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Original Article

Overcoming Operational Inefficiencies through Lean Tools and Change Management: Evidence from a Peruvian Flexible Packaging SME

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Abstract - *Small and medium-sized enterprises in Peru's flexible packaging sector have faced persistent inefficiencies due to long setup times, unplanned downtime, and suboptimal job sequencing. While Lean and TPM tools have improved isolated processes, previous studies seldom addressed the cultural resistance that often undermines implementation. This study proposed an integrated model combining ADKAR-Lewin change management, Johnson's Rule, SMED, and dual maintenance strategies to address these challenges holistically. When implemented at a small-to-medium-sized enterprise in Peru, the model elevated overall production efficiency from 63.85 percent to 72.10 percent, slashed setup times by more than 33 percent, cut processing duration by 18 percent, and boosted equipment reliability, pushing the mean time between failures up to 17.7 percent. These gains underpin the expected synergy between targeted technical upgrades and a disciplined program of behavioral change. Beyond its theoretical merit, the framework delivered clear socio-economic returns, including less scrap material and better use of labor and raw inputs. Continued investigation in other sectors is recommended to test the approach´s generality and to examine its durability under shifting market and technological conditions.*

Keywords – *Lean Manufacturing, Change Management, SMED Technique, TPM Implementation, Production Scheduling, Flexible Packaging Industry.*

1. Introduction

The global plastic-packaging sector has expanded consistently and is now a cornerstone of contemporary manufacturing. Flexible packages drive much of that rise because the food, pharmaceuticals, and personal-care markets demand lighter, resealable, and shelf-stable solutions. When the world produced 348 million tons of plastic in 2017, that total showed both the material's versatility and its tightening grip on everyday commerce [1]. Within this broader picture, Latin America has pursued its own strategy for industrial uplift, and Peru is emerging as a regional hotspot for flexible film and pouch production. While plastics there contribute roughly 4 percent of national manufacturing value added, the sector sustains over 200,000 direct jobs. Small and medium-sized enterprises supply most of the films, lidding materials, and biodegradable blends needed domestically and provide vital export income [2].

Even though companies often have systemic problems that make it hard for them to run their business effectively, one of the critical problems is that it takes too long to make essential machines. This is usually because there are not enough standardized work procedures, and operators do not receive enough procedures. These delays make it harder for the plant to change its production schedule and lower its overall output. Also, machines breaking down frequently due to poor maintenance practices makes operations even more difficult and makes deliveries less reliable [4]. Poorly planned production is another major problem for many of these businesses. Without optimized sequencing strategies, there is often downtime, work-in-progress inventories that build up, and longer lead times [5]. These three problems—setup delays, unplanned downtimes, and bad setups- lead to a lot of waste in the production process and make the company less competitive.

As the market changes, it becomes even more critical to fix these problems. Increasingly, it is critical for manufacturers to meet shorter delivery times, make less waste, and follow changing rules about sustainability [6]. Also, the growth of online shopping and the need for personalized packaging solutions have made it even more critical for small and medium-sized businesses to be more responsive. Operational models that do not fix problems with production put cost competitiveness, customer satisfaction, and long-term viability at risk. So, Small and Medium-Sized businesses (SMEs) in this field need to use integrated improvement strategies that fully and sustainably fix operational problems.

Some methods from Lean Manufacturing and Total Productive Maintenance (TPM) have shown that they can help small and medium-sized manufacturing businesses do better. By standardizing processes and getting rid of unnecessary tasks, the eliminating change of Die (SMED) method has been shown to work to cut down on setup change over reduce ally the pillars of Autonomous Maintenance and Planned Maintenance, also help organizations keep their equipment running, avoid breakdowns, and give frontline workers the power to take care of machines [8], [9]. Using lean tools in similar industrial settings has led to measurable improvements in OEE (Overall Equipment Effectiveness), defect rates, and production lead times [10]. These tools have been shown to work well on their own, but there is not much evidence of models that combine them. Still, the framework is specifically designed for small and medium-sized businesses in the flexible packaging industry.

Another big problem with the literature is that it does not pay enough attention to change management as part of operational transformation efforts. Many projects to make things better do not work out, not because the tools do not work, but because companies do not handle the people side of change well. Employees who do not want to change, poor communication, and weak leadership commitment can all lead to partial adoption and a return to old ways of doing things.

Structured change management models like ADKAR (Awareness, Desire, Knowledge, Ability, Reinforcement) and Lewin's three-step model (Unfreeze–Change–Refreeze) have become more important in recent years to help people deal with this problem [4]. These models show how to deal with emotional and behavioral barriers to change when managing organisational transitions.

Based on what we have learned, this study suggests a complete model for improving production specifically designed for small and medium-sized businesses in the flexible plastic packaging industry. The model combines three main operational strategies: SMED to cut down on setup times, TPM to make equipment more reliable, and Johnson's Rule to make sure that work orders are done in the best order on the production line. Along with these technical changes, there is also a dual change management framework based on ADKAR and Lewin's models. This framework helps the workforce through the transition and makes sure that improvements last. This method goes beyond using tools in isolation by combining process improvement with cultural change.

This study is different from others because it combines Lean and TPM tools with scheduling optimization and structured change management in a way that has not been done before. For example, Haddad et al. showed that combining lean principles with maintenance strategies made the extrusion line more efficient, but they did not include any formal ways to keep these improvements going over time [10]. On the other hand, this study wants to include behavioral reinforcement and cultural alignment in the improvement process from the start. This will make sure that gains are not only made but also made permanent. The result is a model that works and can be used by Small and Medium Enterprises (SMEs) to boost production, cut down on waste, and make their operations more resilient.

In summary, small and medium-sized enterprises in the flexible plastics packaging sector encounter interrelated production challenges that require coordinated, holistic remedies rather than isolated fixes. By offering an integrated model that weaves together Single-Minute Exchange of Dies (SMED), Total Productive Maintenance (TPM), Johnson's Rule, and structured change-management processes, this investigation addresses critical performance deficits and charts a viable path toward sustainable operational excellence. Therefore, the work advances the empirical literature by bridging a methodological void and equips practitioners with actionable insights for modernizing constrained production settings with confidence and clarity.

2. Literature Review

2.1. Optimizing Job Sequencing with Johnson's Rule in Manufacturing SMEs

For a long time, Johnson's Rule has been known to be a very good way to figure out the order of jobs in two-machine flow shop systems. Because it is easy to use and useful, it is especially helpful for Small and Medium Enterprises(SMEs) that often have limited space, a lot of different products, and limited resources. This sequencing strategy can be very helpful in industries like flexible plastic packaging, where people often change jobs, and there are often bottlenecks. It can help cut down on idle time and make the most of throughput. For instance, Gomero-Campos et al. [11] used Johnson's Rule on a small digital printing business in Peru and were able to cut the time it took to make something from 2,536 minutes to 2,078 minutes, which is an 18% improvement. Not only did this improvement get rid of overtime shifts, but it also made more room for maintenance and urgent orders.

Caicedo-Rolón and Parra Llanos [12] did something similar in a small shoe-making business that used a two-machine flow shop system. Their study of heuristic and optimization-based sequencing methods showed that Johnson's Rule cut the Maximum Processing Time (MPT) by 97 minutes compared to traditional methods. The relative gain was about 2.5%, but the improvement was important for operations because it distributed the workload evenly and reduced congestion between processes. In their study of permutation flow shop scheduling problems with setup times, Belabid et al. [13] found that Johnson-based heuristics worked well for small to medium-sized scheduling problems. This supports the rule's usefulness in low-resource environments that are common in SMEs.

In addition, Habib et al. [14] used Johnson's sequencing logic in a leather goods factory and saw an amazing 82.9% drop in total flow time and a 16% rise in machine use. These results show that the method can make production workflows more efficient, even in mostly automated systems that work in batches. In short, recent studies show that Johnson's Rule is still a strong and easy-to-use tool for making small and medium-sized businesses work better. It is a good place to start for bigger lean manufacturing projects because it helps cut down on cycle time, solve scheduling problems, and make things more predictable.

2.2. Implementing SMED to Reduce Setup in SMEs

The Single-Minute Exchange of Dies (SMED) method is very useful in manufacturing settings where products need to be changed often. SMEs in the flexible packaging industry often must deal with many different products and low volumes, making it hard for them to respond quickly because of long setups. Several recent studies show how SMED can change things in these kinds of situations. Singh et al. [3] did a case study in a small Indian crankshaft manufacturing company. They cut setup time by 20.2% daily, greatly increasing the company's annual production capacity. These changes were made by reorganizing internal and external tasks, getting rid of unnecessary steps, and making procedures the same for everyone.

Karam et al. [15] used SMED in a small Romanian pharmaceutical packaging company and found that major changeovers dropped by 30% in a year. Their results also showed other benefits, like better teamwork and process quality. Boran and Ekincioğlu [16] created an integrated SMED framework combining time-motion analysis and layout redesign. This led to even shorter setups than what is usually possible with standard SMED methods. Yazıcı et al. [17] improved the method by combining it with fuzzy Failure Mode and Effects Analysis (FMEA). This cuts setup time by 48% at a plastic injection molding company.

These results show that SMED not only cuts down on non-productive time but also helps organizations learn and make their processes more consistent. In small and medium-sized businesses that use flexible packaging, where changeovers happen often and margins are tight, these improvements directly affect delivery times and cost competitiveness. Adding extra tools like visual aids, mobile carts, and ergonomic changes makes it even easier to adopt SMED in a sustainable way. The literature shows that SMED can cut setup time by 20% to 50%, which greatly increases equipment availability and overall productivity.

2.3. Autonomous Maintenance as a Catalyst for Equipment Reliability

Autonomous Maintenance (AM), which is a key part of Total Productive Maintenance (TPM), gives operators the power to do routine maintenance tasks like cleaning, lubrication, and inspections. This proactive approach encourages people to take ownership, helps them understand how the equipment works, and helps them find problems early. For Small and Medium Enterprises (SMEs) that may not have dedicated maintenance teams, AM is a cost-effective way to keep machines running longer and cut down on small stops. Amorim et al. [18] found that Overall Equipment Effectiveness (OEE) went up by 30% after 2.5 years of using AM in a small manufacturing company in Latin America. Operators learned how to do basic checks, which led to more uptime and throughput.

Ferreira and Leite [19] used AM in a small Brazilian white goods company, making the workers more productive and reducing the time the line stopped. Their study focused on the cultural change that AM brought about, which made operators more involved and willing to work together. Zhang and Chin [6] came up with a phased AM implementation model for Small and Medium Enterprises (SMEs). This model showed that workers became more aware of maintenance and that equipment worked better. In a study focused on TPM, Singh et al. [20] confirmed these results, showing that AM combined with 5S led to big drops in downtime and better product quality. These examples show that AM is a low-cost, scalable way for small and medium-sized businesses to improve their reliability. However, it will only be successful if it gets structured training and management support and is linked to other TPM projects. The literature strongly supports the use of AM as a practical way for Small and Medium Enterprises (SMEs) to improve their maintenance maturity, especially in industries with limited resources, such as flexible packaging.

2.4. Planned Maintenance Strategies to Sustain Equipment Performance

Planned Maintenance (PM) means regularly servicing machines based on how long they have been used, how often they have been used, or how well they are working. Moving from reactive to planned maintenance is an important step for small and medium-sized businesses (SMEs) to take in order to stabilize their operations. Pinto et al. [21] implemented a strategic PM plan at a small CNC machining business and saw a 23% drop in breakdowns on lathes and a 38% drop on machining centers. This led to a 5% rise in OEE, which shows how useful structured maintenance scheduling can be.

After starting a TPM program based on PM, Autonomous Maintenance, and Kaizen, Nallusamy et al. [22] saw a 12.6% increase in OEE at a medium-sized plastics company. Their intervention cut down on small stops and made the machines work better. Bataineh et al. [23] created a step-by-step TPM implementation for a manufacturing company in Jordan. Over the course of nine months, OEE rose by 62.6%, mostly because PM made machines more available. Shehzad et al. [24] used PM in a small flexographic packaging company in Pakistan, which led to small improvements in OEE and a big drop in mechanical downtime.

All these studies show that PM is necessary to keep production going and cut down on unexpected failures. The benefits are especially clear in small and medium enterprises, where there is not much extra equipment. A good PM strategy lowers the mean time between failures (MTBF), lowers maintenance costs, and makes assets last longer. These are all important for staying competitive in the flexible packaging industry.

2.5. Managing Organizational Change with ADKAR and Lewin Models

To ensure that technical improvements in production processes are successful, change management must happen simultaneously. The ADKAR (Awareness, Desire, Knowledge, Ability, Refinement) and Lewin (Unfreeze, Change, Refreeze) models are popular frameworks that help people make transitions that are focused on people. Lewin'sLewin's model gives organizations a big-picture plan for making changes, stressing the importance of getting ready (unfreeze), putting them into action (change), and making them stable (refreeze). AlManei et al. [25] said that not enough unfreezing is one of the main reasons why lean does not work in small and medium-sized businesses.

The ADKAR model looks at things on a small scale, focusing on changes that happen to people. Ariestyadi and Taufik [26] used ADKAR to help them set up an e-procurement system, making sure that the changes they made were appropriate for each stage of the model. Their structured approach made sure that leaders were involved and workers were ready. Asnan et al. [27] did a review that showed that resistance to change is a big problem for lean implementations in both the public and private sectors. They suggested using structured change models to help with this problem. Organizations can systematically build support and skills among employees by linking technical improvements to the ADKAR stages.

Lewin and ADKAR both provide useful ways to look at how to handle change in small and medium-sized businesses. Using these methods ensures that process improvements like SMED, AM, and PM are possible not only from a technical point of view but also from a social point of view. The literature agrees that good change leadership, clear communication, and reinforcement mechanisms are all important for successful production optimization.

3. Contribution

3.1. Proposed Model

Figure 1 shows a production management model meant to help a small business make flexible plastic packaging run more smoothly. This model brought together a few tools by putting them together in a structured order, starting with Component 0, which was the change management layer. At this point, the ADKAR and Lewin models were used to help the organization make the transition, make sure that employees were aware of the changes, and make sure that they were committed to them. Part 1 was about using Johnson's Rule to schedule work orders. The goal was to improve the flow of production and reduce idle times by optimizing the order of tasks in two-machine processes. In Component 2, internal process improvements were implemented through the SMED methodology, which sought to minimize tool or mold changeover times, thereby maximizing productive uptime. Component 3 concentrated on increasing equipment reliability through systematic, advanced planning of maintenance activities. To achieve this aim, the effort merged two closely related practices: Autonomous Maintenance, which trained operators to perform routine checks and everyday upkeep, and Planned Maintenance, which established scheduled preventive actions designed to avert unanticipated breakdowns. This stepwise, coordinated framework created a clear and repeatable methodology that steadily drives long-term improvements in operational efficiency, the primary outcome highlighted at the apex of the underlying conceptual model.

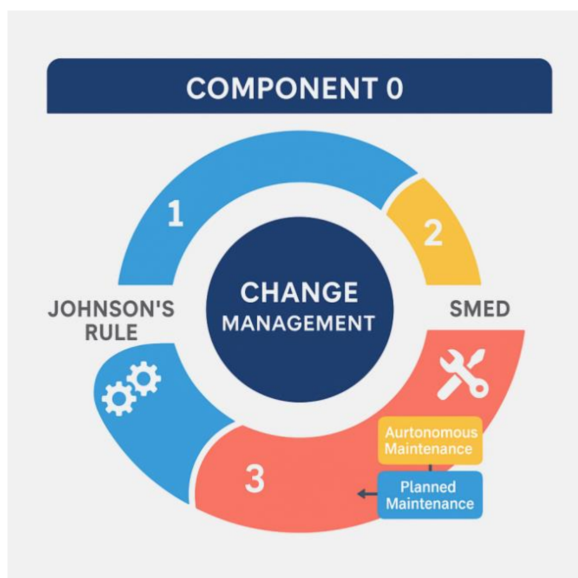

Fig. 1 Proposed model

3.2. Model Components

Figure 1 presents a step-by-step blueprint designed to streamline production in small firms that manufacture flexible plastic packaging. By viewing planning, day-to-day operations, and equipment upkeep as interrelated components, the framework addresses a fundamental gap in process-improvement literature for this industry segment. More than a practical management guide, the proposal contributes to scholarship by integrating established tools from organizational change theories to technical maintenance in a coherent timeline, beginning with ADKAR-led transitions and culminating in PM scheduling. Underpinned by industrial engineering tenets, the model employs Johnson's Rule for sequencing, SMED to minimize setups, and a blend of autonomous and planned maintenance to safeguard equipment availability.

3.2.1. Component 0: Foundations for Organizational Change

Component 0 sits at the base of the model because sound change management must come first. Without a solid grounding here, all later improvements risk being ignored or forgotten, leaving the daily routines untouched. To protect the new processes from that fate, this phase leans on the ADKAR framework and Lewin's three-step approach. It starts by raising awareness of the current pain points, helping people see why a smoother operation is worth the effort. Once the reason is clear, initiatives that lift both personal and team motivation create a genuine wish to support the plan. With the will in place, targeted training delivers practical know-how about the tools and methods coming next. The phase closes by building useful habits and by pairing them with feedback loops that stop old routines from creeping back.

Lewin's classic sequence of unfreezing, changing, and refreezing provides a structured pathway for migrating from the existing production management system to the new one. This phase is critical because it guides employees as they acclimate to a continuous-improvement, efficiency-driven culture that cuts across all departments.

3.2.2. Component 1: Efficient Job Scheduling

Once the workforce accepts the change initiative, Component 1 of the framework launches production planning using Johnson's Rule to sequence jobs at each work cell. Designed specifically for environments with two adjacent workstations, the rule substantially reduces idle time between operations and trims overall process duration. Within the small-to-medium enterprise under study, volumes fluctuated weekly, and orders came in disparate shapes. Job arrivals were in mixed batches, necessitating a clear, repeatable sequencing method. Systematic application of the rule cleared excess waiting, relieved bottlenecks, and evenly distributed work across operators, thus smoothing the production flow. Achieving those gains required detailed process time analysis as well as tight coordination between production, logistics, and planning teams. The rule also offered a transparent way to resolve conflicts when capacity tightened or rush orders appeared, enabling managers to elevate critical tasks without penalizing the system's overall throughput. In short, Johnson's Rule shifted planning from gut feel to a disciplined, data-driven approach that produces predictable, repeatable results.

3.2.3. Component 2: Agile Redesign of Internal Processes.

In Component 2, the Single-Minute Exchange of Die (SMED) technique will be applied to streamline internal workflows. By focusing on the setup format-change time on production lines, the initiative aims to slash these intervals dramatically. SMED is particularly advantageous for small- to medium-sized flexible-packaging firms that routinely adjust product references, runs, and configurations. The method breaks down every pre-change, in-process, and post-change task into discrete steps, allowing teams to remove redundancy, create standard operating procedures, and overlap activities that once followed a rigid sequence. As non-value-adding time disappears, more window hours become available for production, enhancing the plant's ability to pivot in response to sudden demand swings. The detailed SMED analysis also nurtures a culture of kaizen by actively recruiting floor personnel to identify, document, and implement their own incremental improvements.

This section builds on the previous one by arguing that sequencing accuracy improves only when job-change times are rigorously reduced. Together, these components form the model’s operational core, a mechanism designed to streamline both the planning phase and the on-the-floor execution of production activities.

3.2.4. Component 3: Maintenance as a Pillar of Operational Continuity

The final element of the model treats maintenance planning and execution not as an afterthought but as a strategic pillar that determines how reliably operations can be sustained over the long haul. Within that framework, two closely related, functionally distinct pathways emerge: autonomous maintenance and planned maintenance. Autonomous maintenance empowers shop-floor workers to carry out straightforward yet vital chores-cleaning, inspecting, and lubricating equipment-and thus cultivates personal responsibility for the machines they operate. When these small rituals become routine, employees spot signs of wear sooner and grow familiar enough to nurture a prevention-first, attentive, caring workplace climate. For deeper interventions, planned maintenance follows a predetermined cadence determined by run hours, usage trends, and recorded failures. By converting an uncertain breakdown into a scheduled event, this proactive timetable lowers the risk of surprise outages and helps stretch the service life of critical assets. Joined together, the two streams shift the system gradually from emergency fixes to a strong blend of predictive and preventive care, boosting overall reliability.

In practical terms, eliminating nagging technical problems clears the path for smoother production planning and execution, reinforcing the argument advanced in earlier sections. With obstacles removed, sustaining high operational efficiency becomes an attainable long-term goal, validating the model as a robust strategy in fiercely competitive, resource-limited settings.

Collectively, the four elements provide a coordinated framework that examines operational efficiency from multiple dimensions. Moving sequentially through readiness assessments to oversight of technical resources, the approach simplifies execution, curbs push-back, and nurtures an ongoing culture of improvement. Although originally crafted for a modest plastic-packaging firm, the model speaks to any organization wrestling with flexibility, productivity, and sustainability. Structured phases and clear procedures make it easy to adopt at the shop floor level, while established industrial-engineering tools anchor it with dependable technical support. In this way, the proposal serves both as a practical guide for managers and as a substantive scholarly resource poised to yield durable gains in production management.

3.3. Model Indicators

To evaluate the Lean-TPM production model-adapted with ADKAR and Lewin's change-management tools, the research team used performance metrics tailored to the flexible-packaging small-to-medium enterprise under study. Each indicator was linked directly to the sequential phases of the framework so that progress toward higher operational efficiency could be viewed at one glance. This tiered measurement system allowed real-time monitoring and steered managers toward swift, evidence-based choices during implementation. Consequently, the formal review not only recorded gains but also fostered a continual-improvement mindset and helped to anchor the organizational shift over the long haul.

3.3.1. Production Process Efficiency (PPE)

This ratio captures how closely actual output follows the schedule, revealing flow reliability and spotlighting hidden losses in planning or execution.

$$\text{PPE} = \frac{\text{Actual Orders Produced}}{\text{Scheduled Orders}} \times 100$$

3.3.2. Maximum Processing Time (MPT)

The MPT records the longest job-sequence duration, setting the upper bound of daily throughput and showing where bottlenecks stretch overall processing time.

$$\text{MPT} = \sum_{i=1}^{n} \text{Processing Time}_i$$

3.3.3. Setup Time (ST)

It sums every minute spent preparing, installing, adjusting, and inspecting the line between orders, exposing wasted changeover effort and guiding SMED-driven reductions.

$$\text{Setup Time} = (T_{\text{Prep.}} + T_{\text{Installation}} + T_{\text{Adjustment}} + T_{\text{Inspection}})$$

3.3.4. Mean Time Between Failures (MTBF)

MTBF converts downtime events into an intuitive reliability span, showing how long equipment runs on average before trouble strikes and steering preventive-maintenance priorities.

$$\text{MTBF} = \left(\frac{\text{Total Available Time} - \text{Downtime}}{\text{Number of Failures}}\right)$$

4. Validation

4.1. Validation Scenario

The validation scenario occurred in a case study of a Small and Medium Enterprise (SME) in Lima, Peru, which makes flexible packaging. This company worked in the plastic industry and focused on making packaging solutions for the home market. The way it was set up meant that it did not have enough people or technology to deal with operational problems quickly and effectively. It had ongoing problems with planning production, managing non-productive time, and getting access to important equipment. These problems with operations made everything less efficient, causing bottlenecks and times when no one was working. Also, not having a structured maintenance plan made its production even worse. In this situation, it became clear that tools were needed to improve coordination within the company and make better use of plant resources.

4.2. Initial Diagnosis

The case study's diagnostic assessment found several operational issues that were making the flexible packaging production process less efficient. Unplanned machine downtime was the most important problem, making up 40.83% of the total. This was mostly due to functional failures caused by worn parts (23.68%) and bad lubrication, adjustment, and cleaning practices (17.15%). Also, too much time spent setting up accounted for 22.39% of the inefficiency, which was caused by a poor way of preparing and installing dies and plates (22.39%). Another important factor was the long total processing time for work orders (22.31%), which was caused by the wrong order of those orders (22.31%). Lastly, a lack of raw materials caused 14.48% of the inefficiency, which was directly related to delays in getting more inputs (14.48%). These operational problems led to unplanned costs of PEN 49,445.81, which is

26.75% of the company's annual gross profit. These results showed how important it was to have a complete model that would deal with the root causes found in the production process.

4.3. Validation Design

The validation stage used a controlled pilot in a flexible-packaging small and medium-sized business in Peru's plastic sector to test the proposed production-management model, which combined Lean, TPM, and the ADKAR-Lewin change framework. The pilot lasted four months. We used a pre-post quasi-experimental design that included measuring the baseline and keeping an eye on key efficiency parameters every week. Johnson sequencing, SMED workshops, and a dual autonomous-planned maintenance program were put in place. Parallel training modules helped people become more aware and skilled. Continuous feedback loops and cost-benefit tracking ensured that technical gains were matched with organizational readiness, giving a strong assessment of operational impact and economic viability.

The validation was done in a Small and Medium-sized Enterprise (SME) specialising in flexible packaging conversion. Their baseline records showed a production-efficiency gap of 9.15 percentage points compared to the sector benchmark. This gap was caused by long order queues, long changeovers, and frequent stoppages. The implementation described below combined Lean, Total Productive Maintenance, and structured change management ideas to fix that problem.

4.3.1. Strategic Change-Management Framework

We used Lewin's unfreeze-change-refreeze logic along with Prosci's ADKAR model to get people to accept new routines before trying any technical measures. Workshops that reached more than 95% of the workforce helped raise awareness, and diagnostic surveys showed a steady increase in readiness, with mean scores above four on a five-point scale after the last "knowledge" sessions. These results showed that preparatory engagement had broken down cultural resistance, making it easier for Lean and TPM tools to work without any problems. Early signs of productivity, like an 8% drop in absenteeism during the training months, made the coaching costs worth it. However, those numbers are reported elsewhere in the thesis and are not included in this synthesis.

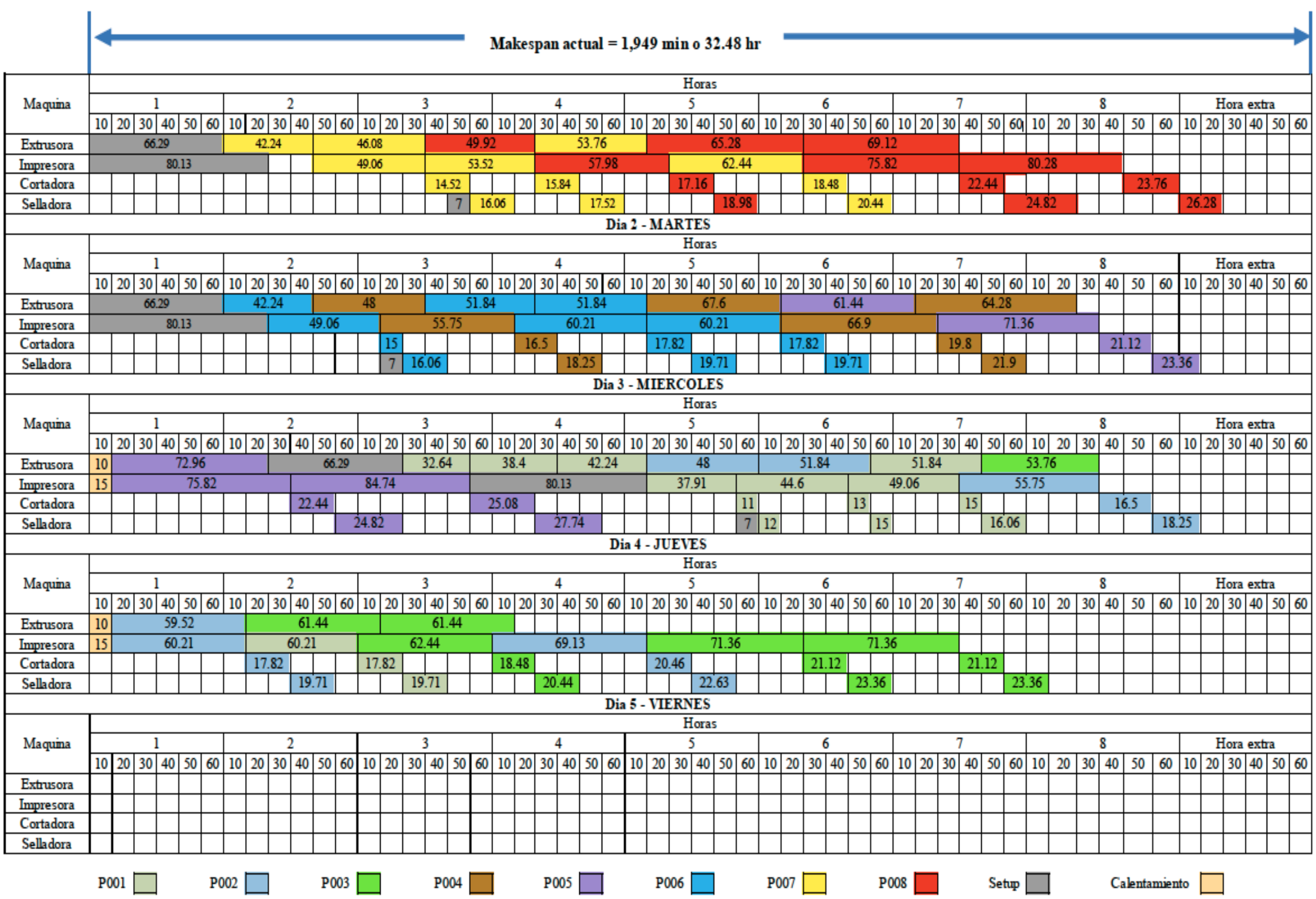

Fig. 2 Weekly Work Order Schedule with Johnson's Rule

4.3.2. Optimised Work-Order Sequencing

Phase 1 dealt with the long MTP that made lead-time promises seem too good to be true. The team made a weekly schedule that rearranged twenty-four representative orders by coding each product family and putting processing times into the Johnson heuristic. The calculated plan cut the total time it took to make things from 2,536 minutes (42.26 hours) to 2,078 minutes (34.64 hours), which shortened the critical-path horizon by 18.0%. The extrusion and flexographic lines worked in series, so this compression got rid of one full overtime shift and gave maintenance or rush jobs an extra half-day. The result confirmed the estimates from the simulation, which had predicted a gain of 15% to 20%, depending on the mix of products.

Figure 2 illustrates the optimized weekly work order schedule using Johnson's Rule. This configuration reduced the MTP to 1,949 minutes (32.48 hours), streamlining task sequences across four machines and minimizing idle time, setups, and overtime. The visual schedule ensures efficient resource utilization and balanced daily workloads.

4.3.3. Accelerated SSeSetup through SMED

Phase 2 got rid of the changeover bottleneck. Time-motion studies broke down the preparation of the extruder and press into fifty-one internal and external parts. Their reallocation, with the help of mobile carts and pre-staging, cut setup time on the extruder from 66.29 minutes to 43.69 minutes (34.1% reduction) and on the press from 70.73 minutes to 46.76 minutes (33.9% reduction). These percentages are a little lower than reference cases with more than thirty-five percent, but the absolute time recovered—over twenty-three minutes per change on each line—made the difference. Internal audits also found that ergonomic risks went down after heavy parts were moved with special trolleys that were added during the third stage of SMED.

Figure 3 illustrates the reduction in setup times for the extruder and printer following the implementation of the SMED methodology. The chart highlights a significant improvement, with setup time decreasing from 66.29 to 43.69 minutes for the extruder and from 70.73 to 46.76 minutes for the printer, enhancing overall efficiency.

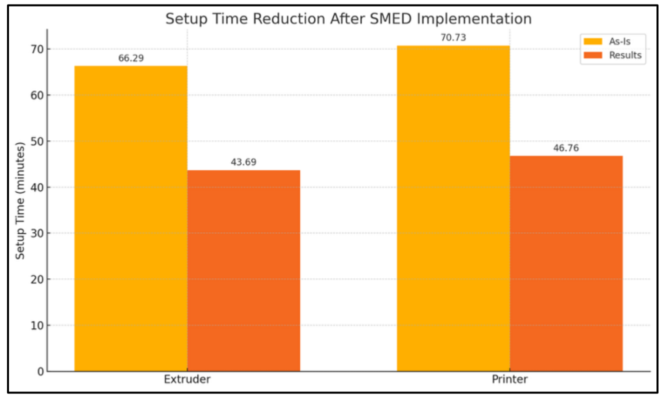

Fig. 3 Setup Time Reduction After SMED Implementation

4.3.4. Reliability Underpinned by Autonomous and Planned Maintenance

Phase 3 focused on technical availability instead. Autonomous-maintenance checklists made daily cleaning and lubrication a part of the routine, while a preventive plan set up 237 actions that followed supplier manuals. When we compared post-implementation logs to baseline data, we found that the average time between failures on the extruder went up from 15.98 hours to 18.27 hours (14.3%), and on the flexographic press, it went up from 20.47 hours to 24.10 hours (17.7%). These increases led to a yearly decrease of more than 100 hours of unplanned stoppages. Better reliability also protected the SMED gains because there were fewer unexpected breakdowns, which meant that scheduled changeovers started on time.

Figure 4 presents the proposed annual preventive maintenance program, which structures 3-weekly, monthly, and bimonthly interventions across four key machines. This schedule ensures consistent upkeep of equipment, reducing unexpected failures and preserving operational continuity throughout the year. The plan supports TPM goals by aligning tasks with production flow and resource availability.

PROGRAMA ANUAL DE MANTENIMIENTO PREVENTIVO

Equipos	Enero				Febrero				Marzo					Abril				Mayo					Junio			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
Extrusora			3S			3S			3S			3S			3S			3S			3S			3S		
Impresora	3S			3S			3S			3S			3S			3S			3S			3S			3S	
Cortadora		M				M				M					M				M					M		
Selladora				B									B									B				

Equipos	Julio				Agosto					Setiembre				Octubre				Noviembre					Diciembre			
	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52
Extrusora	3S			3S			3S			3S			3S			3S			3S			3S			3S	
Impresora		3S			3S			3S			3S			3S			3S			3S			3S			
Cortadora		M				M					M				M				M					M		
Selladora				B									B									M				

Tres semanas 3S **Mensual** M **Bimestral** B

Fig. 4 Proposed annual preventive maintenance program

4.3.5. Overall Performance Improvements

The three technical levers—sequencing, setup, and maintenance—worked together. The efficiency of the production process went up from 63.85% to 72.10%, closing the historic gap with peer converters and showing a 12.9% improvement. The Maximum Processing Time (MTP) went down by 18.0%, and the setup time went down by more than a third on both critical machines.

These improvements had a small effect on finances: MTP compression freed up about 200 productive hours per year, SMED cut down on overtime, and TPM kept scrap and penalty costs down. These numbers will be explained in more detail in later chapters, but they are mentioned here to show that technical metrics led to real economic benefits.

4.3.6. Training, Engagement, and Sustainability Considerations

It was still very important for employees to take part. Attendance records showed that 96% of the targeted staff finished at least four of the six skill modules, and post-course surveys showed that 92% of the staff were satisfied, which supports the behavioural basis of ADKAR. Management has since added quarterly refresher workshops to keep things going, and TPM boards are updated every week to keep things visible. These routines work together to make sure that the hard-won gains in efficiency do not go away over time.

4.4. Results

Table 1 shows how the validated production management model based on Lean and TPM tools and change management methods like ADKAR and Lewin will ensure that the model lasts for a long time. The results showed a big improvement in the efficiency of the production process, which went from 63.85% to 72.10%, which was more than the original goal. The maximum processing time also decreased by 18%, making the whole workflow better. The setup times for the extruder and printer were cut by more than 33%, which cut down on times when nothing happened. Additionally, the Mean Time Between Failures (MTBF) went up in both machines, which shows that they were more available for work because of the use of autonomous and planned maintenance. The results showed that the proposed model was able to solve the case study's problem of low efficiency.

Table 2. Validation Results of the Proposed Production Management Model

Indicator	Machine	Unit	As-Is	To-Be	Results	Variation (%)
Production Process Efficiency	All process	%	63.85%	73%	72.10%	12.9%
Maximum Processing Time	All process	hours	42.26	36.08	34.64	-18.0%
SSeSetupme	Extruder	minute	66.29	45.51	43.69	-34.1%
SSeSetupme	Printer	minute	70.73	48.71	46.76	-33.9%
Mean Time Between Failures	Extruder	hours	15.98	19.03	18.27	14.3%
Mean Time Between Failures	Printer	hours	20.47	24.37	24.10	17.7%

5. Discussion

According to previous research that integrates Lean and TPM tools in manufacturing SMEs, the validation of the suggested model demonstrates a significant improvement in operational efficiency. The over 33% setup reduction is consistent with findings from Singh et al. [3], who reported daily reductions of over 20% in comparable industrial settings. The enhancements are also comparable to those of Yazici et al. [17] and Karam et al. [15], who combined failure mode analysis and ergonomic redesign to reduce changeover times by more than 30%. With respect to maintenance procedures, the rise in MTBF for both machines supports earlier research by Singh et al. [20] and Amorim et al. [18], who highlighted the role of autonomous maintenance in improving equipment availability. The benefits presented by Bataineh et al. [8] and Vieira et al. [10], who showed notable gains when combining Lean and TPM in the plastic industry, are consistent with the 12.9% increase in production process efficiency. Using Johnson's Rule resulted in an 18% reduction in MTP, which is consistent with the findings of Gomero-Campos et al. [11], who also employed this sequencing technique in production environments with limited resources. Finally, the incorporation of change management frameworks like ADKAR and Lewin improved organizational acceptance of technical interventions, supporting the findings of Cancho-Álvaro et al. [4] and AlManei et al. [25], who emphasized the importance of behavioral alignment for sustainably improving operations.

5.1. Study Limitations

Readers should keep in mind several restrictions when drawing conclusions from this work. Because the framework was tested within a single organisation, the findings may not transfer in the same way to different sectors or company cultures. Also, the quasi-experimental design included no equivalent control group, which limits the certainty that the improvements stem only from the new model. The four-month rollout allowed researchers to capture early gains, but that period was too brief to judge whether those gains would persist over years of regular operation. Employee engagement- an outcome heavily shaped by local leadership and workplace norms- was another variable that influenced success and may vary elsewhere. Finally, while shorter setups and less downtime were recorded as technical gains, their complete monetary value could not yet be calculated, leaving that task for follow-up studies.

5.2. Recommendations for SMEs Based on Results

The results point to practical steps that SMEs facing rapid change and tight budgets can adopt right away. Because the model is built in phases, companies can begin with formal change-management training, easing employee fears and drawing more people into the process. Once that foundation is in place, the SMED process guides teams through quicker setups and varied, short production runs, while Johnson's Rule shows them how to schedule work at low cost. Adding planned and autonomous maintenance lets shop-floor staff keep machines in shape, boosting uptime and confidence. When applied together, none of these tools demands expensive equipment or outside consultants, making the approach especially attractive for small shops. On top of this, every step links back to clear metrics, reinforcing a culture of real-time tracking and data-driven improvement across the organization.

5.3. Future Works

Follow-up work should assess the generalizability of the proposed model across mid-sized manufacturing industries that display similar organizational structure, process diversity, and resource constraints. To test its scalability and robustness, parallel trials in facilities with varying levels of Lean and Total Productive Maintenance adoption—ranging from nascent to mature practices—would yield informative comparative data. A richer picture of improvement durability also demands longer observation intervals, ideally from six to twelve months after initial implementation. Integrating digital tools such as Internet-of-Things sensors and interactive dashboards could automate real-time tracking of key maintenance and efficiency metrics, reduce human error and support faster decision cycles. Finally, a comprehensive cost-benefit review that quantifies economic, environmental, and social impacts would reinforce the model's empirical credibility and facilitate its adoption within broader sustainable-manufacturing and circular-economy frameworks.

6. Conclusion

This work presents a cohesive production framework designed to boost the operational performance of a small-to-medium metal-processing enterprise in Peru. Analysis of key performance indicators reveals significant gains from the model, which merges a cultural change program, order sequencing via Johnson's Rule, quick changeovers based on SMED, and a blended maintenance strategy. Setup Time dropped by 33.3 percent, making the span shortened by 18 percent, process efficiency improved by 12.9 percent, and mean time between failures widened noticeably. These gains, recorded over four months, demonstrate that Lean Manufacturing and TPM techniques can be applied successfully in a step-by-step, mutually supporting way when backed by deliberate change management.

In an environment where small and medium firms constantly confront fiscal and technical constraints, the search for sustainable competitiveness grows urgent. Scholars and practitioners alike underscore flexible improvement models that balance hardware gains with soft factors, particularly employee attitudes that can either support or impede progress. Adopting a structured, change-first mindset secures early buy-in from shop-floor teams and clears the path for seamless lean-tool deployment, allowing gains to accrue faster and with deeper organizational reach.

The proposed model advances knowledge by offering a step-by-step, low-cost pathway that resource-limited firms can adopt to improve performance without large upfront capital outlays. Its value lies in the clear, repeatable way each component is defined and implemented, which minimizes disruption and supports continuous refinement over time. The framework also grounds process improvements in concrete data, narrowing the gap between theory taught in classrooms and the realities engineers face on factory floors.

Subsequent investigations could test the model across different sectors, explore digital dashboards that track real-time performance indicators, or lengthen the review period to see whether gains endure over years rather than months. Researchers are also encouraged to measure their financial returns and scalability more rigorously, thereby helping small-and medium-sized enterprises build systems that are efficient, resilient, and growth-oriented.

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