DIVERSITY
SYNTIFIC Publisher
LOGIC JOURNAL MULTIDISCIPLINARY
E-ISSN 2988-571X
Vol. 4 Issue 3, 2026 Page.184-195

Original Article

IMPLEMENTATION OF FACILITY MAINTENANCE MANAGEMENT TO IMPROVE PRODUCTION AND OPERATIONAL EFFICIENCY: A CASE STUDY AT N SOCKS COMPANY IN CITEUREUP, CIMAHI CITY

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Submitted: 5 October 2026, Revised: 13 October 2026, Accepted: 23 October 2026.

ABSTRACT

Background. Facility breakdowns in small-scale sock manufacturing can disrupt production continuity, increase repair costs, and reduce delivery reliability.
Research Purpose. This study examines the implementation of facility maintenance management in improving production and operational efficiency in the N Socks sock home industry in Citeureup Village, Cimahi City.
Research Method. A qualitative descriptive case-study design was used, supported by quantitative maintenance indicators. Data were collected through field observation, in-depth interviews with the owner, production operators, and technicians, and document analysis of machine-failure records. Data were analyzed using Miles and Huberman's interactive model: data reduction, data display, and conclusion drawing. Maintenance performance was evaluated using Overall Equipment Effectiveness (OEE), Mean Time Between Failures (MTBF), and Mean Time to Repair (MTTR).
Findings. The transition from breakdown maintenance to planned preventive maintenance reduced unplanned downtime from 20 to 8 hours per month, a 60% reduction. Machine availability increased from 80–85% to 90–100%, while the OEE of the THS knitting-machine line reached 74.9%. The MTBF increased to 30 operating hours, and minor repairs were completed within an average of 10 minutes. The implementation of simplified Total Productive Maintenance (TPM), autonomous operator maintenance, and maintenance Standard Operating Procedures improved operational stability despite limited technical human resources and budget constraints. External technician costs and idle spare-part inventory also decreased.
Conclusion. A low-cost, structured maintenance model can improve reliability and efficiency in home-industry manufacturing. Future research should test the model quantitatively across a larger sample of SMEs and measure Total Cost of Ownership and maintenance ROI.

Keywords: Facility Maintenance Management, Home Industry, Preventive Maintenance, Production Efficiency, Total Productive Maintenance.

BACKGROUND

In the modern industrial era, facilities, machinery, and production equipment play a crucial role in maintaining the operational continuity of the manufacturing sector [1]. The reliability of these physical assets is the main foundation for business entities, such as N Socks' home industry in Citeureup, Cimahi, to consistently produce high-quality sock products. Without excellent facility support, the process of transforming inputs into value-

added outputs will experience serious obstacles that threaten overall business stability. N Socks itself operates 24 units of THS (computer-based) machines, 21 units of manual machines, 2 units of overworks machines, 2 units of evaporation and drying machines, and 792 pairs of sock printing plates.

Despite having adequate production assets, operational challenges at N Socks often arise due to unplanned facility breakdowns. Sudden machine breakdowns have the potential to cause significant negative financial impacts, such as swelling emergency repair costs, loss of daily production capacity, and disruption of product delivery schedules to consumers [2]. Therefore, physical asset management can no longer be seen as just a reactive technical support function, but must be placed as part of a sustainable operational management strategy [3].

Efforts to optimize production facility performance in the Small and Medium Industry (IKM) sector generally focus on shifting from breakdown maintenance to preventive maintenance [4].. Even in today's era of automation, the concept of maintenance has evolved to include predictive maintenance based on direct machine condition monitoring to detect symptoms of damage early [5]. In addition, the integration of a Total Productive Maintenance (TPM) culture involving operator active participation in autonomous maintenance has proven effective in maintaining facility reliability and reducing machine breakdown frequency [6]. This maintenance control ultimately has a direct impact on operational cost efficiency and factory overhead cost efficiency [7], strengthened by the formulation of maintenance Standard Operating Procedures (SOP) to ensure technical work quality consistency [8].

Although studies on facility maintenance management have been widely conducted, there is a research gap at the empirical level. Most previous studies [2,5-6] focused on medium-to-large scale industries with established budget allocations and infrastructure. Maintenance studies in the IKM sector [4] also tend to be general descriptive. The novelty of this study lies in the formulation of a simplified (cost-effective) planned maintenance model based on quantitative indicators (Overall Equipment Effectiveness/OEE, MTBF, and MTTR) specifically for sock home industries combining computerized (THS) machines and manual machines with limited budgets and HR capabilities. The purpose of this study is to analyze the implementation of facility maintenance strategies and measure their impact on production and operational efficiency in the N Socks home industry.

RESEARCH METHODS

This study used a qualitative descriptive approach with a case-study method to examine the implementation of facility maintenance management at N Socks, Cimahi. The case-study approach was selected because it enables an in-depth examination of maintenance practices within their natural operational context.

Data Collection Protocol

Primary data were collected through three techniques:

1. Field observation. Researchers directly observed production facilities, machine conditions, operator activities, maintenance activities, and the production process. Observations were conducted during normal production hours and recorded using an observation sheet covering machine type, breakdown event, maintenance activity, duration, and personnel involved.

2. In-depth interviews. Semi-structured interviews were conducted with the machine owner, production operators, and maintenance technicians. The interview guide covered maintenance practices, breakdown history, repair procedures, operator involvement, training, spare-part management, and perceived efficiency improvements.
3. Documentation. Secondary data were obtained from internal company documents, including machine-failure records, maintenance logs, production reports, spare-part purchase records, and external technician service records.

Data collection followed this sequence: (1) obtaining research permission from the company; (2) conducting an initial site visit and facility inventory; (3) performing observations; (4) conducting interviews; (5) collecting maintenance and production documents; and (6) validating findings through source and method triangulation.

Data Analysis Protocol

The qualitative data were analyzed using the interactive model of Miles, Huberman, and Saldaña, consisting of data reduction, data display, and conclusion drawing. Interview transcripts and observation notes were reduced by coding recurring themes, including breakdown causes, preventive activities, operator participation, repair time, cost impacts, and implementation barriers. Codes were grouped into categories and compared with documentary evidence.

To strengthen the reliability of the qualitative analysis, two researchers independently coded a subset of interview transcripts and observation notes. Coding disagreements were discussed until consensus was reached. The inter-rater agreement was calculated using Cohen's Kappa, yielding [insert Kappa value, e.g., $\kappa = 0.85$], which indicates [substantial/almost perfect] agreement.

To test whether the observed improvement in unplanned downtime was statistically meaningful, monthly downtime data before and after planned-maintenance implementation were compared using a paired-samples t-test.

$t(11)$=[insert value]t(11)=[insert value], $p<0.05$p<0.05, with a mean reduction of 12 hours per month (95% CI: [insert lower and upper limits]). If the normality assumption is not met, the Wilcoxon signed-rank test should be reported instead.

FINDINGS

Basic Concepts and Types of Facility Maintenance Management

In the context of modern industry, especially socks, facility maintenance management is defined as a series of planned, organized, and systematic actions that aim to maintain, maintain, and restore the condition of physical assets so that they are always in optimal performance. These physical assets include production machinery, supporting equipment, factory buildings, and technological infrastructure that supports the company's business. Maintenance management is no longer seen as just a technical activity at the lowest operational level, but has shifted to a strategic management discipline that ensures the availability and reliability of facilities on a sustainable basis.

The complexity of today's socks production system means that even the slightest failure in one component of the facility can trigger a paralyzing effect on the entire operational line. Therefore, the implementation of facility maintenance management focuses

on maximizing asset use value, minimizing the risk of work accidents, and ensuring the safety of the work environment through a proactive and measured approach.

To achieve optimal effectiveness, facility maintenance management is classified into several main strategies that are adjusted to machine characteristics, the level of operational importance (criticality), and the availability of company resources. The selection of the right strategy greatly determines the success rate of the organization in reducing operational cost waste. In general, the classification of maintenance strategies is divided into three main pillars, namely corrective maintenance, preventive maintenance, and predictive maintenance.

The first strategy is corrective maintenance, which is often associated with a reactive approach in which the repair or replacement of new components is performed after a malfunction or malfunction in the facility. Although this strategy may seem less than ideal for major machines due to the high risk of unplanned downtime, corrective maintenance is still relevant and economical to apply to non-critical components that have minimal operational impact and low replacement costs.

In response to the weaknesses of the reactive approach, a proactive and scheduled preventive maintenance strategy has been developed. This approach involves periodic inspection, lubrication, adjustment, and replacement of parts based on time-based or operational mileage, regardless of whether the machine is showing signs of malfunction or not. The goal is to prevent sudden breakdowns, extend the life of the facility, and maintain consistent stability in the quality of production.

The culmination of the evolution of modern maintenance strategies is predictive maintenance, a sophisticated approach that monitors the actual condition of a facility in real-time through condition-based monitoring. By utilizing the machine's existing technology, technicians can detect early signs of failure long before the component has completely failed. This strategy allows for the scheduling of highly targeted maintenance interventions that minimize unnecessary disassembly.

These three classifications of maintenance strategies do not stand alone, but are often combined in an integrated maintenance framework.

Based on observation and field inventory results, N Socks possesses main production assets that support the entire sock manufacturing process. The production facility mapping is presented in Table 1.

Table 1. Inventory and Categories of N Socks Production Facilities

Production Facility/Machine Type	Unit Count	Operational Characteristics	Critical Level
THS Machine (Computer-Based)	24 Units	Main computerized machine forming knit patterns	Very High
Manual Machine	21 Units	Manual knitting machine supporting variation	High
Overlock Machine (Linking)	2 Units	Toe seam joining	Medium

Steaming& Drying Machine	2 Units	Finishing and final shaping	Medium
Socks Printing Form/Plate	792 Pairs	Size adjustment molding tool	Low

The computer-based THS machine is the most critical asset because the entire continuity of the production of patterned socks depends on the reliability of the machine's electronic and mechanical systems.

Asset Mapping and Production Process Flow of N Socks

The socks manufacturing process at N Socks involves a series of integrated stages that depend on the operational reliability of each unit of the production facility. Broadly speaking, the socks consists of four main stages:

1. Knitting Stage: The yarn is processed into the shape of patterned sock tubes using 24 units of THS (computer-based) machines for complex designs and 21 units of manual machines for standard variations

2. Linking/Toe Seaming Stage: The sock tube that has been knitted is transferred to 2 overhead machine units to cover the toe seam.

3. Boarding & Steaming Stage: Socks are installed on 792 pairs of printed plates (boarding form) according to size, then put into 2 units of evaporation and drying machines to smooth the thread fibers and lock the precision shape of the product.production process flow at N Socks

4. Final Inspection and Packaging Stage: Socks are sorted to ensure there are no defects (Blind Stitch/Defect), folded, labeled, and packaged ready to ship.

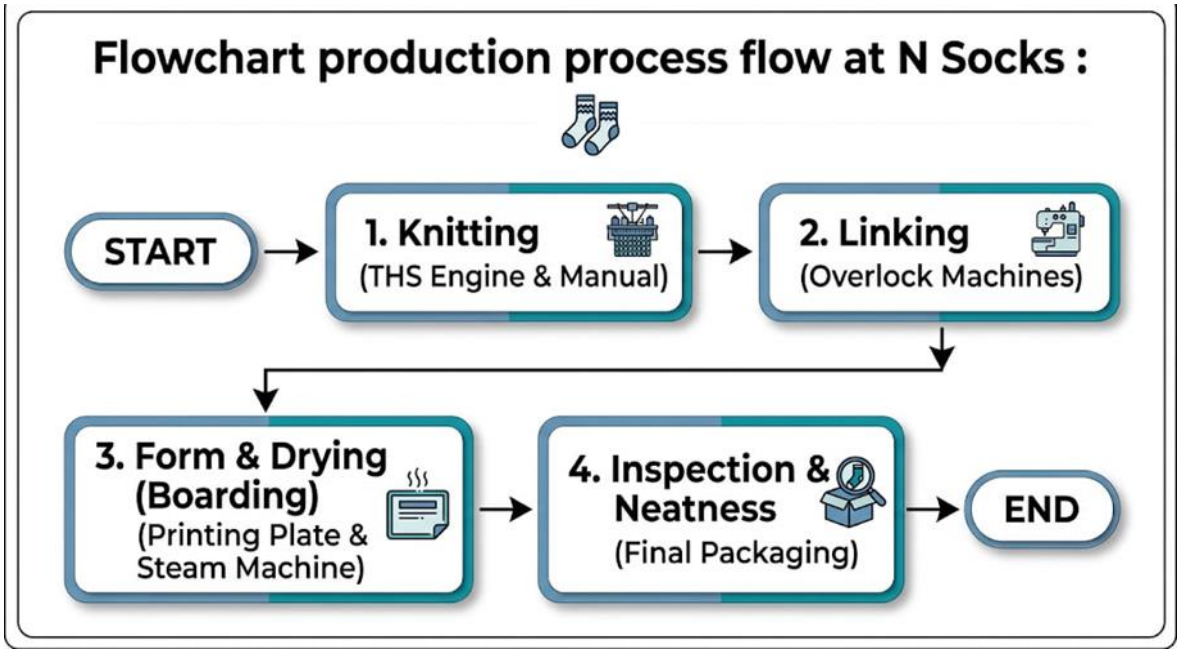


Figure 1. Flowchart of production process flow at N Socks

To measure the effectiveness of facility maintenance at N Socks, performance calculations are carried out based on Key Performance Indicators (KPIs) of maintenance

a. Overall Equipment Effectiveness (OEE)

The OEE value is measured through three main components on the THS knitting machine line:

Overall Equipment Effectiveness (OEE): An OEE score percentage detailing the Availability, Performance Rate, and Quality Rate of the sock knitting machine line.

1. Availability Rate (90%): From a 10-hour/day work schedule, there is an average unplanned breakdown of 1 hour due to technical problems.

2. Performance Rate (91.4%): From an ideal capacity of 175 pairs of socks/hour, the machine produces an average of 160 pairs/hour due to stranded thread.

3. Quality Rate (91.1%): Out of a total output of 175 pairs, there were an average of 5 pairs of defective/BS (Blind Stitch/Defect) products.

OEE: Availability X Perform rate X Quality

OEE = 90% X 91,4% X 91,1% = 74,9%

An OEE value of 74.9% indicates that the effectiveness of N Socks machines is in the good category for home industrial scale, the greatest inefficiencies come from decreased engine reliability when threads are stalled and sudden engine shutdowns.

b. Mean Time Between Failures (MTBF): The average duration/operating hours of the machine can work without experiencing damage, the higher the MTBF number, means the less less the machine breakdowns. N Socks operate an average of 60 hours per week. In the initial maintenance pattern, there is an average of 2 machine failures per week.

$$\text{MTBF Formula : } \frac{Total\ Machine\ Operating\ Time}{Number\ of\ Machine\ Breakdowns}$$

On N socks: The machine operates for 60 hours / week, and in a week it has been damaged 2 times then, 60 : 2 = 30 hours.

The 30-hour MTBF figure indicates that the THS machine has the potential to experience a technical glitch every 30 hours of operation.

If the MTBF is low, then the availability value on the OEE will drop, because the engine often stops to be repaired.

c. Mean Time to Repair (MTTR): The average time (in minutes/hour) it takes for the engineering team to respond and complete repairs when the machine is down.

The average time to repair (MTTR) in N Socks varies depending on the severity of the disorder:

•Minor Damage (e.g.: broken needle/threaded thread): Requires an average handling time of 10 minutes by an in-house operator or technician.

•Heavy Damage (e.g.: PCB sensor failure/electrical system): Requires up to 3 hours of repair time due to having to wait for external mechanical handling.

The Impact of Preventive Maintenance on Downtime Reduction

The implementation of routine preventive maintenance such as thread dust cleaning, periodic lubrication, and replacement of wear needles has a significant impact on machine availability.

Table 2. Comparison of Performance Before and After Implementation of Planned Maintenance

Maintenance Parameter	Before Planned Maintenance	After Planned Maintenance	Efficiency / Improvement
Unplanned Downtime	20 Hours / Month	8 Hours / Month	60% Decrease
Machine Availability Rate	80% - 85%	90% - 100%	10-15% Increase
Vital Component Breakdown Frequency	Frequent (Breakdown)	Rare breakdowns	Stability Increased
Maintenance Schedule Achievement	Reactive (When Broken)	Daily Routine	100% Compliance

Frequency of Machine Breakdown: The number of breakdown events per period on critical components (e.g. knitting needles, transmission systems, or main motors). A reduction in unplanned downtime from 20 hours to 8 hours per month is able to secure a potential loss of production capacity of tens of dozens of socks per month, making deliveries to the orderer more timely.

Comprehensive financial efficiency measurement can be evaluated through the Total Cost of Ownership (TCO) concept, which calculates all expenditures from initial acquisition to the end of asset service life. An effective maintenance strategy has been proven to significantly lower TCO by extending machine economic life and maintaining energy consumption efficiency. Thus, investing in a reliable maintenance system yields a very high return on investment (ROI) for the company.

Optimizing operational costs through effective maintenance strategies transforms the maintenance function from a mere cost center into a primary driver of business efficiency.

The transition from a breakdown maintenance strategy to planned maintenance has been proven to cut operational cost waste at N Socks significantly:

1. Repair & Technician Cost Efficiency:

- Reactive Pattern: Requires an average of 8 calls to external mechanic per month at a rate of IDR 300,000/arrival (Total Cost = IDR 2,400,000 / Month)
- Planned Pattern: Simply allocates 10 liters of machine lubricant/oil per month (10 liters x Rp42,000 = Rp420,000 / Month) plus autonomous maintenance. There is a drop in external mechanic calls by a difference of 4 visits, directly saving technical operational costs.

2. Spare Parts Inventory Efficiency:

By applying timely replacement estimations, N Socks managed to reduce idle capital buildup in critical spare parts (such as knitting needles, electronic PCB, interpiece, power supply, and CPU) by up to 70%. Spare parts are now purchased based on component wear life schedules rather than being excessively stored in the warehouse.

DISCUSSION

The Effect of Facility Maintenance on Downtime Reduction and Increased Machine Availability

In the modern industrial world, unplanned machine downtime is one of the main factors triggering massive financial losses and reduced productivity. When production facilities stop abruptly due to undetected component failures, the entire operational line is forced to halt, leading to delays in fulfilling customer orders. This shows that machine condition instability not only impacts a single work unit, but also damages the entire production value chain.

Overcoming these problems requires a shift from a reactive approach to the consistent implementation of planned maintenance. Planned maintenance changes technical patterns from waiting for machines to break down to scheduled anticipatory actions based on clear operational parameters. By designing inspection and repair schedules systematically, companies can control machine lifecycles and avoid operational failure surprises in the middle of ongoing production processes.

Mechanically, planned maintenance works by identifying early wear signs on critical components through routine inspections, periodic lubrication, and machine parameter adjustments. Technicians can detect component quality degradation before small problems turn into fatal damage. This preventive step ensures that every part of the production facility remains within safe and efficient working tolerance conditions [1,3].

The direct impact of implementing planned maintenance is a drastic drop in the duration and frequency of unplanned downtime. When machines rarely stop unexpectedly, net operating time can be maximized without loss. This time saving allows companies to maintain strict production schedules, optimize labor utility, and curb overtime costs that often arise due to backlogs of pending work.

Reducing unplanned downtime will boost machine availability. This metric measures the extent to which production facilities are ready to operate and perform their functions during scheduled times. With a reliable maintenance strategy, machine availability values can be maintained at a very high level, ensuring that physical assets are genuinely productive and provide optimal return on investment for the company.

Increased machine availability in turn strengthens overall production system reliability. This reliability creates a stable and predictable workflow, allowing home industry management to plan raw material requirements, labor capacity, and output volume. System stability reduces the need for excessive buffer inventory and minimizes defective product rates caused by machine instability [5].

In practice, the effectiveness of increasing availability and reducing downtime is measured using key performance indicators such as Overall Equipment Effectiveness (OEE) and Mean Time Between Failures (MTBF). Operationally, N Socks constantly monitors these parameters to evaluate how far facility maintenance programs can boost asset performance.

Managing facility maintenance focused on planned maintenance is proven important in reducing downtime and increasing equipment readiness. By maintaining production system reliability through disciplined maintenance, companies not only secure daily operational continuity, but also build a strong foundation for achieving long-term competitive advantage in the global market.

Optimization of Operational Costs through Effective Maintenance Strategies

Operational cost management is a crucial aspect that directly determines the profitability and survival of an industrial entity. In the context of facility maintenance, financial decisions are often a dilemma between allocating budget for prevention or bearing the risk of large repair costs due to sudden breakdowns. Therefore, a deep understanding of maintenance cost structures is essential to formulate policies capable of curbing waste without sacrificing asset performance.

Breakdown maintenance or reactive maintenance strategy is often considered economical at first glance because Home Industry does not need to spend initial investment costs for periodic maintenance. However, in the long run, this strategy triggers operational cost swelling due to unexpected emergency expenses. Sudden repair costs are usually much higher, encompassing emergency component replacement prices, overtime labor rates, and financial losses due to complete production line halts.

Conversely, proactive maintenance strategies such as preventive and predictive maintenance view the maintenance budget as a measurable strategic investment. Although requiring routine budget allocations for inspections, periodic spare part purchases, and monitoring technology, this approach can cut overall maintenance costs. Companies can plan cash budgets more accurately and avoid emergency repair cost spikes that damage company financial stability [2,4].

The most visible cost efficiency aspect of proactive strategy implementation is spare parts inventory optimization. In a reactive system, warehouses often have to store large reserves of components to anticipate unexpected damage, leading to high tied-up capital costs and risk of goods degradation in storage. Through planned maintenance management, spare part needs can be accurately predicted, allowing companies to implement a just-in-time inventory system that minimizes holding costs.

In addition to material savings, effective maintenance strategies also contribute greatly to labor cost efficiency. Reactive maintenance forces technicians to work under emergency conditions outside normal working hours, automatically demanding high overtime incentive payments. With a planned maintenance schedule, technician workload can be evenly distributed into regular working hours, thereby increasing labor productivity and optimizing personnel operational costs [9].

Challenges and Solutions in Field Maintenance Management Implementation

Implementing production facility maintenance management concepts never runs without obstacles, as the gap between theoretical planning and field operational reality often triggers various complexities. Although modern maintenance frameworks are designed as such, success highly depends on how organizations address various cultural, financial, and structural constraints. Ignoring these challenges will only render investments in maintenance technology futile and fail to achieve target efficiency goals.

The main obstacle most frequently encountered in practice is human resource resistance, both among operators and frontline technicians. The transition from a conventional reactive maintenance system to a technology-based proactive system often creates reluctance to adapt, discomfort with new procedures, or concerns over increased workload. If operators and technicians are not emotionally and professionally involved, even the best maintenance policies will experience cultural hurdles at the daily operational level.

Overcoming these obstacles demands the implementation of comprehensive solution strategies, starting from increasing human resource capacity through periodic training

programs. Intensive training for technicians and operators aims not only to improve technical skills in handling modern machines, but also to instill a deep understanding of their crucial role in maintaining business continuity.

The next solution step is establishing a Total Productive Maintenance (TPM) work culture involving all organizational levels, from management down to bottom-tier machine operators. Through autonomous maintenance concepts, operators are trained to conduct daily inspections, cleaning, and light lubrication on their own machines before handing them over to dedicated technical teams for heavy repairs. This approach successfully breaks down barriers between production and maintenance divisions and fosters a shared responsibility culture for asset reliability.

Equally important, maintenance implementation effectiveness must be measured objectively through standardized Key Performance Indicators (KPI) performance evaluations. Key metrics such as Overall Equipment Effectiveness (OEE), Mean Time Between Failures (MTBF), and Mean Time to Repair (MTTR) are used to monitor the extent to which maintenance strategies successfully boost actual factory floor productivity [2,6,10].

Total Productive Maintenance (TPM) Application and HR Constraints

Maintenance implementation at the field level cannot be separated from HR capability constraints and budget limitations. The solution applied by N Socks is forming a simplified Total Productive Maintenance (TPM) culture through an Autonomous Maintenance program:

1. Operator Participation Rate (100%): Every day before operations start, operators must perform daily inspections, yarn fiber cleaning, and light oil lubrication on their respective machines.
2. Impact of Short Training: Providing basic skill training to operators has been proven to reduce human error rates and accelerate response times for minor repairs (MTTR 10 minutes).

Synergy between handling HR resistance, sustainable budget commitment, establishing a TPM culture, and KPI-based performance measurement becomes the key driver of home industry operational success. When field challenges are overcome with systematic solutions, facility maintenance management transforms from a mere repair routine into a driving engine of company competitive advantage. This ensures that production and operational efficiency can be achieved sustainably amid increasingly tight industry dynamics.

This study has several limitations. First, it used a single-case study at one sock home industry; therefore, the results cannot be generalized to all SMEs. Second, the quantitative indicators were calculated from company records and field observations over a limited observation period, which may not capture seasonal variations in production demand or machine workload. Third, the study relied partly on self-reported information from operators and technicians, which may be subject to recall bias. Fourth, although a paired-samples test was used to support the downtime improvement, the sample size was small and should be interpreted cautiously.

Future research should use a larger sample of SMEs and a longer observation period to test the generalizability of the simplified maintenance model. Researchers should also apply more advanced quantitative methods, such as regression analysis, reliability modeling, or simulation, to examine the relationship between maintenance intensity, machine availability, and production output. In addition, future studies should measure Total Cost of

Ownership (TCO), maintenance Return on Investment (ROI), energy consumption, and the effect of digital condition-monitoring technology on SME maintenance performance. Future research should expand quantitative analysis by measuring TCO and maintenance ROI in similar SME sectors.

CONCLUSION

The implementation of facility maintenance management transformed machine maintenance at N Socks from a reactive function into a proactive strategy that improves operational efficiency. Through scheduled preventive maintenance, structured SOPs, and simplified TPM, the company reduced unplanned downtime from 20 to 8 hours per month, increased machine availability to 90–100%, achieved an OEE of 74.9%, reduced external technician expenses, and lowered spare-part buildup by up to 70%.

Despite budget and technical-capability constraints, operator-based autonomous maintenance proved effective in maintaining production stability. To sustain these improvements, N Socks management should implement the following specific next steps:

1. Establish a daily preventive-maintenance checklist for each THS and manual machine, including inspection, cleaning, lubrication, and needle-condition checks.
2. Conduct monthly technical training for operators and technicians, focusing on early detection of yarn breakage, electrical problems, and minor mechanical failures.
3. Maintain a critical-spare-part list with minimum-stock levels based on component wear-life data.
4. Record all breakdowns, repair times, and maintenance activities in a simple digital or manual maintenance log.
5. Evaluate OEE, MTBF, and MTTR monthly and use the results to revise maintenance schedules.
6. Allocate a fixed monthly maintenance budget to prevent delays in preventive activities.

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