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Optimizing Operations And Supply Chain Performance: Implementation Of Total Productive Maintenance (TPM) To Reduce Lead Time In An Indonesian Telecommunication Equipment Company

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Abstract

In the modern era of intense industrial competition, manufacturing organizations must continuously optimize their operations and supply chain performance to meet rapidly changing market demands. Electronic and telecommunication equipment manufacturers invest heavily in automated machinery to maintain high output. However, frequent equipment breakdowns severely inflate production lead times and disrupt downstream supply chain schedules. This study evaluates the implementation of Total Productive Maintenance (TPM) lean tools to reduce machine downtime and total lead time in a leading Indonesian telecommunication equipment manufacturer located in West Java. A structured six-month ground study was conducted on a production line to establish baseline equipment performance, followed by Pareto breakdown analysis, root cause identification, and the execution of autonomous and planned maintenance protocols. The empirical results demonstrate a 78.2% reduction in monthly machine breakdown hours, dropping from a baseline average of 117.6 hours to 25.6 hours per month. This improvement far exceeded the company's initial 40% downtime reduction target, stabilizing line throughput, eliminating workforce idle time, and significantly enhancing overall supply chain responsiveness. The average production lead was estimated to decrease from approximately 14 days before TPM implementation to 9 days after implementation, representing a 35.7% reduction. The findings provide operational managers with a validated blueprint for combining proactive maintenance with lean supply chain strategies in high-tech manufacturing environments.

Keywords: *Operations Management, Supply Chain Resilience, Total Productive Maintenance (TPM), Lead Time Reduction, Lean Operations, Electronics Industry.*

INTRODUCTION

In today's global market, manufacturing organizations face relentless pressure to improve operational efficiency and supply chain performance. To survive and remain competitive, companies must adapt swiftly to shifting customer demands while keeping operational costs low. Modern electronics manufacturers invest significantly in automated production equipment to secure high throughput. Nevertheless, automated systems remain vulnerable to unexpected mechanical and electrical failures. Frequent equipment breakdowns prolong manufacturing lead times and cause severe supply chain disruptions (Qureshi et al., 2023). When production stops unexpectedly, finished goods

deliveries are delayed, operational expenses escalate, and customer trust deteriorates rapidly (Saxena, 2022).

Lean manufacturing offers a proven operational philosophy focused on the systematic elimination of non-value-added activities across the value stream. In electronics assembly operations, unplanned equipment downtime represents one of the most critical forms of waste. Downtime halts the physical flow of materials and creates artificial bottlenecks. Indonesian manufacturing firms, particularly those in the consumer electronics and telecommunication equipment sectors, operate in volatile supply environments where components are sourced globally. Operational agility in this context requires an unfailing production system that minimizes lead time variance and protects supply chain continuity (Xu & Zhao, 2022).

To eliminate downtime waste, progressive manufacturing firms deploy proactive equipment management tools. Among these methodologies, Total Productive Maintenance (TPM) stands out as an integrative framework designed to maximize total equipment effectiveness. TPM shifts the organizational paradigm from reactive repairs to continuous equipment improvement and autonomous operator care (Drewniak & Drewniak, 2022). By integrating operators directly into daily maintenance routines, TPM eliminates small stops, prevents recurring failures, and stabilizes manufacturing output (Ahuja & Khamba, 2021).

This empirical research investigates the implementation of TPM in a prominent Indonesian telecommunication equipment company located in West Java. The facility experienced excessive breakdown hours on its Surface Mount Technology assembly line, causing severe lead time delays and inventory backlogs. The primary objective of this project was to implement targeted TPM pillars to reduce monthly breakdown hours by at least forty percent and stabilize supply chain deliveries. By achieving these targets, the study demonstrates how equipment maintenance serves as a core engine for operational reliability and competitive supply chain strategy (Singh et al., 2020; Syamil et al., 2003).

THEORETICAL FRAMEWORK AND LITERATURE REVIEW

The foundational theory supporting this research unites lean manufacturing principles with modern supply chain operations management. Lean thinking posits that any activity consuming resources without adding direct value to the end product must be identified and eliminated (Xu & Zhao, 2022). In high-volume electronics manufacturing, equipment breakdown is a major driver of operational waste. Downtime halts downstream processes, inflates work-in-process inventory, and disrupts production schedules (Tortorella et al., 2021). Maximizing overall equipment effectiveness is therefore an essential condition for achieving true operational lean status.

Total Productive Maintenance addresses equipment reliability through eight structured pillars: Autonomous Maintenance, Planned Maintenance, Quality Maintenance, Focused Improvement, Early Equipment Management, Training and Education, Safety and Health, and Office TPM (Saxena, 2022). Autonomous maintenance empowers machine operators to conduct routine cleaning, lubrication, and inspection tasks. This shift releases maintenance technicians to perform complex preventive work and predictive diagnostics (Antosz & Ratnayake, 2021). Through cross-departmental collaboration, TPM creates an organizational culture focused on total equipment care.

In supply chain management, lead time is defined as the total time required from initial order placement to final product delivery. In fast-paced electronics markets, short

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and predictable lead times provide a substantial competitive advantage (Qureshi et al., 2023). Unplanned equipment stoppages directly inflate manufacturing lead time, forcing managers to maintain costly safety stocks to buffer against supply chain failure (Wakjira & Singh, 2021). Implementing TPM directly mitigates lead time volatility, enabling lean, agile supply chain execution.

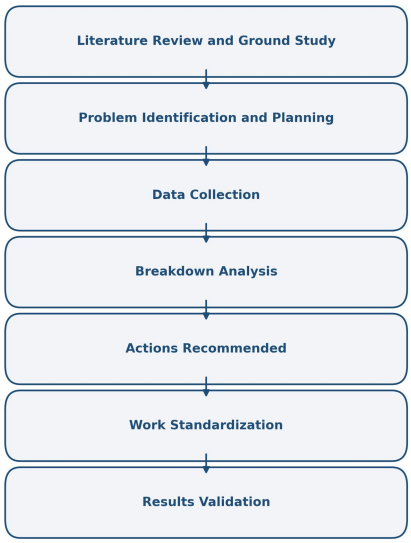
Furthermore, maintenance decisions must be tightly integrated with spare parts management and inventory policy. Traditional spare parts management often suffers from poor forecasting and stockout risks. Combining TPM with systematic spare parts classification models ensures that critical components are available when maintenance activities occur (Manalu et al., 2024). Aligning maintenance schedules with spare parts inventory prevents extended line stoppages caused by missing repair materials (Poduval & Pramod, 2020).

Finally, modern operations literature emphasizes the role of organizational learning and managerial leadership in executing operational transformations. Effective cross-functional problem solving relies on structured learning practices and team communication (Hong et al., 1996). Strong managerial oversight and leadership commitment are essential to sustain lean initiatives and align maintenance goals with top-level supply chain strategy (Syamil et al., 2003).

METHODOLOGY

This study adopted an action-oriented empirical research design within an Indonesian telecommunication equipment facility in West Java. The methodology followed a logical sequence spanning problem definition, baseline data collection, breakdown analysis, action plan execution, work standardization, and final result validation (Antosz & Ratnayake, 2021). The research focused on the factory's primary production line, which served as the operational bottleneck for printed circuit board assembly.

The structured execution framework developed for this research is illustrated in Figure 1. Figure 1 shows the methodology flow chart used to guide this research, depicting the step-by-step progression from initial ground study to final result validation (Saxena, 2022; Poduval & Pramod, 2020).



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Figure 1. Methodology Flow Chart for TPM Implementation

Data collection was conducted in two distinct six-month phases during 2024. Phase I established the operational baseline by recording daily equipment runtime logs, maintenance intervention records, and breakdown incidents from January to June 2024 (Drewniak & Drewniak, 2022; Singh et al., 2020). Maintenance records were categorized into mechanical and electrical failure types to evaluate the frequency and duration of line halts.

A cross-functional TPM task force was formed, comprising one maintenance manager, two shift facilitators, four technicians, and eight operators. The team analyzed baseline failure data using Pareto analysis to isolate critical machine components contributing to total downtime. Root causes were established using root cause analysis techniques, leading to specific corrective and preventive action plans (Xu & Zhao, 2022; Ahuja & Khamba, 2021). Finally, post-implementation performance data were collected from September to November 2024 to validate operational lead time improvements.

DATA COLLECTION AND BASELINE ANALYSIS

The research site manufactures specialized telecommunication printed circuit board assemblies for domestic and global technology clients. The facility's production line operates as the primary stage of assembly. Any equipment failure on this line immediately halts component placement, starves downstream manual assembly stations, and delays outbound logistics (Xu & Zhao, 2022). Internal company standards mandated a maximum allowable equipment breakdown limit of 20 hours per month.

Baseline breakdown data collected during the first quarter of 2024 are summarized in Table 1. Table 1 shows the breakdown data collected from January to March 2024, revealing severe mechanical and electrical stoppages that heavily exceeded the company's operational target (Qureshi et al., 2023; Drewniak & Drewniak, 2022).

Breakdown Category	Jan 2024 (hrs)	Feb 2024 (hrs)	Mar 2024 (hrs)	Monthly Average (hrs)
Mechanical Failures	70	85	90	81.6
Electrical Failures	40	40	40	40.0
Total Loss Hours	**110**	**125**	**130**	**121.6**

Table 1. Breakdown Data Collection Phase I (January to March 2024)

Data collection continued into the second quarter of 2024 to confirm operational failure trends. Table 2 presents the breakdown data collected from April to June 2024, demonstrating an alarming persistence in high breakdown hours (Saxena, 2022; Wakjira & Singh, 2021). The baseline average for the second quarter stood at 117.6 hours per month, almost six times higher than the allowable maximum threshold.

Breakdown Category	Apr 2024 (hrs)	May 2024 (hrs)	Jun 2024 (hrs)	Monthly Average (hrs)
Mechanical Failures	80	85	78	81.0
Electrical Failures	35	35	40	36.6
Total Loss Hours	**115**	**120**	**118**	**117.6**

Table 2. Breakdown Data Collection Phase II (April to June 2024)

To pinpoint the primary operational bottlenecks, the TPM team conducted a detailed machine breakdown analysis across the production line. Figure 2 illustrates the Pareto analysis for the breakdowns in the production line, identifying nozzle clogging on the Pick and Place machine and conveyor belt slippage in the Reflow Oven as the vital few causes of downtime (Tortorella et al., 2021; Singh et al., 2020). Table 3 provides a

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detailed breakdown of the time lost per machine component, showing that these two component failures accounted for 3,300 minutes (77.6%) of total downtime.

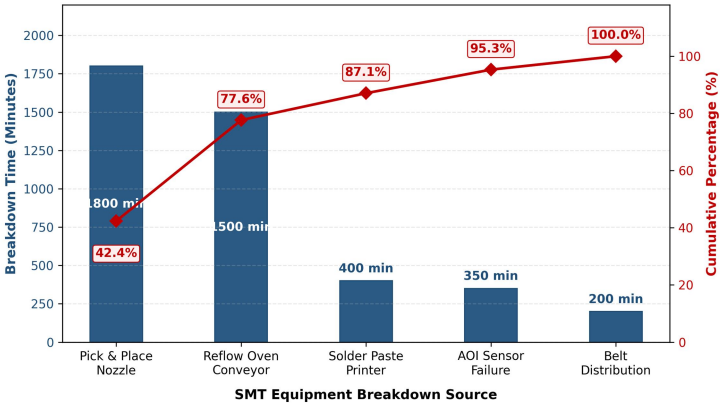


Figure 2. Pareto Diagram for Production Line Breakdowns

Sl. No.	Machine Component	Breakdown Time (Minutes)	Percentage (%)	Cumulative (%)
1	Pick and Place Nozzle	1800	42.4%	42.4%
2	Reflow Oven Conveyor	1500	35.3%	77.6%
3	Solder Paste Printer	400	9.4%	87.1%
4	AOI Sensor Failure	350	8.2%	95.3%
5	Belt Distribution System	200	4.7%	100.0%

Table 3. Machine Component Breakdown Time Distribution

The operational impact of these stoppages extended across the factory's internal supply chain. Because production line placement is the initial manufacturing step, line halts immediately halted manual component insertion lines downstream. Assembly operators were forced to remain idle during machine repairs, leading to labor cost inefficiency and severe production schedule backlogs (Manalu et al., 2024; Qureshi et al., 2023). Addressing these root causes was essential to restore flow across the facility.

RECOMMENDED ACTIONS AND TPM IMPLEMENTATION

To address the identified failure modes, the TPM task force implemented targeted proactive countermeasures grounded in autonomous, planned, and quality maintenance pillars (Saxena, 2022; Antosz & Ratnayake, 2021). The objective was to eliminate recurring mechanical faults and build operator ownership of daily equipment condition. Specific root causes and implemented corrective actions are outlined in Table 4. Table 4 outlines the specific root causes and the immediate corrective actions implemented to stabilize operations (Drewniak & Drewniak, 2022; Ahuja & Khamba, 2021).

Machine Equipment	Breakdown Issue	Root Cause Analysis	Implemented Corrective Action
Pick and Place Machine	Nozzle Clogging	Solder paste residue accumulation due to irregular manual cleaning	Installed automated daily ultrasonic cleaning routine and operator inspection checklist.
Reflow Soldering Oven	Conveyor Belt Slip	Motor bearing thermal wear caused by prolonged high heat	Upgraded motor drive to high-temperature ceramic bearings and recalibrated belt tension.
Automated Optical Inspection	Sensor Failure	Voltage fluctuations triggering sensor recalibration halts	Installed dedicated line voltage stabilizer and implemented weekly sensor calibration routine.

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Table 4. Root Cause Analysis and Implemented Corrective Actions

Preventive maintenance protocols were overhauled completely. Operators received hands-on training to perform 10-minute pre-shift cleaning, lubrication, and alignment checks. Furthermore, predictive maintenance technologies, including vibration monitoring sensors on main conveyor motor drives, were installed to detect bearing wear before major failure occurred (Ghobakhloo & Fathi, 2021).

Work processes were standardized through clear Standard Operating Procedures (SOPs) mounted directly at each machine station. Visual management controls, including color-coded lubrication tags and pressure range indicators, were introduced to assist operators during daily inspections. Cross-functional review meetings were held weekly to evaluate maintenance compliance and resolve emerging machine anomalies (Hong et al., 1996; Poduval & Pramod, 2020).

RESULTS AND DISCUSSION

Following the execution of TPM corrective actions, equipment performance was monitored closely from September to November 2024. Table 5 summarizes the total loss in hours before and after the TPM implementation, showing a dramatic decrease in machine downtime across the production line.

Before TPM Period	Baseline Loss (Hours)	After TPM Period	Post-TPM Loss (Hours)
April 2024	115.0	September 2024	32.0
May 2024	120.0	October 2024	25.0
June 2024	118.0	November 2024	20.0
Monthly Average	**117.6**	**Monthly Average**	**25.6**

Table 5. Total Stoppage Loss Hours Before and After TPM Implementation

The quantitative results show a 78.2% reduction in monthly breakdown hours, plummeting from a baseline average of 117.6 hours down to 25.6 hours per month. By November 2024, total downtime reached 20.0 hours, successfully meeting the company's stringent internal reliability target. This outcome far exceeded the initial project goal of a forty percent downtime reduction

This substantial downtime reduction yielded immediate benefits for supply chain flow. the average production lead time was estimated to decrease from approximately 14 days before TPM implementation to 9 days after implementation, representing a 35.7% reduction. This improvement enhanced production flow stability and increased overall supply chain responsiveness. Production line throughput stabilized, allowing component placement to proceed according to scheduled cycle times. Downstream manual assembly line stoppage was eliminated, reducing work-in-process inventory buffers and restoring predictable order lead times (Manalu et al., 2024; Xu & Zhao, 2022).

Beyond numerical operational gains, TPM fostered a culture of continuous improvement (Kaizen) on the shop floor. Operator morale improved noticeably as unexpected breakdown pressure decreased. Machine operators developed pride in equipment maintenance, confirming that cultural empowerment is a vital ingredient for sustainable lean manufacturing success (Tortorella et al., 2021; Wakjira & Singh, 2021).

MANAGERIAL IMPLICATIONS AND FUTURE RESEARCH

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The managerial implications of this research are highly relevant for operations directors in developing economies. First, shop-floor equipment maintenance must be recognized as a strategic component of supply chain management rather than an isolated engineering function. Increasing equipment uptime stabilizes production throughput and protects downstream distribution schedules from unexpected delays (Xu & Zhao, 2022; Syamil et al., 2003).

Second, executive leadership must actively support TPM transformations by providing training resources and allocating time for operator autonomous maintenance routines. Without consistent top-down commitment, autonomous maintenance initiatives risk reverting to reactive repair habits over time (Hong et al., 1996; Antosz & Ratnayake, 2021).

Future research should investigate the integration of Industry 4.0 IoT sensors with TPM frameworks. Real-time condition monitoring, automated anomaly detection, and cloud-based predictive analytics represent logical extensions of lean maintenance, further strengthening supply chain resilience in smart manufacturing environments (Ghobakhloo & Fathi, 2021; Qureshi et al., 2023).

CONCLUSION

This empirical research confirms that Total Productive Maintenance is a powerful tool for reducing breakdown hours and optimizing supply chain operations in high-tech manufacturing. The implementation of TPM on a production line in an Indonesian telecommunication equipment factory achieved a 78.2% reduction in downtime hours, far exceeding initial operational targets. By addressing root causes through autonomous maintenance, structured cleaning, and equipment upgrades, the company restored operational throughput and stabilized order lead times. Sustainable operational success requires continuous operator training, strict SOP adherence, and active executive leadership in lean supply chain strategies (Ahuja & Khamba, 2021; Drewniak & Drewniak, 2022).

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