from observations, interviews, and documentation to provide an integrated assessment of maintenance management at PT Alendros Global Production.

3. RESULTS AND DISCUSSION

3.1. Maintenance Planning Analysis

Maintenance planning is a fundamental element of operational asset management, providing a structured mechanism to preserve machine reliability, mitigate unexpected breakdowns, and ensure seamless manufacturing flows. By scheduling upkeep actions prior to component degradation, industrial plants can optimize machinery utilization, reduce operational expenditures, and enhance factory throughput. According to (Romero Meza & D'Urso, 2024) organized preventive upkeep serves as the absolute cornerstone of Total Productive Maintenance TPM, designed to optimize asset efficiency across its complete functional lifecycle Current Preventive Maintenance StructureThe empirical analysis indicates that PT Alendros Global Production has formulated a baseline maintenance framework for its Single Needle sewing machine inventory. This system integrates periodic preventive schedules, corrective reporting channels, and tracking records. To minimize disruptions to regular assembly shifts, preventive actions are strategically carried out during weekends or plant holidays. These routine procedures encompass equipment sanitation, lubrication, detailed structural inspection, and the swap-out of degraded elements based on operational conditions. This targeted scheduling underscores management's intent to sustain machine throughput while safeguarding production continuity.Limitations in Preventive ExecutionDespite the presence of a preventive schedule, the diagnostic audit revealed major operational limitations:Experience-Driven Replacements: Component replacement cycles rely heavily on technician intuition rather than standardized equipment life-cycle statistics or predictive condition indicators.Reactive Component Swaps: Critical parts are frequently replaced only after clear performance loss is noticed, inflating the risk of sudden equipment failure and floor disruptions.Prior research emphasizes that preventive actions must be supported by asset condition monitoring and component longevity tracking to enhance structural efficiency and minimize downtime metrics(West, Siddhpura, Evangelista, & Haddad, 2024; Yazdi, 2024). Corrective Maintenance and Communication Flows Corrective maintenance actions are triggered via an established internal reporting channel. When a sewing machine fails mid-shift, line operators immediately page maintenance personnel using the plant's active communication loop. Technicians are required to react rapidly to shorten operational delays and restore machinery functions. This established workflow indicates that the plant possesses a functional emergency response mechanism capable of reducing equipment idle times. Lack of Standardized Corrective Protocols However, the field analysis shows that the factory's corrective maintenance framework lacks comprehensive standardization:Absence of Priority Criteria: The company lacks written priority guidelines mapped to the severity of mechanical faults, leaving repair decisions to the personal judgment of available technicians.Resource Allocation Bottlenecks: This lack of clear damage classification undermines repair speed, particularly during peak production periods when multiple machines experience simultaneous breakdowns. According to Wireman 2004, establishing standardized corrective protocols improves repair consistency, accelerates service speeds, and maximizes resource allocation efficiency (Ewin & Oye, 2025; Titu, Grecu, Pop, & Șugar, 2025). Challenges of Paper-Based DocumentationAsset documentation is another weak point in the plant's planning structure. Maintenance logs, downtime logs, and historical repair records are recorded manually using physical logbooks and paper worksheets. While these files preserve historical summaries, they are completely isolated from any centralized, computerized maintenance management system that could enable real-time tracking or predictive analysis. This paper-reliant system introduces several operational risks: Incomplete Data Logging: Fragmented or lost entries undermine data integrity. Poor Traceability: Finding specific equipment repair histories is time-consuming. Limited Evaluation Capability: High data isolation makes it difficult to detect recurring technical faults or analyze historical metrics. Extensive literature demonstrates that computerized maintenance systems optimize scheduling, facilitate live equipment tracking, and enable data-driven operational choices, directly contributing to superior asset reliability and floor efficiency (Shamim, 2025). Summary of Planning Evaluation In conclusion, the maintenance planning framework at PT Alendros Global Production successfully covers the foundational aspects of preventive and corrective actions. However, significant strategic gaps remain, particularly regarding the adoption of predictive engineering indicators, the standardization of corrective response workflows, and the digitization of asset documentation. Bridging these operational gaps is vital to improve upkeep efficiency, reduce floor downtime, and successfully transition toward a mature Total Productive Maintenance TPM model. These insights align with TPM philosophies, which stress that systematic planning, continuous optimization, and floor-level involvement are mandatory to drive Overall Equipment Effectiveness OEE benchmarks (Carneiro et al., 2026).

3.2. Maintenance Implementation Analysis

3.2.1. Theoretical Framework of Maintenance Execution

Maintenance implementation represents the active execution phase within the asset management life cycle, where planned procedures are translated into field actions to safeguard machinery reliability and protect manufacturing continuity. Flawless execution is critical to driving down unexpected equipment downtime, averting sudden failures, and maximizing the operational lifespan of factory assets. Under the Total Productive Maintenance TPM philosophy, successful execution depends heavily on open, cross-functional collaboration among line operators, dedicated maintenance technicians, and plant management to eliminate floor inefficiencies (BHADURY, 2012). Execution of Preventive Maintenance Protocols The field evaluation reveals that PT Alendros Global Production deploys a dual upkeep model for its Single Needle sewing machine fleets, combining structured preventive maintenance with reactive corrective responses. Real-world preventive tasks are executed according to pre-established calendars. These interventions focus on deep equipment sanitation, lubrication, critical mechanism checks, the tightening of loose components, and the proactive replacement of worn parts before an actual breakdown occurs. This defensive approach is designed to maintain high machine performance and minimize line stoppages. Operational Barriers in Preventive Compliance Despite the existence of these protocols, the study identified critical operational bottlenecks during actual execution: Target-Driven Delays: Preventive schedules are frequently postponed or skipped entirely to meet urgent, short-term production quotas. Compounded Wear-and-Tear: Due to delayed servicing, multiple sewing machines continue running despite showing visible early signs of mechanical fatigue, drastically inflating the risk of sudden floor breakdowns. Methodological literature warns that delaying scheduled preventive tasks severely compromises asset reliability and drives up total overhead costs, as minor mechanical faults rapidly compound into catastrophic component failures (Wascom, 2026).

Corrective Maintenance Response Workflows When a sewing machine breaks down mid-production, the plant triggers its corrective maintenance workflow. Line operators immediately notify the technical team via the company's internal communication channel. Technicians then report to the specific station, run diagnostics, isolate the damaged parts, and execute repairs or component swaps to bring the machine back online as quickly as possible. This rapid-response approach is intended to shorten operational delays and restore production flows. The Pitfalls of a Predominantly Reactive CultureHowever, the diagnostic audit highlights that despite swift technician responses, the overall maintenance culture remains highly reactive:Absence of Predictive Engineering: Upkeep actions are almost exclusively reactive, initiated only after a failure has stopped the line, rather than being guided by predictive indicators or condition-based monitoring.Downtime Inflation: Consequently, sudden mechanical breakdowns remain the largest contributor to production losses and factory downtime. As noted by BHADURY, (2012), over-reliance on corrective repairs indicates that a facility has not yet achieved the core objectives of TPM, which mandates stopping failures before they ever surface. Logistical Bottlenecks in Spare Parts Management The field study identified spare parts inventory management as a major obstacle to efficient maintenance execution. Maintenance staff noted that critical machine repairs were frequently stalled because essential replacement components were out of stock. These supply chain delays prolonged repair times and increased machine idle periods, directly reducing overall equipment availability.

Optimizing spare parts logistics is therefore vital to improve maintenance responsiveness and floor efficiency. This finding strongly aligns with research by Muchiri and Pintelon 2008, which concluded that poor spare parts availability severely degrades Overall Equipment Effectiveness OEE benchmarks. Operational Constraints of Paper-Based Documentation The implementation analysis also revealed that maintenance reporting remains locked in a manual setup, relying entirely on handwritten logbooks and paper worksheets. Although these documents capture baseline breakdown events and basic repair activities, they are completely isolated from any digital asset management framework. This creates significant operational drawbacks: Slow

Data Retrieval: Accessing historical machine profiles is slow and cumbersome. Blind Spots in Trend Analysis: Detecting recurring technical faults or systematic component failures is highly difficult. Inefficient Strategic Planning: Long-term resource scheduling remains unoptimized due to the lack of historical data. In contrast, digital maintenance databases have been proven to streamline scheduling, facilitate live equipment tracking, and enable data-driven continuous improvement initiatives within manufacturing organizations (Karim, 2025). Summary of Implementation EvaluationIn summary, maintenance execution at PT Alendros Global Production successfully covers basic preventive and corrective practices to keep the production floor running. However, real-world execution is hindered by its reactive nature, caused by frequent preventive schedule delays, unoptimized spare parts stock levels, and manual data logging. These combined weaknesses lead to high machine downtime and reduced asset utility. To overcome these limitations, the company must strictly enforce preventive maintenance schedules, optimize inventory control policies, digitize asset tracking workflows, and deeper integrate TPM philosophies. Implementing these structural adjustments will improve machinery reliability, eliminate mid-shift production stoppages, and maximize the plant's overall operational performance (BHADURY, 2012).

3.2.2. Quantitative Data Collection and OEE Analysis Method

The quantitative analysis in this study was conducted to evaluate the effectiveness of maintenance management through the measurement of Overall Equipment Effectiveness (OEE) on Single Needle sewing machines at PT Alendros Global Production. The quantitative data used in the analysis were operational data collected from the Single Needle sewing machine fleet during the period of July to December 2024. The data consisted of information related to machine operating time, planned production time, downtime, production output, ideal production time, and defective products. These operational records were used as the basis for calculating the three main OEE components, namely Availability Rate, Performance Rate, and Quality Rate.

The data collection process involved compiling the available machine operation and maintenance records for each observation period. Machine downtime was identified from records of equipment breakdowns and maintenance activities, while production data were obtained from the recorded production output during the operating period. The collected data were then organized systematically according to the observation period to enable the calculation and comparison of OEE values. This quantitative approach complements the field observations and maintenance implementation analysis by providing numerical evidence of equipment effectiveness.

3.2.3. Availability Rate

Availability Rate was calculated to determine the proportion of planned production time during which the sewing machines were actually available for operation. The calculation considered planned production time and machine downtime. Planned production time represents the total scheduled production time, whereas downtime represents the period during which the machine was unavailable because of breakdowns, repairs, or other maintenance-related interruptions. The Availability Rate was calculated using the following formula:

$$\text{Availability Rate (\%)} = (\text{Operating Time} / \text{Planned Production Time}) \times 100$$

where:

$$\text{Operating Time} = \text{Planned Production Time} - \text{Downtime}$$

A lower Availability Rate indicates that a greater proportion of planned production time was lost because the equipment was unavailable.

3.2.4. Performance Rate

Performance Rate was calculated to evaluate whether the sewing machines operated at their expected production speed during available operating time. This calculation compares the actual production output with the production capacity that should theoretically have been achieved based on the ideal cycle time. The Performance Rate was calculated using the following formula:

$$\text{Performance Rate (\%)} = (\text{Ideal Cycle Time} \times \text{Total Units Produced} / \text{Operating Time}) \times 100$$

The calculation allows the study to identify production losses caused by reduced operating speed, minor stoppages, or other performance-related inefficiencies. Therefore, even when a machine is available for production, a low-Performance Rate indicates that the equipment is not operating at its expected production capability.

3.2.5. Quality Rate

Quality Rate was calculated to determine the proportion of products produced that met the required quality standard. The calculation distinguishes between total production output and defective products generated during the production process. The Quality Rate was calculated using the following formula:

Quality Rate (%) = ((Total Units Produced − Defective Units) / Total Units Produced) × 100

A high-Quality Rate indicates that most of the products produced by the machines meet the required quality standards, whereas a lower value indicates greater production losses resulting from defective products.

Overall Equipment Effectiveness Calculation

After Availability Rate, Performance Rate, and Quality Rate were obtained, the three components were combined to determine the overall OEE value. OEE was calculated using the following formula:

OEE (%) = Availability Rate × Performance Rate × Quality Rate

The three percentage values were converted into decimal form before multiplication and the resulting value was subsequently expressed as a percentage. For example, if Availability Rate, Performance Rate, and Quality Rate were 90%, 85%, and 95%, respectively, the resulting OEE would be:

$$OEE = 0.90 \times 0.85 \times 0.95 \times 100 = 72.68\%$$

This calculation provides an integrated measurement of equipment effectiveness because it simultaneously considers machine availability, operating performance, and production quality.

3.2.6. Quantitative Data Analysis and Interpretation

The calculated OEE values for the Single Needle sewing machines were analyzed for the July–December 2024 observation period. The analysis focused on identifying the level of equipment effectiveness and determining which OEE component contributed most significantly to production losses. The results of the Availability, Performance, and Quality calculations were compared to identify the dominant sources of inefficiency in the maintenance and production processes.

The resulting OEE values were subsequently compared with the benchmark used in the study. The manuscript adopts the JIPM benchmark of 85% as an indication of high-level manufacturing performance. Therefore, OEE values below this benchmark indicate that the equipment has not yet achieved the targeted level of overall effectiveness and that improvement opportunities remain in one or more of the Availability, Performance, or Quality components. This comparison was used to support the evaluation of the maintenance management system at PT Alendros Global Production.

The quantitative findings were then interpreted together with the qualitative findings concerning preventive maintenance execution, corrective maintenance response, spare-parts availability, and paper-based maintenance documentation. This integrated analysis enables the study to explain not only the numerical level of OEE but also the operational conditions that may contribute to equipment losses and reduced manufacturing effectiveness.

3.3. Overall Equipment Effectiveness OEE Evaluation

Overall Equipment Effectiveness OEE is a popular measure used in the Total Productive Maintenance TPM approach to assess how efficiently manufacturing equipment is performing. OEE combines three important factors—Availability Rate, Performance Rate, and Quality Rate—to show how well production equipment is performing compared to its best possible level. The Japan Institute of Plant Maintenance JIPM says that having an OEE score of 85% or more shows top-level manufacturing performance. So, OEE gives a full picture of how well equipment is being used and also shows where operations can be improved (Juraev, 2022)

In this study, the OEE assessment was done using operational data from the Single Needle sewing machines at PT Alendros Global Production between July and december 2024. The analysis involved figuring out the Availability Rate, Performance Rate, and Quality Rate, then using those to find the overall OEE value. The calculated OEE was then checked against the JIPM benchmark to see how well the company's maintenance management system was working.

Table 1. Overall Equipment Effectiveness OEE Results

OEE Component	Result %	JIPM Standard %	Evaluation
Availability Rate	77.20	≥ 90.00	Below Standard
Performance Rate	77.74	≥ 95.00	Below Standard
Quality Rate	96.03	≥ 99.00	Slightly Below Standard
Overall Equipment Effectiveness OEE	57.63	≥ 85.00	Needs Improvement

3.4. Overall Equipment Effectiveness OEE Analysis

3.4.1. Availability RateThe Availability Rate

Measures the proportion of scheduled production time that the machinery is actually operational after accounting for total downtime. The analysis indicates that the Single Needle sewing machines achieved an

Availability Rate of 77.20%, which falls substantially short of the 90% benchmark recommended by the Japan Institute of Plant Maintenance JIPM. This deficit highlights that equipment downtime remains a severe operational bottleneck within the facility. Recurrent mechanical failures, prolonged repair cycles, and extensive waiting times for replacement components collectively restricted machine availability, thereby constraining the plant's overall production capacity. This low availability metric directly reflects the factory's heavily reactive upkeep culture over proactive strategies. While preventive schedules exist on paper, they are frequently bypassed to prioritize short-term manufacturing quotas, leading to compounded mechanical wear and extended repair windows. According to Juraev, (2022); Nakajima, (1988), maximizing asset availability requires disciplined preventive scheduling, rapid technical response mechanisms, and streamlined spare parts logistics. These observations align with research by Muchiri and Pintelon 2008, which identified machine downtime as a primary driver of suppressed equipment efficiency in manufacturing environments.

3.4.2. Performance Rate

The Performance Rate evaluates floor operating speed against the machinery's ideal designed capacity. The study reveals that the Single Needle sewing machines operated at a Performance Rate of 77.74%, a figure considerably below the 95% JIPM international standard. This outcome demonstrates that the asset fleet consistently underperformed relative to its engineered output capacity, which severely dragged down manufacturing productivity. This performance loss was driven by a combination of minor equipment stoppages, speed reductions caused by component wear, frequent on-line adjustments by operators, and intermittent machine instability. These factors combined to leak productivity even during active operation. Prior literature establishes that neglected maintenance and gradual machine degradation directly erode operating speeds, thereby undermining total manufacturing efficiency (Eusufzai, 2025; Sari, Saputra, & Handinata, 2024).

3.4.3. Quality Rate

The Quality Rate assesses the percentage of defect-free goods produced relative to total output. The empirical data reveals a Quality Rate of 96.03%, indicating that the majority of the garment output successfully met the company's quality control standards. While this score is relatively high, it still fails to achieve the 99% world-class benchmark designated by JIPM.This metric proves that the assembly lines can still turn out acceptable products despite underlying mechanical instabilities. However, product defects continued to surface due to needle instability, worn sewing components, misaligned machine calibration, and manual mid-shift overrides by operators. These results show that upgrading maintenance discipline would not only secure machine availability but also directly reduce fabric defects. This conclusion strongly corroborates the findings of (Muhaba, 2026), who emphasized that asset reliability serves as a primary foundation for operational quality assurance.

3.4.4. Overall Equipment Effectiveness

OEE Integrating these three metrics yields a cumulative Overall Equipment Effectiveness OEE score of 57.63%. This score sits substantially below the 85% JIPM world-class threshold, classifying the performance of the Single Needle sewing machines at PT Alendros Global Production as "Needs Improvement" and indicating massive opportunities for structural enhancement. Text OEE=textAvailability 77.20%times textPerformance 77.74%times textQuality 96.03%=57.63%This low OEE score stems from the compounded impact of excessive downtime, degraded operating speeds, and quality reject losses. Among these, low Availability and Performance rates were the primary drivers of efficiency loss, proving that the existing maintenance management framework requires major structural upgrades. Within the TPM philosophy, maximizing this index requires rigorous preventive maintenance, autonomous operator practices, continuous line engagement, and systematic performance tracking (Nakajima, 1988). In short, the OEE diagnostic proves that the current upkeep framework fails to capture optimal equipment performance. To bridge this gap, the plant must strictly enforce preventive maintenance windows, optimize spare parts inventory thresholds, build operator ownership via autonomous upkeep training, and transition to a digital maintenance management infrastructure. Implementing these targeted improvements will eliminate chronic downtime, optimize floor output, and steadily move the facility's OEE profile toward the world-class benchmarks set by (BHADURY, 2012).

3.4.5. Comparison of OEE with Similar Industries

To provide a stronger context for the OEE results obtained at PT Alendros Global Production, the findings were compared with OEE performance reported in similar garment and apparel manufacturing industries. Such a comparison is important because the commonly cited 85% OEE benchmark represents a world-class reference, but OEE performance can vary considerably across manufacturing sectors depending on the level of automation, production characteristics, labor intensity, product variety, and operating conditions.

Recent research indicates that OEE values in the apparel industry commonly range between 40% and 60%. This relatively lower range is associated with the labor-intensive nature of apparel production, limited automation, product variety, and flexibility requirements. In contrast, highly automated sectors such as automotive manufacturing can achieve OEE levels of 85% or higher. Koç and Eryürük (2025) therefore suggest that an OEE target of approximately 75% can represent a more realistic and sustainable improvement target for apparel manufacturing.

The comparison with previous garment-industry studies further demonstrates the variability of OEE performance within the sector. A study of a garment manufacturing unit reported an initial OEE of 39.15%, consisting of an Availability Rate of 82.13%, a Performance Rate of 82.24%, and a Quality Rate of 57.96%. Following continuous improvement initiatives, the OEE increased to 65.11%, with Availability, Performance, and Quality improving to 88.64%, 87.44%, and 84%, respectively. Another study in the textile and garment industry reported that OEE increased from approximately 57% to 69% following the implementation of a hybrid Total Productive Maintenance (TPM) approach. A worsted fabric mills also demonstrated an improvement from 66% to 79% after TPM implementation.

These findings provide an important reference for interpreting the OEE results of PT Alendros Global Production. Rather than evaluating the company's OEE solely against the 85% world-class benchmark, its performance should also be considered in relation to the typical OEE range of the apparel industry. If the OEE obtained in this study falls below the 40–60% range, this indicates that the equipment effectiveness at PT Alendros Global Production is comparatively low even within the labor-intensive apparel sector. Conversely, an OEE value within the 40–60% range would indicate that the company is operating within the commonly reported industry range, although substantial opportunities for improvement would remain.

The relatively low OEE can be further explained by the maintenance conditions identified through the qualitative analysis. The field findings indicate that preventive maintenance activities are sometimes postponed because of production targets, while machine breakdowns are frequently addressed reactively after failures occur. In addition, shortages of spare parts can extend repair duration and increase machine downtime. The continued use of paper-based maintenance documentation also limits the company's ability to identify recurring failures and develop data-driven maintenance strategies. These operational conditions are consistent with the major factors identified in apparel manufacturing research, where downtime, performance losses, quality problems, limited automation, and production flexibility can significantly reduce OEE.

Therefore, the OEE results should not merely be interpreted as an indication that the company has failed to achieve the 85% world-class benchmark. More importantly, the comparison demonstrates the relative position of PT Alendros Global Production within the apparel manufacturing context and identifies the areas requiring improvement. Based on the literature, an improvement trajectory toward approximately 75% may represent a more realistic medium- to long-term objective for the company, while the immediate priority should be to reduce unplanned downtime, improve preventive maintenance compliance, ensure spare-parts availability, and strengthen the accuracy and accessibility of maintenance data.

Overall, the comparison with similar industries strengthens the interpretation of the OEE findings by demonstrating that the company's performance must be evaluated within the operational characteristics of apparel manufacturing. The findings also indicate that improving maintenance practices, particularly through a transition from reactive maintenance toward more systematic preventive and condition-based approaches, is essential for increasing equipment availability, production performance, and overall equipment effectiveness.

3.5. Six Big Losses AnalysisTheoretical

Overview of the Six Big Losses FrameworkThe Six Big Losses framework represents a cornerstone diagnostic tool within the Total Productive Maintenance TPM paradigm, specifically engineered to isolate and quantify the primary vectors of operational waste that compromise machinery utility. These losses directly degrade the three foundational pillars of Overall Equipment Effectiveness OEE: Availability, Performance, and Quality. By meticulously dissecting each loss classification, manufacturing enterprises can pinpoint the root causes of suppressed asset efficiency and formulate targeted strategic interventions. As established by Nakajima, (1988), systematically eradicating these six distinct categories of production waste is an absolute prerequisite for attaining world-class manufacturing excellence and maximizing cumulative OEE benchmarks (Nakajima, 1988) Methodological Application and Context. In this study, the Six Big Losses diagnostic was applied directly to the empirical operational logs of the Single Needle sewing machine fleets at PT Alendros Global Production, spanning the tracking window from July to December 2025. This auditing procedure comprehensively evaluated six standardized dimensions of industrial waste:Equipment Failure Losses sudden mechanical breakdownsSetup and Adjustment Losses line changeovers and calibration delays .Idling and Minor Stoppage Losses brief operational pauses and sensor blocksReduced Speed Losses machinery operating below engineered capacityProcess Defect Losses scrap, reworks, and immediate fabric rejectsReduced Yield Losses startup inefficiencies and stabilization wasteThe ultimate objective of this targeted breakdown was to isolate the dominant operational drains that caused the facility's low 57.63% OEE score, providing a data-driven foundation for continuous improvement.

Table 4 Six Big Losses Analysis

Six Big Losses	Percentage %	Contribution
Equipment Failure Losses	22.80	Highest
Setup and Adjustment Losses	3.15	Low
Idling and Minor Stoppage Losses	5.42	Moderate
Reduced Speed Losses	14.21	High
Process Defect Losses	3.97	Low
Reduced Yield Losses	1.18	Lowest

3.5.1. Equipment Failure Losses

The analysis indicates that Equipment Failure Losses represent the largest source of productivity loss, accounting for 22.80% of the total losses. This finding demonstrates that unexpected machine breakdowns are the most critical factor limiting the productivity of Single Needle sewing machines at PT Alendros Global Production. Equipment failure directly reduces machine availability because production must be stopped until the damaged component is identified, repaired, and the machine is returned to normal operating condition. In addition, the impact of breakdowns extends beyond the actual repair period because operators remain idle, work-in-process may accumulate, and production schedules must be rearranged to compensate for lost operating time.

The field observations and maintenance records show that several breakdowns were associated with worn components, delayed preventive maintenance, and limited availability of replacement parts. For example, when a sewing machine experienced component failure, production could not immediately resume because the required spare part was not always available in the maintenance inventory. Consequently, technicians had to wait for the component to be procured, extending downtime beyond the actual repair time. This situation indicates that equipment failure losses were caused not only by mechanical problems but also by weaknesses in the company's maintenance and spare-parts management systems.

The high proportion of Equipment Failure Losses also reflects the reactive nature of the current maintenance system. Maintenance activities are frequently performed after a failure has occurred rather than before deterioration reaches a critical condition. Worn components that are not identified through regular inspection can therefore continue operating until they fail during production. According to Nakajima (1988), excessive equipment failure losses indicate that preventive maintenance has not been sufficiently optimized. Similarly, Bhadury (2012) reported that equipment breakdown is a major contributor to low equipment effectiveness in manufacturing industries. Therefore, reducing Equipment Failure Losses requires an integrated approach involving timely preventive maintenance, routine operator inspection, adequate spare-parts availability, and faster communication between production and maintenance personnel.

3.5.2. Setup and Adjustment Losses

The percentage of Setup and Adjustment Losses was relatively low at 3.15%, indicating that machine setup activities and production changeovers were generally performed efficiently. Operators were able to complete machine adjustments within acceptable time limits before production resumed. Nevertheless, minor delays occasionally occurred during machine calibration and thread replacement, particularly when different product specifications required additional machine settings.

Although setup losses were not the dominant contributor to productivity loss, continuous improvement in setup standardization and operator training would further reduce production interruptions. According to (Pereira et al., 2025), standardized setup procedures and the implementation of Single-Minute Exchange of Dies SMED principles can significantly reduce setup time and improve production flexibility.

3.5.3. Idling and Minor Stoppage Losses

The study found that Idling and Minor Stoppage Losses contributed 5.42% of total production losses. These losses resulted from temporary machine stoppages caused by thread breakage, needle replacement, fabric positioning, and minor machine adjustments that occurred during production. Although these interruptions were relatively short, their cumulative impact substantially reduced machine operating time and overall production efficiency.

Previous studies have shown that minor stoppages often remain unnoticed because they occur repeatedly throughout the production process. Nevertheless, their accumulated effect can significantly reduce equipment performance. Therefore, improving operator skills, machine condition monitoring, and autonomous maintenance practices can effectively minimize minor stoppages (Nakajima, 1988).

3.5.4. Reduced Speed Losses

The second-largest contributor to productivity losses was Reduced Speed Losses, accounting for 14.21% of total losses. The sewing machines frequently operated below their ideal production speed due to machine wear, reduced component performance, vibration, and operator adjustments during production. As a result, production output was lower than the machine's theoretical production capacity, reducing the Performance Rate component of Overall Equipment Effectiveness.

The relatively high reduced speed losses indicate that machine performance has gradually declined because of aging components and inconsistent maintenance implementation. According to (Fernandes, Reis, Melão, Teixeira, & Amorim, 2021), reduced speed losses frequently occur when equipment is allowed to operate with deteriorating components instead of receiving timely preventive maintenance.

3.5.5. Process Defect Losses

The analysis shows that Process Defect Losses accounted for 3.97% of total production losses. Product defects mainly resulted from unstable machine operation, improper machine settings, worn sewing needles, and inconsistent stitch quality during production. Although the company achieved a relatively high-Quality Rate, these defects still contributed to production inefficiency because defective products required rework or rejection.

Previous research has demonstrated that effective maintenance management contributes directly to product quality by maintaining equipment stability and reducing process variation. Therefore, improving preventive maintenance and routine machine inspection is expected to reduce product defects and improve manufacturing quality performance (Fasuludeen Kunju, Naveed, Anwar, & Ul Haq, 2022).

3.5.6. Reduced Yield Losses

Among the six categories, Reduced Yield Losses represented the smallest contributor, accounting for only 1.18% of total losses. These losses occurred primarily during machine start-up and production initialization before stable operating conditions were achieved. Because the company has implemented standardized production procedures, start-up losses remained relatively low throughout the observation period.

Although reduced yield losses were minimal, continuous monitoring during production start-up remains necessary to prevent unnecessary material waste and ensure consistent production quality. Continuous improvement in start-up procedures also supports the long-term objectives of Total Productive Maintenance TPM.

3.6. Discussion

The results of this study show that the maintenance management system used at PT Alendros Global Production has not yet reached the best level of equipment performance. Although the company has set up preventive and corrective maintenance programs, they mostly handle issues after they happen instead of before. Sometimes, preventive maintenance plans are delayed because production needs come first, but after machines break down, most of the maintenance work is done to fix the problems. Because of this, the company has a lot of time when it's not working properly and its production isn't as good as it could be. These results match the ideas behind Total Productive Maintenance TPM, which say that maintenance efforts should mainly aim to stop machines from breaking down instead of fixing them after they stop working (Nakajima, 1988).

The assessment of Overall Equipment Effectiveness OEE shows that the average OEE for the Single Needle sewing machines was only 57.63%, which is much lower than the 85% standard set by the Japan Institute of Plant Maintenance JIPM. This result shows that the production equipment is still in the "Needs Improvement" group. The OEE score was not very high because the availability and performance were both low, but the quality was much better than average. These results show that the quality of the products has mostly stayed the same; but the machines stopping for repairs and running slower than usual still make it harder to produce things quickly overall. Other researchers, like (Cheah, Prakash, & Ong, 2020), have also found similar results. They said that having the right equipment and how well it works are the main factors affecting OEE in manufacturing.

The study of the Six Big Losses showed that Equipment Failure Losses were the biggest cause of production loss, and Reduced Speed Losses came next. Machines kept breaking down, which stopped production and made the machines less available. Even when the machines were still working, they ran slower, which cut down the amount of product made. These results show that the existing maintenance system hasn't completely stopped the equipment from breaking down. Nakajima 1988 says that machine breakdowns are one of the biggest problems for getting top manufacturing performance because they lower how much equipment is used and raise production costs. (Gomez, Peceros, & Pozo, 2025) also came to similar conclusions, highlighting that reducing breakdown losses is a main goal of implementing TPM.

Another important finding is about how preventive maintenance is carried out. Even though there are plans for regular maintenance, some repair tasks are put off because the production work is taking priority. This delay means parts aren't replaced on time, which makes it more likely that machines will break down unexpectedly. Besides that, the system for keeping track of spare parts is not working as well as it could be, which makes maintenance workers wait longer for the parts they need when fixing equipment. These operational conditions cause longer periods when the system is not working and lower the overall output. Research shows that doing regular maintenance and managing spare parts well can make machines work better and stop them from breaking down as much (Säfsten & Elgh, 2020).

The study also found problems with how maintenance records and information were handled. Maintenance records are still made by hand using paper logbooks, which makes it hard for the company to look back at past machine problems and check how well maintenance is working in a proper way. Not having a computerized maintenance management system makes it hard to check equipment conditions in real time and slows down making smart maintenance decisions based on data. (Márquez, 2022) said that digital maintenance information systems help with better maintenance planning, make it easier to assess performance, and help organizations keep improving over time in manufacturing.

From a manager's point of view, the results show that PT Alendros Global Production needs to improve how they carry out Total Productive Maintenance TPM by focusing more on preventive and self-initiated maintenance tasks. Operators need to take part in regular checks of machines, keep them clean, add lubricant as needed, and spot any unusual problems early on. In addition, the company should create uniform maintenance steps, better manage the stock of spare parts, use computer systems to track maintenance records, and provide regular training for the people who do the maintenance work. These improvement efforts are likely to cut down on equipment downtime, boost machine uptime, enhance production output, and slowly bring the Overall Equipment Effectiveness up to the 85% world-class level suggested by (Nakajima, 1988)

This study's results are useful in both theory and real-world applications. This study shows that TPM and OEE can be useful tools for assessing how well maintenance is managed in garment manufacturing, providing a complete way to look at maintenance practices. In real-world situations, the study shows that having a clear plan for maintenance, carrying out maintenance well, and keeping track of how equipment is working are all important for making operations run better and helping the company stay competitive. So, by constantly improving using TPM principles, it is expected that sustainable manufacturing performance will be supported and the long-term productivity of PT Alendros Global Production will be increased.

The results show that the Single Needle sewing machines at PT Alendros Global Production have an average Overall Equipment Effectiveness (OEE) of 57.63%, which is below the 85% World Class benchmark. The main contributors to this low effectiveness are equipment failures, reduced operating speed, delayed preventive maintenance, inadequate maintenance records, and spare-parts shortages. Therefore, management should implement an integrated maintenance improvement program based on Total Productive Maintenance (TPM), with clear procedures, responsibilities, schedules, and performance indicators.

First, the company should strengthen its preventive maintenance program by establishing a fixed maintenance schedule based on machine operating hours, equipment condition, and the recommended service intervals of critical components. The maintenance department should prepare a monthly preventive maintenance calendar and assign responsible technicians for each machine. Completion should be monitored using a maintenance checklist, and overdue activities should be reported to the production and maintenance managers. Routine activities should include cleaning, lubrication, inspection of belts, needles, motors, electrical components, and other critical parts. A preventive maintenance compliance target of at least 95% should be established to reduce unexpected breakdowns. This approach is consistent with Nakajima (1988), who emphasized preventive maintenance as an essential element of TPM.

Second, Autonomous Maintenance should be implemented progressively by involving machine operators in basic equipment care. Operators should receive structured training covering cleaning, lubrication, visual inspection, abnormality identification, and basic equipment checks. A daily inspection checklist should be completed at the beginning or end of each shift. Any abnormal noise, vibration, overheating, oil leakage, or deterioration should be recorded and immediately reported to maintenance personnel. This system enables early detection of problems and allows technicians to focus on more complex maintenance activities.

Third, spare-parts management should be improved to prevent repair delays. Management should identify critical spare parts based on failure frequency, equipment criticality, lead time, and historical consumption. Minimum and maximum stock levels should be established for critical components, together with safety-stock quantities. Inventory should be reviewed regularly, and purchasing personnel should receive automatic notifications when stock reaches the reorder point. This system can reduce waiting time for replacement parts and shorten mean time to repair.

Fourth, the company should implement a Computerized Maintenance Management System (CMMS) to replace fragmented manual records. Each sewing machine should have a digital maintenance history containing breakdown dates, failure types, repair duration, replaced components, technician actions, and maintenance costs. The system should also generate preventive maintenance reminders and monthly performance reports. Management can use these records to identify recurring failures, evaluate technician performance, and prioritize maintenance resources.

Fifth, management should establish a structured training program for operators and maintenance technicians. Training should cover machine operation, basic troubleshooting, preventive maintenance procedures, safety practices, and TPM implementation. Operator competency should be evaluated periodically through practical assessments. This ensures that employees possess the skills required to identify equipment abnormalities before they develop into major failures.

Finally, OEE should be monitored continuously as the primary performance indicator. Management should review Availability, Performance, and Quality on a weekly and monthly basis and compare the results with the 85% benchmark. The Six Big Losses should also be reviewed regularly to determine whether breakdowns, setup losses, reduced speed, minor stoppages, or quality losses remain the dominant problems. Improvement targets should be established progressively, for example by increasing OEE from 57.63% to 65% in the initial stage and subsequently toward 75% and 85%. Through systematic monitoring and continuous improvement, PT Alendros Global Production can reduce equipment downtime, improve machine reliability, and increase production efficiency.

4. CONCLUSION

This study is subject to several limitations and provides opportunities for further research. The analysis focused only on Single Needle sewing machines at one garment manufacturing company using operational data collected from July to December 2025. Therefore, future research could extend the investigation to other garment manufacturing facilities and compare maintenance performance across companies with different production scales, maintenance systems, and production capacities. Comparative studies across different industrial sectors, such as automotive, food processing, electronics, and metal manufacturing, could also examine whether the proposed TPM–OEE–Six Big Losses framework produces similar results under different operating conditions. In addition, future studies could investigate other types of production equipment, including Overlock, Flatlock, Cutting, Embroidery, and Finishing machines, to identify differences in equipment-related losses and maintenance requirements. Further research could also integrate predictive maintenance technologies, Internet of Things (IoT) sensors, machine condition monitoring, and Industry 4.0 applications to enable real-time detection of equipment abnormalities. Finally, longitudinal studies are recommended to evaluate the effectiveness of TPM implementation over a longer period and to examine its impact not only on OEE, but also on maintenance costs, production capacity, product quality, delivery performance, and overall business competitiveness.

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