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Original Article

Improving Operational Performance in Peruvian Advertising SMEs: A Case Study Integrating Lean and TPM Practices

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Abstract *- This study addresses the operational challenges faced by Small and Medium-sized Enterprises (SMEs) in the advertising sector, focusing on producing banners and vinyl. Existing research highlights the effectiveness of Lean Manufacturing and Total Productive Maintenance (TPM) in improving process efficiency, yet little attention has been given to their application in this niche sector. Limited resources sometimes cause small companies to have low output and constant breakdowns in equipment. Intending to reduce machinery malfunction and human mistakes, the study recommends a production model that integrates TPM techniques with Poka Yoke. The model in the presented case study was assessed based on a series of primary key performance indicators, including MTBF, MTTR, and OEE. Results from case studies revealed an MTBF increase of 50% and an OEE increase of 6%, implying more operational optimization. These findings confirm present knowledge by presenting a practical, straightforward solution to increasing process efficiency under strict financial circumstances. This research calls for further research into the effects of these methods, especially when used together with digital solutions designed to improve operational sustainability control.*

Keywords *- Process Optimization, Continuous Improvement, Equipment Reliability, Waste Reduction, Productivity Efficiency.*

1. Introduction

The advertising Small and Medium-sized Enterprises (SMEs) market is a vital segment not only in the context of Latin America and Peru but on a global scale. These firms bolster the region's local markets and contribute significantly towards innovation and the creation of new job opportunities. Citing an earlier study, [1] reported that around 99% of all businesses in Latin America are MSMEs, which also employ around 60% of the workforce in the region. Peru is also not an exception, as this country's advertisement banner and vinyl production sector has been emerging and expanding at a rapid pace, fueling economic development in the country during the period of digitalization and globalization [2]. The competition in advertising and visual marketing industries has sustainably increased demand as well as competition, creating a niche in efficient production [3].
This calls attention to the need to optimize these SMEs' processes to meet sustainability and growth amid increasingly competitive environments.

Advertising-based SMEs confront numerous inefficiencies and competitiveness problems stemming from multitasking production concerns. Some issues that need to be addressed are low overall equipment efficiency, availability unavailability, and quality rating [4]. Lack of maintenance or poorly configured production processes leads to indefensible deficiencies in the system [5]. Other reasons include the snuffiest resources and inadequate training that curtails these firms from altering their processes [6]. As an aggregate consequence, these factors not only drive substandard productivity but also erode customer satisfaction, driving loss of market opportunities [7]. Hence, a solution must be defined and constructed to close the gap and enhance SME performance operationally.

The importance of correcting these issues should not be disregarded. It is vital to enable product and operational enhancements to frame the competitive tree for the SME in the market [8]. Proposed and already used techniques, like Lean Manufacturing or Total Productive Maintenance (TPM), work as promising solutions towards process optimization and efficiency streamlining across industries [9]. These methodologies not only help improve OEE but also foster a culture of continuous improvement and empower employees to actively participate in identifying problems and seeking solutions [10]. Thus, SMES must adopt these practices to survive and thrive in an increasingly competitive business environment.

Despite the growing attention towards process improvement in SMEs, a significant gap in the literature specifically addresses the challenges and solutions within the context of producing advertising items, banners, and vinyl. Most studies have focused on larger sectors or different industries, leaving SMEs in this niche relatively unattended [11]. This research aims to fill that gap by developing a production model that integrates Lean Manufacturing tools, such as Poka Yoke and TPM, adapted to the specific needs of these companies [12]. The uniqueness of this method stems from its application, which aims to enhance both operational efficiency and foster innovation and flexibility in the ever-changing industry [13]. Unlike earlier attempts focusing on frameworks and underlying principles, this study option seeks to play a constructive role in the context of industrial SMEs, adding value to existing knowledge.

To summarize, optimization processes for SMEs focused on advertising operations, banners, and vinyl production are essential for sustaining growth. Addressing issues within production involves applying appropriate methodologies and addressing the existing literature knowledge void, allowing these enterprises to enhance their performance and competitiveness. With the changing market dynamics, SMEs need to adopt strategies to ensure sustainability and succeed in a challenging business environment.

2. Literature Review

2.1. Lean Manufacturing in SMEs Producing Advertising Products

Adopting Lean Manufacturing in Small and Medium-sized Enterprises (SMEs), such as those producing advertising banners and vinyl, has proven to improve operational efficiency and reduce wasted resources. As pointed out by Achanga et al. in reference [14], the more relevant elements for effective implementation of Lean in SMEs are organizational culture, transformational leadership, and training. These authors further explain that adopting Lean practices is expected to enhance productivity, improve employee relations, and foster collaboration within the workplace. Additionally, Dora et al. highlight that food industry SMEs, which are resource-constrained like advertising product companies, have successfully adopted Lean practices even when operating under financial constraints [15]. This suggests that other SMEs might be able to adapt these practices to their different contexts.

On the other hand, from an economic and ecologic perspective, Qureshi et al. argue that Lean implementation in SMEs is beneficial as it reduces waste and improves resource utilization [16]. This is especially true for advertising product SMEs, where cost reductions significantly improve profit margins. Also, Maware et al. state that using Lean Manufacturing in the advertising industry, like in other industries, is critical to achieving enhanced sustainability results [17]. So, advertently, the literature suggests that the Lean Manufacturing approach applied to advertising product SMEs is not only feasible but also vital for their existence in an advanced competitive environment.

2.2. Application of Poka Yoke in the Production of Advertising Products

The Poka-Yoke approaches have been translated into “error-proofing”, which methods have been recognized across several sectors to curb irrepressible gaps and blunders in the production works. Regarding SMEs dealing with product advertising, adopting Poka Yoke techniques can be highly relevant to maintaining the quality of advertising products. As highlighted by Iqbal et al., adopting Poka Yoke techniques has proven effective in improving quality and reducing costs in SMEs [18]. This technique enables firms to detect and make real-time corrections to mistakes, which is very important in manufacturing personalized products, such as banners and vinyl.

Moreover, the study conducted by Yadav et al. sheds light on the gaps regarding the barriers to applying Poka Yoke in SMEs, primarily a lack of knowledge and inadequate employee training [19]. These attempts to teach these techniques offer training that closely enhances these practices and significantly enhances product quality overall. Saini and Singh, in their respective work on Poka Yoke, have shown that adding Poka Yoke enhances output quality without discounting customer satisfaction by lowering the number of faults [20]. In the field of advertising goods, this is most significant because the customer’s brand loyalty highly depends on the perceived quality of goods.

Last, Thanki and Thakkar indicate that adopting Poka Yoke in SMEs can be a competitive advantage, enabling them to sell better products at reasonable prices [21]. The literature suggests that although there are some difficulties in adopting Poka Yoke, the opportunity costs in quality and efficiency for SMEs within the advertising products industry are quite favorable.

2.3. Total Productive Maintenance (TPM) in SMEs

Total Productive Maintenance (TPM) is a methodology focused on maximizing equipment productivity while limiting downtimes. Implementing TPM can facilitate smooth and effective production cycles for SMEs focused on advertising products. Ahmad et al. note that SMEs that adopt the policy of TPM record significant improvements in equipment uptime and product quality [22]. This is highly relevant in manufacturing advertising products because a client’s satisfaction largely depends on delivery time and quality.

Also, research conducted by Kumar and Vinodh identifies training employees in TPM as critical to the practice's success [23]. Involving employees in the maintenance of the equipment not only improves efficiency but also builds a culture of ownership and accountability among employees.

Likewise, Rupasinghe and Wijethilake's work shows that applying TPM can enhance supply chain sustainability through waste reduction and resource optimization [24]. This is especially true for advertising product SMEs, where material utilization is very crucial from a profit perspective.

To summarize, M.P. et al.'s study illustrates that the integration of TPM into SMEs not only improves operational efficiency but also assists in the advancement of new innovations [25]. This is important for the advertising products market because quickly capitalising on new opportunities is vital for a business's success or failure. From the literature conducted, the use of TPM in SMEs that manufacture advertising products is a viable option for operational efficiency and increased competitiveness in ever-changing environments.

2.4. Autonomous Maintenance in SMEs

Autonomous maintenance implies that the operators are trained to perform basic tasks such as cleaning and servicing. In small and medium-sized advertising firms, that type of maintenance can be pivotal in meeting the productivity and idling requirements. As described by Bhasin, autonomous maintenance enables the operators to participate in dealing with minor problems that, if unattended or unresolved, exacerbate the availability of the equipment [26]. This is especially important in advertising product production, where time is arguably the most valuable asset one can consume.

In addition, the research by Thanki and Thakkar noted that the lack of maintenance training documents and inadequate maintenance tools and materials for training is a constraint to the implementation of autonomous maintenance at SMEs [21]. However, this type of maintenance can easily be adopted with proper training and active support from the upper management. Such support can enhance operational efficiency.

Moreover, the study by Dora et al. pointed out the fact that maintenance performed at a basic level enhances operational efficiency, but aside from that, it also improves the attitude of the employees toward the working environment and boosts morale by giving them a sense of ownership over the equipment [27]. For small and medium-sized enterprises (SMEs), such employee motivation is essential for productivity.

In addition, Saini and Singh's study reflects that implementing autonomous maintenance practices can increase the competitiveness of SMEs [20]. Such approaches increase adaptability to changes in a business and improve responsive maintenance product quality, among other factors. Generally, the literature is relatively consistent in the view that autonomous maintenance constitutes a practical approach to dealing with operational effectiveness of efficiency and competitiveness for those SMEs involved in manufacturing advertising products.

2.5. Preventive Maintenance in SMEs

Preventive maintenance implements major equipment operability and efficiency changes tailored for Small and Medium-sized Enterprises (SMEs). A case example would be advertising product manufacturing SMEs. Having a preventive maintenance program limits operational downtimes without affecting product quality. As Iqbal et al. noted, "SMEs which practice preventive maintenance incur significantly less costs on repairs and enjoy better longevity of their equipment" [18]. This becomes critical in advertising product manufacturing, where meeting deadlines require equipment to be operated non-stop.

Similarly, Yadav et al. work pointed out how not having a preventive maintenance program increases the chances for sudden, expensive breakdowns [27]. Such frameworks can help SMEs to be more responsive and aggressive when it comes to problem-solving. Dora et al. highlighted that enhanced maintenance policies contribute towards the operational efficiency and waste reduction of a unit [28]. These policy changes allow firms to further advance towards their sustainability goals. Moreover, resource optimization proves to be crucial within the advertising product industry, where effective utilization of resources greatly enhances overall profitability.

The study conducted by Maware et al. confirms that implementing preventive maintenance can facilitate innovation and new product development in Small and Medium Enterprises (SMEs) [17]. Firms can respond to market changes and produce quality products when their equipment is optimally maintained. To summarize, the literature highlights preventive maintenance s a crucial approach to enhancing advertising SMEs' operational efficiency and competitive edge.

3. Contribution

3.1. Proposed Model

Figure 1 displays a production model incorporating Poka Yoke tools aligned with the Lean Manufacturing approach. This is combined with a systematic application of Total Productive Maintenance (TPM) to an SME in the graphic arts industry which specializes in digital printing of banners and vinyls to enhance Overall Equipment Effectiveness (OEE).

This model sought to remedy specific errors within the production process, including mistakes during cutting, unanticipated machine downtime, and poor equipment calibration that diminished availability and operational efficiency.

Poka Yoke principles emphasized the complete structural implementation of fail-safe systems, practically engineered solutions to mitigate human error towards enhancing the quality of the cutting process. In parallel, TPM focused on failure prevention maintenance through the iterative processes of definition, measurement, analysis, control, and improvement, steadfastly aiming to eliminate equipment failures and maximize utilization. This semi-automated systems model empowered the firm to improve its operational consistency and dependability. It reduced its integration and cycle times, which are the hallmarks of operational agility sought in Lean Manufacturing, adapting the principles of efficiency and continuous improvement through competition in the market.

3.2. Model Components

The production model in Figure 1 indicates a Dual Strategy Integration for Total Productive Maintenance (TPM) Tools and Poka Yoke developed under the Lean Manufacturing principles framework for enhancing the Overall Equipment Effectiveness (OEE) of an SME operating in the graphic and advertising industry, which specializes in digital prints, banners, and vinyl.

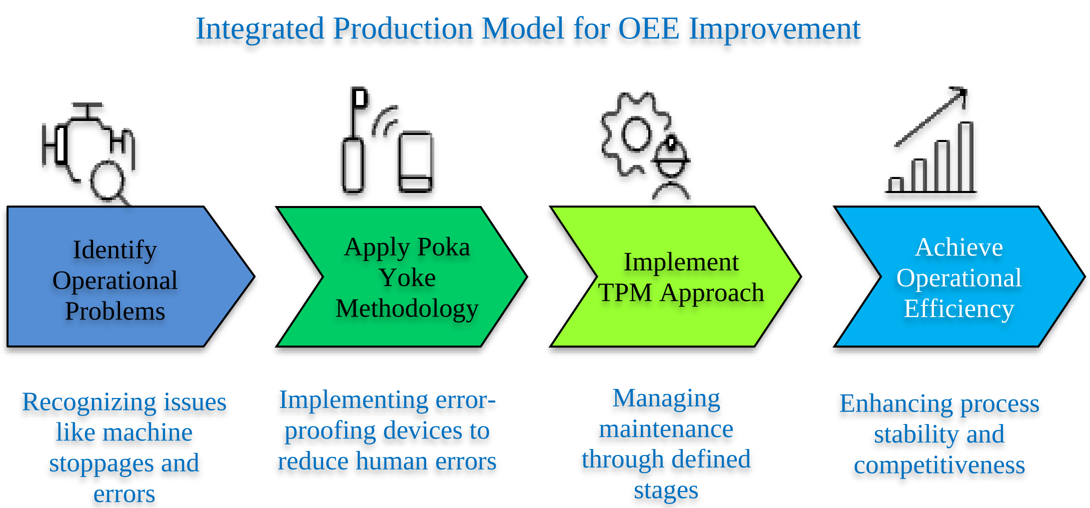

Fig. 1 Proposed model

The integration aims to address the optimization of the most severe recurring machinery downtimes induced by human error during cutting and equipment calibration, ungoverned equipment nominal performance, and low operational efficiency eroded windows of opportunity. With this model, not only operational stability was sought but also to contain and eliminate errors, improve product quality, and properly manage maintenance activities.

The model has two main components: one of them is applying Poka Yoke for human error detection and correction in the cutting process, and the second is applying all levels of equipment maintenance TPM stages.

Both approaches underwent development in a coordinated and complementary fashion to achieve integrated changes in the company's core processes. Each constituent part of the model framework, along with its methodology and target objectives, is elaborated in subsequent sections of this document.

3.2.1. Poka Yoke: Error Prevention in the Cutting Procedure

The Poka Yoke approach was applied with the intention of reducing human errors in the cutting process, which is one of the most important activities in the digital printing production process. This step-by-step approach was carried out in five fairly distinct stages:

Stage 1: Error Identification

Initial steps included pinpointing the most salient sources of mistakes in the cutting operation through direct observational and retrospective analyses of defect log files.

The consistent errors of inaccurate measuring, cutting above or below-defined tolerances, and setup procedures not being followed during machine preparation were noted. This stage served as the basis for developing the remainder of the model.

Stage 2: Selection of Poka Yoke Devices

After the mistakes were defined, the most appropriate Poka Yoke methods to eliminate them were chosen. These methods included hardware devices and electronic monitors that both prevented improper adjustments and warned operators of possible deviations from the set process. The selection process took into account technical practicality as well as cost-benefit analysis.

Stage 3: Design and Implementation of Poka Yoke Devices

In this phase, each of the chosen devices was designed and installed at appropriate workstations within the system. Each device was custom-built to mitigate the identified issues to effectively avert potential failures. Implementation with verification was done to ensure proper performance before no longer monitoring daily activities.

Stage 4: Staff Training

In order to guarantee that Poka Yoke devices were properly utilized, it was necessary to train the operators. Hands-on training sessions were held to boost employees' familiarity with new instruments, which cemented the corporate culture of quality and continuous improvement. The staff's endorsement of the changes significantly contributed to the success of this stage.

Stage 5: Control and Monitoring

Finally, a control and monitoring system was set up to measure how effective the Poka Yoke devices were in using the built-in evaluation features. This system ensured that necessary adjustments could be made to maintain the level of improvement that had already been reached. Consistent feedback enabled the detection of other possible enhancement opportunities.

3.2.2. Total Productive Maintenance (TPM): Efficient Equipment Maintenance Management

The second component of the model was the application of TPM, focused on ensuring equipment availability through structured preventive maintenance in five stages:

Stage 1: Definition of Maintenance Objectives

In this stage of the maintenance program, the objectives were explicitly delineated, ensuring coherence with the strategic goals of OEE enhancement and production requirements. Equipment performance was gauged through defined key performance indicators, which enabled the prioritization of the most critical areas to be addressed.

Stage 2: Measurement of Current Equipment Condition

Assessing the given equipment's condition formed a baseline regarding its performance and operational status. This information was needed to recognize failure trends and schedule corrective and preventive maintenance activities.

Stage 3: Failure Cause Analysis

An in-depth analysis of the causes of failure provided rich insights into the underlying reasons for machine stoppages. Such analysis was performed using cause and effect diagrams and the five whys method to get to the root of the most common issues.

Stage 4: Maintenance Control and Execution

In this phase, Preventive and Corrective Maintenance actions, according to the maintenance plan, were put into operation. Operators also undertook Periodic Inspection and Autonomous Maintenance routines, diminishing reliance on the Maintenance team.

Stage 5: Continuous Maintenance Improvement

As a core principle of the Total Productivity Maintenance (TPM) method, continuous improvement was prioritized. Review cycles were instituted to analyse results and create new challenges. Feedback provided ensured that the adaptation of the maintenance program was kept in line with the requirements of the operation.

This production system incorporating Poka Yoke and TPM offered a holistic answer to the operational problems confronted by Small and Medium-sized Enterprises (SMEs) in the graphic and advertising industries. The combination of both approaches did not only enhance Overall Equipment Effectiveness (OEE) but also fostered a culture of prevention of defects and thorough maintenance. A proactive approach resulted in dependable and efficient operations compared to operational benchmarks aligned with Lean Manufacturing, further fortifying the company's SME competitiveness in time-sensitive and demanding markets.

3.3. Model Indicators

An evaluation was performed on the productivity of digital printing SMEs using a production model based on Lean tools—specifically Poka Yoke and Total Productive Maintenance (TPM)—through a designed set of measurement criteria pertinent to the context. These indicators were developed within the framework of comprehensive performance evaluation to analyse the most critical areas of concern within the production process. This, in turn, allowed for an effective longitudinal study into operational performance, monitoring, and continuous improvement. This enhanced operational performance by emphasizing the optimally available work factors and the reliable process execution. These factors provide a focus for measuring and confirming the further advancements in the scope of enduring value improvement while adhering to lean manufacturing principles.

3.3.1. MTBF (Mean Time Between Failures)

MTBF measures the average operating time between equipment failures, indicating reliability. A higher MTBF reflects better equipment performance and fewer interruptions.

$$MTBF = \frac{\text{Total Operating Time}}{\text{Number of Failures}}$$

3.3.2. MTTR (Mean Time to Repair)

MTTR indicates the average time required to repair equipment after a failure. Reducing MTTR improves machine availability and operational efficiency.

$$MTTR = \frac{\text{Total Downtime}}{\text{Number of Failures}}$$

3.3.3. Availability

Availability measures the proportion of time equipment is available for production compared to the total scheduled time.

$$Availability = \frac{\text{Operating Time}}{\text{Scheduled Time}} \times 100$$

3.3.4. Performance (Efficiency)

Performance reflects how effectively equipment operates at its designed speed. It compares actual production time to ideal production time.

$$Performance = \frac{\text{Actual Output}}{\text{Theoretical Output}} \times 100$$

3.3.5. Quality Rate

Quality rate indicates the percentage of products meeting quality standards without rework or defects.

$$Quality\ ate = \frac{\text{Good Products}}{\text{Total Products Produced}} \times 100$$

3.3.6. OEE (Overall Equipment Effectiveness)

OEE combines availability, performance, and quality to provide a comprehensive view of equipment efficiency.

$$OEE = \frac{\text{Availability} \times \text{Performance} \times \text{Quality}}{100}$$

4. Validation

4.1. Validation Scenario

The validation scenario was performed in a case study of an SME from the graphic and advertising industry based in Lima, Peru. This company focused on producing digital prints, banners and vinyl, carving a niche for itself in the local market. Notwithstanding its seasoned background in the field, the organization suffered from profound operational difficulties that impacted its efficiency and effectiveness. Some of the principal problems witnessed were chronic machine downtime, recurrent rework, inadequate equipment calibration, and excessive downtime, which resulted in productivity losses. This case showed that the organization required a holistic approach to stabilize and optimize its processes. To address these constraints, the firm sought to advance operational efficiency, decrease required maintenance and rework, and improve production flow while enhancing its sustainability and competitiveness in the graphic sector.

4.2. Initial Diagnosis

In the case study analysis, it has been noted that the low OEE of 79% over the advertising products production line's OEE in the last 12 months was below the industry benchmark of 85%. This creates a gap that needs attention. This performance deficiency was largely due to low equipment availability, 74%, and quality losses, which constituted 26%. Within the low availability category, 85.88% of machine stoppages were due to preventive maintenance, 13.86% to corrective maintenance, and 0.25% to equipment calibration issues. Quality losses were associated with 100% of the rework occurring at the manual cutting station, which significantly increased the volume of non-conforming products. These deficiencies caused an estimated economic impact of 665,000 PEN due to high downtime and rework, equivalent to 13.3% of monthly revenue. This situation highlighted the urgent need to implement corrective actions to close the OEE gap and optimize the production process.

4.3. Validation Design

The proposed production model, which integrates Lean tools—specifically Poka Yoke—and Total Productive Maintenance (TPM), was validated through a pilot implementation in the case study. This process spanned four months and aimed at increasing the Overall Equipment Effectiveness (OEE) of the machines in a small advertising company focused on digital printing, banners, and vinyl production. The validation plan was based upon three fundamental principles: the application of Poka Yoke to avert human error, maintenance optimization via TPM to minimize equipment downtime, and standardization for reliability. This method facilitated an assessment of improvement impact and cost-effectiveness based on empirical evidence.

The design of the production model incorporated the use of Total Productive Maintenance (TPM), Poka Yoke tools, and Lean Manufacturing, as determined during the diagnosis's key deficiency analysis. The aim was to improve Overall Equipment Effectiveness (OEE) stemming from unplanned downtimes and human errors in the cutting process of the cutter. The model was developed incrementally so that each tool could last over time.

4.3.1. Implementing Total Productive Maintenance (TPM): Ensuring Availability

The implementation of Total Productive Maintenance (TPM) was divided into five distinct steps aimed at increasing the availability of machines and decreasing the amount of downtime. This approach stemmed from fostering a culture where maintenance activities are performed proactively by both operators and technical staff.

Stage 1: Initial Diagnosis and Maintenance Plan Definition

At this stage, the analysis of the root causes of machine downtimes has been comprehensively studied. It was found that 85.88% of the stoppages were linked to activities with preventive maintenance, while 13.86% pertained to corrective maintenance, indicating that a plan is warranted. Important checkpoints for the HP FB 550 digital printer were determined, and their priority levels for intervention were defined.

Stage 2: Designing the Preventive Maintenance Schedule

A preventive maintenance schedule was crafted, considering the occurrence and impact of all identified failures. Preventive actions included weekly inspections of vital components and servicing moving components. The entire team was briefed on the schedule to ensure effective role allocation.

Stage 3: Personnel Training and Autonomous Maintenance

The active participation of the operators was critical to the success of TPM. Operators were trained in the practical exercises of performing autonomous maintenance and failure detection at lower levels through specialized workshops tailored to their roles. Operators were instructed on using standardized machine-specific inspection checklists, facilitating proactive anomaly detection.

Stage 4: Planned Maintenance Execution and Monitoring

During this phase, the technical team performed preventive maintenance activities according to the established schedule. A digital recording system was used to document each intervention, facilitating real-time monitoring of results. As a result, Mean Time Between Failures (MTBF) increased from 646 hours to 969 hours, while Mean Time to Repair (MTTR) was reduced from 102 hours to 94 hours, significantly improving machine availability.

Stage 5: Continuous Evaluation and Process Improvement

Finally, a continuous improvement cycle was established based on the monthly review of key performance indicators.

This stage allowed adjustments to the maintenance schedule according to operational needs and optimized autonomous maintenance activities. Machine availability increased from 86% to 92%, reflecting the effectiveness of the implemented approach.

Figure 2 shows the HP FB 550 digital printing machine, the most critical digital printing production line equipment. A pilot test focused on the preventive maintenance pillar of Total Productive Maintenance (TPM).

Scheduled maintenance was performed every Saturday to reduce failures and improve machine reliability.

Table 1. Maintenance Task Schedule for HP FB 550 Machine

MAINTENANCE TASK SCHEDULE – HP MACHINE					
TASK	**FREQUENCY (HOURS)**		**NECESSARY TOOLS**	**DAY**	**USER DIAGNOSIS**
	CMYKcm	**CMYKW**			
Cleaning and lubrication of rail belts	40	20	Oil-moistened wipes Lint-free cleaning wipes	Saturday	At the machine’s discretion
Cleaning of the carriage sensor belt	40	20	Lint-free cleaning wipe cleaning liquid	Saturday	At the machine’s discretion
Cleaning of printheads	40	20	Three lint-free cleaning wipes Pair of gloves cleaning liquid	Saturday	At the machine’s discretion
Cleaning of carriage home position sensor	80		Long cotton swabCleaning liquid	Saturday	At the machine’s discretion
Cleaning of service station cleaner rails	80	40	Lubricant pack Pair of gloves Cotton swab cleaning liquid	Saturday	At the machine’s discretion
Cleaning of the service station cleaner	80	40	Lint-free cleaning wipe Pair of gloves cleaning liquid	Saturday	At the machine’s discretion
Cleaning of carriage wheels	40		Three long cotton swabs of cleaning liquid	Saturday	At the machine’s discretion
Vacuuming under the carriage	80		Vacuum cleaner	Saturday	At the machine’s discretion
Replacement of UV lamp filters	250		UV lamp filter kit	Saturday	At the machine’s discretion
Cleaning of electronic box filters	250		Vacuum cleaner	Saturday	At the machine’s discretion
Replacement of service station cleaner	250		Cleaner spatulaPhillips screwdriver	Saturday	At the machine’s discretion
Cleaning of ionized needles	250		Ionized needle cleaning brush	Saturday	At the machine’s discretion
Ink waste container drainage	40	20	Ink waste container	Saturday	At the machine’s discretion
Cleaning of print material thickness sensor	250		Lint-free cleaning wipe cleaning liquid	Saturday	At the machine’s discretion
Cleaning of cover exhaust fans	250		Vacuum cleaner	Saturday	At the machine’s discretion
Replacement of UV lamp bulbs	500–1000		HP UV lamp 2-bulb replacement kit	Saturday	At the machine’s discretion

Fig. 2 HP FB 550 Digital Printing Machine

Table 1 shows the preventive maintenance schedule for the HP FB 550 machine, detailing tasks, frequency, required tools, and diagnostic criteria. Tasks are categorized by cleaning, lubrication, and component replacement, aiming to optimize equipment performance and extend operational life. Maintenance frequency varies between 40 to 1000 hours, depending on task criticality.

Figure 3 shows inspection checklists used to monitor maintenance indicators for the HP machine. These checklists assist in assessing processes and classifying states according to their Mean Time Between Failures (MTBF). A traffic light system was implemented to cap the upper limits for each parameter set to avoid delays in intervention and avert failures.

Fig. 3 Inspection Checklists for HP Machine

4.3.2. Poka Yoke: Preventing Errors in the Manual Cutting Process

The model's second part concerned employing Poka Yoke to mitigate human mistakes and reduce rework at the manual cutting station. This tool was fundamental in maintaining product quality and removing discrepancies in cutting deviations. The integration of multiple steps into Poka Yoke Design Philosophy was done to make certain that it would be successfully assimilated into the production process.

Stage 1: Identification of Critical Errors

A distinguishing study of the manual cutting operations was undertaken to uncover the most notable potential discrepancies. All data collected indicated that all (100%) non-conforming products stemmed from failures at this stage. The primary errors included contravention of other disciplines' authors' measurements and faulty guide settings.

Stage 2: Designing Error-Proof Devices

At this stage, particular devices were created to eliminate the errors given above. A major device in this regard was a visual guide system that guaranteed the correct positioning of the material before cutting. Incorporated were some proximity sensors that would set off alarms if the equipment was set incorrectly so that no defective cuts would be made.

Stage 3: Device Validation and Process Adjustment

The devices were validated through pilot tests to ensure they functioned as intended. These tests incorporated design changes to improve functionality. The validation process was successful and indicated that the cutting error measured was notably less, thus enhancing precision in the process.

Stage 4: Training on Poka Yoke Usage

As noted previously, the success of the implementation rested on the correct use of devices by operators. Device operation and Poka Yoke principles taught in the course were incorporated into training. Staff engagement enhanced the successful integration of practices.

Stage 5: Monitoring Results and Continuous Improvement

A monitoring system was established to evaluate the effectiveness of devices over time. The results showed a reduction in non-conforming products from 3% to 1%, increasing product quality to 99%. This feedback system allowed periodic adjustments and ensured the sustainability of the improvements.

The production model based on the integration of TPM and Poka Yoke proved to be an effective strategy for improving the operational performance of the SME, increasing OEE from 79% to 85% and significantly reducing losses associated with downtime and rework. The implementation stages allowed a systematic and organized application of each tool, ensuring sustainable results aligned with continuous improvement principles. This approach can be replicated in other companies within the sector, adapting the tools to the specific needs of each production process.

Table 2 presents common errors in the manual cutting station, such as material waste, incorrectly cut shapes, and improper figure distribution. These failures affect productivity and quality. The Poka Yoke method is applied through failure prevention and control to reduce rework, ensuring greater accuracy and optimal material utilization.

Tabe 2. Errors Identified in the Cutting Process and Poka Yoke Application

Failures in the Cutting Station	Description of the Failure	Type of Poka Yoke
Material Waste	Each time the printed material is cut, waste is generated, which can be avoided with proper training on correctly cutting the printed product.	Failure prevention and control
Incorrectly Cut Shapes	Being a manual process, operators present incorrectly cut shapes. These are detected during the quality review process, requiring the figure to be reprinted and cut again.	Failure prevention and control
Incorrect Distribution of Shapes	When distributing shapes, they are not being arranged correctly. The average utilization rate is 65%, which should be at least 90%.	Failure prevention and control

4.4. Results

Table 3 shows the results of implementing the production model based on Lean tools, specifically Poka Yoke and Total Productive Maintenance (TPM), in a small and medium-sized enterprise (SME) dedicated to manufacturing advertising products such as banners and vinyls. Key performance indicators were compared between the initial situation (As-Is) and the improved situation (To-Be), revealing significant improvements. MTBF increased by 50%, while MTTR decreased by 8%, indicating greater reliability and faster corrective interventions. System availability improved by 6%, while process quality reached 99%. Performance remained stable at 94%, indicating no variations in production speed. Finally, OEE increased by 6%, consolidating the overall effectiveness of the process. These results confirm the effectiveness of the proposed model in addressing the company’s limitations, improving its operational performance, and promoting sustainability in the production of advertising products.

5. Discussion

The results of this study corroborate earlier research on the application of Lean Manufacturing in combination with Total Productive Maintenance (TPM) specific to small and medium-sized enterprises (SMEs) in the manufacturing industry. The boosts in equipment uptime and the decreases in downtime are in accordance with the findings of Kumar and Vinodh, who stressed the importance of training in TPM practices for model success, which leads to vastly improved operational efficiency and supply chain sustainability [23]. Thanki and Thakkar also stated that using Poka Yoke can differentiate participants in competitive markets by reducing errors in important functions [21]. Further, the sustainable performance evaluation put forth by Maware et al. supports the arguments put forth in this study, which advanced the idea that incorporating Lean practices alongside TPM improves waste and resource management in SMEs, thereby enhancing their performance, as depicted in Figure 1 [17]. All these arguments strengthen the model's validity as an appropriate answer to specific problems within the industry.

5.1. Study Limitations

As noted earlier, this study has had some shortcomings which are worth mentioning. The research was conducted within a singular Small Medium Enterprise (SME) from graphic and advertisement services based in Lima, Peru, which, therefore, does not permit the generalisation of the findings to alternative sectors or regions.

Additionally, the model's implementation and validation period was shorter, which does not allow for the examination of its long-term viability. Another important point is the dependence on operational staff’s loyalty and commitment toward the model's success, which concerns organizations with high turnover rates. Lastly, the model’s effectiveness during the validation period is influenced by external factors, such as demand in the market, which were not considered in the model.

5.2. Practical Implications

This study's results can help SMEs aim for higher operational efficiency and competitiveness. Incorporating Lean tools, Poka Yoke and TPM, unlocks a new level of error minimization and resource optimization. Companies can implement these models as a core strategy in range for reducing downtime, enhancing equipment availability, and further improving product quality. Also, the maintenance training staff receive pertaining to error-proof devices fosters a culture of continuous improvement at the organizational level of resilience against operational adversity. Other manufacturing companies can use and modify this model with specific process requirements and other tailored tools.

5.3 Future Works

Further study could seek to confirm the effectiveness and applicability of the suggested model in several sectors and locations by means of new contextual checks. It would also be valuable to assess the long-lasting influence of the model on maintaining operations and competitiveness in SMEs.

Another promising project is research on integrating digital paradigms like the Internet of Things (IoT) and predictive maintenance into the model to amplify its benefits. Ultimately, comparison studies of businesses using this approach and those using traditional methods could help to expand knowledge of its efficacy, therefore exposing gaps in practices and approaches relative to ideal use.

Table 3. Results of the pilot

Indicator	Unit	As-Is	To-Be	Results	% Variation
MTBF	**hours**	646	950	969	50%
MTTR	**hours**	102	90	94	-8%
Availability	**%**	86%	96%	92%	6%
Performance	**%**	94%	94%	94%	0%
Quality	**%**	97%	99%	99%	2%
OEE	**%**	79%	90%	85%	6%

6. Conclusion

The primary results of this research show that the use of Lean Manufacturing techniques, especially Poka Yoke and Total Productive Maintenance (TPM), substantially raises operational efficiency and equipment availability in small businesses within the graphic and advertising industry. The suggested production method solves major production issues, like machine downtime and accuracy problems in manual cutting operations, hence raising Overall Equipment Effectiveness (OEE) significantly. The validation process verifies that the methodical use of these instruments increases machine dependability, lowers human mistakes, and promotes a culture of continuous betterment.

This study highlights how small and medium-sized businesses need process optimization, particularly in industries under great competition and resource constraints. By emphasizing error prevention and proactive maintenance, the study offers small businesses a good path to increase their operational resilience and flexibility. The practical nature of the model, coupled with its scalability, makes it a relevant tool for organizations seeking to remain competitive in a dynamic market. Emphasizing constant improvement also highlights the necessity of a long-term strategic approach to operational excellence.

This research's contributions provide a systematic and flexible framework for including Lean Manufacturing ideas in small companies with minimal means. This study emphasizes the particular requirements of the graphic and advertising industry rather than general frameworks and offers custom solutions ready for use. The results show that the mix of Poka Yoke and TPM raises process efficiency and corresponds with the overall goals of sustainable production and quality betterment, thereby filling a significant hole in the prior research.

Further study should investigate the long-term viability of the suggested model via extended validation periods in several industries and geographical settings. Further improvement could come from incorporating sophisticated technologies like the Internet of Things (IoT) and predictive maintenance. Comparative analysis of businesses using this approach with those employing conventional techniques would give more insight into best practices and regions where improvements could be made.

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