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Management Model Applying Lean Manufacturing Tools to Increase the OEE Index in a Plastics Industry Company

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Abstract

The purpose of this study is to increase the Overall Equipment Effectiveness (OEE) index in a Peruvian plastic packaging company through the implementation of Preventive Maintenance, Autonomous Maintenance, and SMED. The initial diagnosis showed an average OEE of 66.71%, a value below the 85% standard. To address this gap, Preventive Maintenance was introduced as a measure to reduce machine downtime, focusing exclusively on the molds to ensure proper condition, reliability, and reduction of mold-related failures. Subsequently, the SMED methodology was applied to optimize and standardize mold changeover activities, further minimizing production stoppages. Finally, Autonomous Maintenance was implemented to reduce defects caused by contamination in the injection machine components through routine cleaning, inspection, and basic operator-led maintenance. The proposal was validated through a pilot test and a simulation in Arena software, which demonstrated significant improvements, achieving a final OEE of 77%. The economic evaluation confirmed the project's feasibility, reporting an NPV of S/ 25,398, an IRR of 31%, and a recovery period of 2.5 years, demonstrating the investment's profitability and sustainability. Overall, the implemented improvements resulted in more efficient and stable operational performance.

Keywords

OEE, Preventive Maintenance, Autonomous Maintenance, SMED, Continuous Improvement.

1. Introduction

The plastics industry is an essential component of modern manufacturing due to its broad applications across sectors such as packaging, construction, automotive, consumer goods, and agriculture. In Peru, the industry has demonstrated resilience and sustained growth in recent years, contributing significantly to the national economy and export performance. In 2024, the plastics sector in Peru grew by approximately 5.5% compared to the previous year, mainly driven by increased accessibility and reduced costs of plastic resins, which enabled an expansion in production oriented toward domestic consumption. The best-performing sectors were stationery items (37.7%), plastic packaging (27.0%), and sheets, tubes, and plates (24.9%), while other lines, such as PVC accessories (–31%), cleaning products (–58.8%), and PVC profiles (–63.2%), showed significant declines. This results in a value added of S/ 2,661 million, which represents about 0.5% of the country's Gross Domestic Product (GDP) and 3.7% of the manufacturing sector (Oficina General de Evaluación de Impacto y Estudios Económicos 2025).

According to the National Institute of Statistics and Informatics (INEI 2022), micro and small enterprises constitute the majority of the plastics manufacturing sector in Peru. More than 85% of the productive units in this industry are micro enterprises employing fewer than 10 workers, playing a significant role in formal employment generation. These microenterprises are primarily involved in the production of plastic containers and household plastic goods and are mainly concentrated in Lima and other key manufacturing regions. Despite their predominance, the sector faces challenges related to modernization and technological upgrading to enhance productivity and competitiveness.

From an international perspective, the plastics sector plays a relevant role in Peru's manufacturing exports. According to the Association of Exporters of Peru (ADEX), exports of plastic-based products, particularly in the packaging and containers segment, exceeded USD 600 million in 2024, with the United States, Chile, and Bolivia among the main destination markets. This performance highlights the strategic importance of operational efficiency and production reliability to sustain competitiveness in international manufacturing markets (ADEX 2024).

This research is motivated by the need to address these operational inefficiencies in the Peruvian plastics manufacturing sector, focusing on a company that produces plastic packaging for the cosmetics industry through injection molding. In the analyzed company, the 2024 operational results show a significant gap compared to industry standards. Availability reached 84.08%, Performance was 85.48%, and Quality reached 92.81%, resulting in a total OEE of 66.71%, a value considerably lower than the 85% considered world-class (Clements et al. 2018). The study seeks to diagnose and propose improvements in the maintenance and production processes to reduce losses and defects, increase equipment reliability, and improve the company's overall operational effectiveness and competitiveness in the industry.

1.1 Objectives

The objective of this study is to increase the Overall Equipment Effectiveness (OEE) to 85% in a plastic manufacturing company through the implementation of preventive maintenance, autonomous maintenance, and the SMED methodology. The research focuses on reducing machine downtime, minimizing mold installation errors, and establishing standardized cleaning practices to improve equipment reliability, process efficiency, and overall production performance.

2. Literature Review

2.1 Equipment Availability in the Plastics Industry

The analysis of Overall Equipment Effectiveness (OEE) in plastic manufacturing companies indicates that low equipment availability is a critical factor limiting global effectiveness. Several studies show that differences in availability are not exclusively associated with mechanical failures, but rather with inefficient manual procedures, mold condition, and material-related characteristics (AlMashaqbeh and Munive-Hernández 2024; Fernández et al. 2023). In this sense, the gap between machines with high and low availability is mainly explained by operational practices that reduce effective productive time, particularly in SMEs with limited maintenance planning (Domingo et al. 2020).

In blow molding processes, breakdowns account for approximately 36% of total losses, while setups and adjustments represent around 20%, evidencing the combined impact of unplanned failures and scheduled activities (Hadisaputra and Hasibuan 2022). These findings are consistent with studies indicating that both unexpected stoppages and planned adjustments significantly affect equipment availability (Hedman et al. 2016). Empirical research in plastic injection plants further confirms that TPM-based preventive maintenance strategies can increase availability from critical levels below 70% to values above 85% (Mora et al. 2023).

Additionally, deficient cleaning routines have been identified as a recurring cause of availability losses. Residue accumulation in plastic processing equipment generates unplanned interruptions and extended downtime (Nwanya et al. 2017), while the absence of systematic cleaning routines increases micro-stoppages related to blockages and minor failures (Khan et al. 2023). In Peruvian SMEs, excessive setup times during mold changes and improper mold installation have been identified as critical bottlenecks that reduce equipment availability and plant competitiveness (Silva Reyes and Salas Castro 2017; Mujica-Suarez et al. 2023). Complementarily, productivity losses in the national plastic sector have been associated with unplanned stoppages, inefficient use of technical and human resources, and an imbalance between productivity and quality (Allende et al. 2023).

2.2 Quality and Defect Generation

The generation of defective products constitutes one of the main sources of loss within the quality component of OEE. In extrusion processes, excessive moisture and inadequate additive dosing reduce production speed and increase rejection rates (Setiawan et al. 2022). Similarly, in injection molding operations, variability in process parameters, mold condition, and material properties significantly increases defect rates (Nahvi et al. 2024; Fernández et al. 2023).

Defects such as burrs and deformations are commonly associated with unstable pressure, temperature, and cycle time conditions (Hong et al. 2025). Likewise, the appearance of black spots has been linked to the use of degraded or contaminated materials, reinforcing the relationship between raw material quality and process stability (Curbano 2023). Studies focused on SMED applications report that incorrect mold installation and long setup times contribute not only to downtime but also to defect generation during start-up phases (Bhade and Hegde 2020; Nugroho and Prasetyo 2024).

Recurrent defects such as burrs, warpage, and bubbles have also been associated with inadequate machine parameter control and lack of standardization, leading to rework and material waste (Mourya and Arora 2023). Furthermore, plastic SMEs tend to exhibit high rejection rates due to the absence of planned maintenance and weak process control systems (Sangiacomo-Espinosa et al. 2024).

2.3 Performance and Hidden Losses

Low performance in plastic manufacturing processes is primarily related to repetitive and often invisible micro-stoppages. In blowing and injection processes, frequent losses are associated with pressure fluctuations, minor adjustments, and inefficient setup activities which, when accumulated, significantly reduce overall performance (Hadisaputra and Hasibuan 2022; Handoyo and Prasetia 2024). These brief stoppages are commonly overlooked in conventional production analyses, leading to biased interpretations of OEE results (Corrales et al. 2020).

Research conducted in plastic SMEs shows that the lack of standardized continuous improvement methodologies limits the control of hidden losses and hinders process stabilization (Sangiacomo-Espinosa et al. 2024). The application of Autonomous Maintenance, supported by visual management and standardized work, has demonstrated reductions in minor stoppages, repetitive failures, and performance variability (Vega-Alvites and Quiroz-Flores 2022; Flores et al. 2020). Additionally, integrated Lean models combining Autonomous Maintenance and standardized work have reported measurable improvements in global efficiency and line reliability (López et al. 2022).

2.4 Research Gap and Contribution

While the benefits of TPM and SMED in the plastics industry are well-documented (Mora et al. 2023; Nugroho and Prasetyo 2024), a significant research gap remains regarding their integrated implementation in Peruvian SMEs in the plastics sector, particularly those supplying the cosmetics industry, where quality and process reliability requirements are more stringent. Studies suggest that OEE improvements often fail because Lean tools are applied in a fragmented manner, lacking a cohesive framework (Tortorella et al. 2020), particularly in emerging economies where technical oversight is limited (Garza-Reyes et al. 2022).

Consequently, the main contribution of this research is an integrated operational model that synchronizes Preventive Maintenance, Autonomous Maintenance, and SMED. This study fills the identified gap by providing a tailored framework to address "hidden losses" in injection molding, offering a validated pathway to transform the current OEE of 66.71% into a world-class standard of 85% within the Peruvian manufacturing context.

3. Methods

This research was conducted under a non-experimental, cross-sectional–comparative design, appropriate for industrial environments where random manipulation of process conditions is not feasible. The improvement actions were implemented directly on the injection molding line, and their effects were assessed through a before-and-after comparison of operational and performance indicators. The methodological approach focuses on analyzing the relationships between technical-operational factors and process efficiency under real operating conditions, rather than on statistical generalization.

The independent variables correspond to the technical and operational factors modified by the proposed model, namely: mold condition, internal and external set-up times, level of standardization, and degree of autonomous inspection. The dependent variable is process efficiency, primarily measured through the Overall Equipment Effectiveness (OEE) and its components (availability, performance, and quality). Complementary indicators, such as defect percentage, failure frequency, and total set-up time, were also considered to provide a comprehensive evaluation of the process behavior.

3.1 Methodological Procedure

The methodological procedure was structured into three sequential stages:

- Initial Diagnosis:
  Historical production and maintenance data were analyzed, injection cycles were observed, and mold conditions were inspected. This stage led to the identification of an 18% technical gap relative to sector benchmarks, mainly associated with cavity residues, mold wear, excessive set-up times, and inadequate cleaning and inspection routines.
- Implementation:
  A comprehensive improvement model was applied, integrating Preventive Maintenance, SMED, and Autonomous Maintenance. Preventive Maintenance and SMED focused on reducing stoppages and optimizing set-up activities through scheduled cleaning, lubrication, dimensional verification, separation of internal and external activities, waste elimination, and visual standardization. Autonomous Maintenance strengthened operational discipline through operator training, daily inspection routines, and visual records for early anomaly detection.
- Evaluation:
  Process performance indicators were compared before and after the simulation, including OEE, defect rate, failure frequency, and total set-up time, in order to verify the operational impact of the proposed model under real production conditions.

4. Data Collection

The study population included all production lines within the plastic manufacturing plant. Data were collected from company internal records and production reports corresponding to a one-year period 2024, including information on production volume and sales for all manufactured product lines. This preliminary analysis allowed the identification of the product category with the greatest impact on the company's performance. As a result, plastic packaging products for the cosmetics sector, representing 33.9% of total sales, were selected as the focus of the study. Consequently, the sample was intentionally delimited to the cosmetic container injection line, which was identified as the area with the highest frequency of operational issues, unplanned downtime, and efficiency losses. This purposeful selection ensured a detailed and in-depth analysis of the most critical process within the facility.

Data collection was carried out through direct observation of the machine–mold cycle and real operational conditions. These data included planned production time, actual operating time, ideal production rate, total number of pieces produced, and number of good pieces. The collected data provides the necessary input to evaluate the three fundamental components of OEE: availability, performance, and quality. Planned production time and operating time were used to assess equipment availability; the ideal production rate was used as a reference to evaluate performance; and the quantities of total and good pieces were used to assess production quality.

5. Results and Discussion

5.1 Numerical Results

This section presents the numerical results obtained from the analysis of the selected production line. Table 1 summarizes the main operational data used as input for the OEE calculation, including planned production time, operating time, ideal production rate, and production quantities. These data constitute the basis for calculating the Availability, Performance, and Quality components of the OEE indicator

Table 1. Result

Concept	Data
Operating time	2,778 hours
Planned time	3,304 hours
Ideal production rate	120 pieces/hour
Total pieces produced	284,950 pieces
Good pieces	264,474 pieces

Using the values presented in Table 2, the OEE components were calculated and are reported in Table 1. The multiplication of Availability, Performance, and Quality resulted in an overall OEE value of 66.71%, which reflects the current operational performance of the analyzed production process and highlights the need for improvement opportunities (Table 2).

Table 2. OEE components

OEE Factor	Calculation	Result
Availability	Operating time / Planned time	84.08%
Performance	(Total pieces / Operating time) / Ideal production rate	85.48%
Quality	Good pieces / Total pieces	92.81%
Total OEE	Availability × Performance × Quality	66.71%

5.2 Graphical Results

To identify the root causes affecting each component of the Overall Equipment Effectiveness (OEE), a graphical analysis was conducted by decomposing the indicator into its three components: availability, quality, and performance. Historical operational data were analyzed and represented through Pareto charts and cause–effect relationships to visually identify the factors with the greatest impact on process losses. To integrate the results obtained from the availability, quality, and performance analyses, a problem tree was developed to visualize the relationships between the main losses and their underlying causes. This graphical representation, shown in Figure 1**,** highlights how machine stoppages, quality defects, and cycle inefficiencies collectively contribute to the low OEE value observed in the production process (Figure 1).

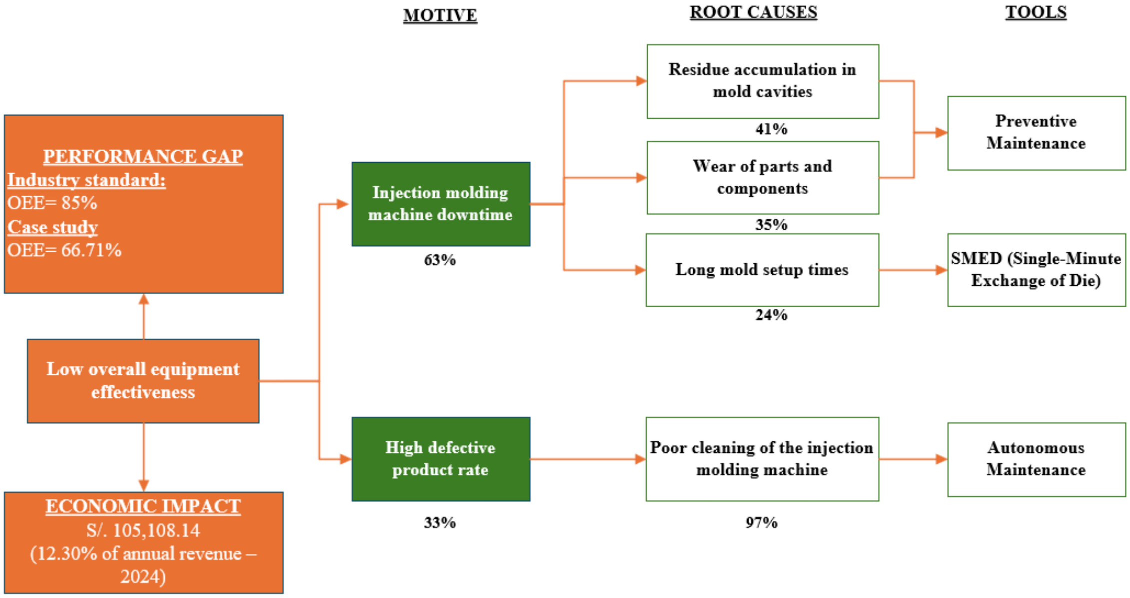

Figure 1. Motive

5.3 Proposed Improvements

Preventive maintenance

An analysis of mold cleaning, alignment, and assembly tasks was conducted to identify frequent errors and critical points that generate wear. Based on this analysis, a detailed sequence of steps was defined, including standard times, required tools, and the responsible operator for each action. A laminated visual checklist was developed covering cavity cleaning, lubrication, verification of guide pins, and mold alignment. Subsequently, production operators were trained through a 45-minute internal training session. The formats were then placed in the work area, and their daily use was initiated. Finally, the procedure was supervised for a two-week period and adjusted when potential failure points were detected. Table 3. presents the preventive maintenance plan established for the mold and injection equipment.

Table 3. Preventive maintenance plan

Activity	Frequency	Time (min)	Responsible	Key Details	Actions in Case of Anomalies
Surface cleaning	Weekly	5	Maintenance technician	Remove dust, residues, and burrs from cavities, parting lines, and closing areas. Clean external surfaces.	Apply neutral degreaser and soft brushes if residues persist. Report corrosion or resin stains for deep cleaning or polishing.
Component inspection	Weekly	8	Maintenance technician	Inspect resin leaks, impact marks, residue buildup, cavities, parting lines, and ejector pins.	Mark deviations, report to supervisor, and stop operation until adjustment is made.
Lubrication	Weekly	10	Maintenance technician	Lubricate guide bushings, slides, ejectors, and mold guides.	Remove excess or contaminated grease and reapply clean lubricant.
Partial disassembly of moving part	Monthly	10	Maintenance technician	Disassemble moving components (plates, ejectors, guides, columns) for inspection.	Separate damaged parts and report. Do not continue until repair or replacement.
Internal cleaning	Monthly	10	Maintenance technician	Apply degreaser to cavities, injection channels, and internal surfaces with residue buildup.	Repeat cleaning or increase exposure time. Report corrosion for specialized cleaning.
Dimensional verification	Monthly	8	Maintenance technician	Measure critical components using vernier calipers according to tolerance limits.	Reapply cleaning or apply corrosion inhibitor if deviations or oxidation are detected.
Functional inspection of mechanisms	Monthly	7	Maintenance technician	Verify smooth ejector movement, spring compression, and condition of slides and stops.	Clean, replace defective components, and record findings.
Lubrication of disassembled parts	Monthly	10	Maintenance technician	Lubricate contact and friction areas according to defined lubrication points.	Clean and reapply grease if contamination or lack of retention is detected.
Reassembly	Monthly	12	Maintenance technician	Reassemble components following technical order and validate ejection system.	Stop assembly if misalignment occurs; verify numbering and component condition.
Complete disassembly of moving part	Quarterly	30	Maintenance technician	Fully disassemble moving components and organize parts in labeled containers.	Report damaged or deformed parts before proceeding.
Component cleaning and cooling	Quarterly	22	Maintenance technician	Apply heated degreaser, brush surfaces, dry with compressed air, and inspect cooling channels.	Report persistent stains or corrosion for specialized cleaning or polishing.

channel inspection					
Cooling channel verification	Quarterly	25	Maintenance technician	Verify flow, pressure stability, and absence of leaks or obstructions.	Apply chemical cleaning or send mold for repair if leaks or cracks are detected.
Alignment and clearance verification	Quarterly	15	Maintenance technician	Check alignment and free play using gauges and manual pressure.	Report misalignment or excessive clearance and stop assembly until corrected.
Reassembly and final test	Quarterly	45	Maintenance technician	Reassemble mold, torque bolts to specification, and perform manual operation tests.	Disassemble if ejection is not smooth; record deviations before finalizing.
Final inspection	Quarterly	6	Technical supervisor	Verify cleanliness, absence of loose parts, tools, or labels.	Repeat cleaning or inspection. Do not approve checklist until all criteria are met.

Single-Minute Exchange of Die (SMED)

SMED methodology was applied to the mold setup process. Initially, the activities involved in the current mold changeover were identified and classified into internal and external tasks, distinguishing those that must be performed while the machine is stopped from those that can be prepared in advance or executed in parallel. The mold changeover process consists of a total of 41 activities with an overall duration of 8,605 seconds. Of these activities, 37 were classified as internal activities (86.93%), while only 4 correspond to external activities (13.07%).

Subsequently, actions were identified to convert internal activities into external ones. The activities converted to external execution included transporting the tools to the machine (Activity 5), moving and positioning the mobile gantry next to the machine (Activity 7), transferring the new mold to the machine (Activity 14), removing the mobile gantry from the work area (Activity 24), and cleaning the mold plates (Activity 34). These changes allow several preparatory tasks to be performed while the machine is still operating, thereby reducing setup-related downtime. In addition, waste present in both internal and external activities was analyzed. Improvement actions were proposed, including the implementation of quick couplings, alignment guides, standardized fastening systems, and visual checklists, aimed at streamlining the setup process and ensuring correct and consistent execution. As shown in Table 4, the changes in activity type and the corresponding improvement actions are summarized, highlighting how internal activities were converted to external ones and the specific enhancements implemented for each activity (Table 4).

Table 4. SMED

N°	Activity	Type of Activity	Improvement Opportunity	Time(s)
1	Planning and Review (Preparation)	EXTERNAL		120
2	Stop the machine and open the mold	INTERNAL		80
3	Disconnect the mold temperature controllers	INTERNAL		20
4	Disconnect Water/Cooling Hoses	INTERNAL		30
5	Bring the tools to the machine	EXTERNAL	Prepare a standardized tool kit before the mold change, avoiding time losses searching or transporting	127

6	Disconnect the Ejector and Retract Rods	INTERNAL		107
7	Move and position the mobile gantry next to the machine	EXTERNAL	Perform this transfer while the machine is still operating, before stopping it for the change	110
8	Hook chains to the used mold	INTERNAL	Keep chains ready and hung on the gantry before starting the change	184
9	Remove Clamps and Fastening Bolts	INTERNAL		215
10	Lift and Remove the Used Mold	INTERNAL	Ensure a visual guide or marks to correctly align during extraction	118
11	Lower the Mold into the Cart	INTERNAL	Place the cart in position in advance before disassembly	96
12	Remove the chain from the used mold	INTERNAL		138
13	Move the mold to the maintenance area	INTERNAL	Have clear and assigned paths for the transfer	197
14	Move the new mold to the machine	EXTERNAL	Have the new mold prepared and near the machine before disassembly	200
15	Hook chain to the new mold	INTERNAL		185
16	Lift the new mold	INTERNAL		389
17	Align the mold between fixed and moving parts	INTERNAL	Place visual guides or alignment marks on the machine base	266
18	Lower the mold into position	INTERNAL	Use stops or references to ensure correct position without trial-and-error	148
19	Close fixed and moving parts	INTERNAL	Coordinate with an assistant to perform visual verification in parallel	116
20	Verify Fit of the Centering Ring	INTERNAL	Mark the fitting point visually to speed up verification	123
21	Place and Adjust Clamping Flanges	INTERNAL		410
22	Secure the mold with bolts	INTERNAL		416
23	Remove the chain from the mold	INTERNAL		140
24	Remove the mobile gantry from the work area	EXTERNAL	Remove while another operator connects the hoses	81
25	Open the mold for water hose connection	INTERNAL		20
26	Connect water hoses	INTERNAL		318
27	Check for Water Leaks and Flow	INTERNAL	Use a quick visual checklist for verification	144
28	Connect mold temperature controllers	INTERNAL		192
29	Align machine ejectors with mold	INTERNAL		316
30	Adjust ejector rod lengths	INTERNAL		400
31	Check Ejection System Operation	INTERNAL		298
32	Set closing force on control panel	INTERNAL		177
33	Verify proper mold functioning	INTERNAL	Perform a functional verification checklist	103
34	Quick cleaning of mold plates	EXTERNAL	Perform cleaning before moving the mold	97
35	Adjust injector carriage to sprue and activate sensor	INTERNAL		196

36	Start mold heating	INTERNAL		53
37	Wait for the mold to reach the required temperature	INTERNAL		300
38	Configure process parameters	INTERNAL		195
39	Inject first test pieces	EXTERNAL		225
40	Verify part quality	EXTERNAL	Use a rapid inspection format with defined criteria	249
41	Final parameter adjustment	EXTERNAL	Record final parameters as a standard for future changes	247
	Total seconds			7546
	Total hours			2.10

As a result of the SMED implementation, a redistribution of internal and external activities was achieved, leading to a 12.3% reduction in the total execution time of internal activities, which decreased from 8,605 seconds to 7,546 seconds. In this process, the number of internal activities decreased from 37 to 32, while the number of external activities increased from 4 to 9, reflecting a more efficient allocation of tasks between machine stoppage and operating periods.

Autonomous maintenance

Autonomous maintenance was implemented with the objective of reducing defective products generated during the injection process. As a first step, an initial cleaning and inspection was carried out to assess the actual condition of the injection machine. The main critical areas identified were the hopper, where pellets were found trapped in narrow corners, as well as the screw and the nozzle, where burned material adhered to internal cavities that are difficult to access. Based on these observations, preliminary standards were developed, incorporating these critical areas into basic cleaning and inspection routines.

Table 5 presents the critical parts of the injection machine, along with the defined cleaning criteria, inspection frequency, required tools, and responsible personnel. This structured approach ensures that critical contamination points are systematically addressed and controlled.

Table 5. Injection machine

Machine Part	Findings	Immediate Action (Operator)	Technical Pending
Hopper	Dust accumulated on internal walls; pellets trapped in hard-to-reach corners	Cleaning with brush and compressed air	
Barrel	Oil stain on lateral joint; dust on external surface	Surface cleaning with dry cloth	Check and seal the connection leak
Screw	Burnt material residues visible in initial purge; irregular resin output	Purge with neutral resin and superficial cleaning	Evaluate internal wear of the screw
Nozzle	Tip with solidified residues; slight blockage of the orifice	Cleaning with bristle brush and dry cloth	
Hydraulic Cylinder	Slight oil leak in hose; wet surface	Cleaning of the affected area	Replace hydraulic hose
Motor and Gears	Unusual noise when rotating; noticeable vibration at startup		Gear inspection and alignment
Clamping System	Burrs adhered to moving plates; marks on contact surfaces	Cleaning with brush and anti-static cloth	Check mold parallelism
Cooling System	Excessive condensation at water connection; possible minor leak	Superficial cleaning	Check pressure and connection seal

In addition, a list of potential anomalies associated with each critical component was identified, together with the corresponding corrective actions to be taken by operators. These anomalies include material buildup, residue contamination, abnormal wear, and blockage in material flow, all of which directly affect product quality if not detected in a timely manner. The definition of clear response actions supports early problem detection and prevents the generation of defective products. Finally, the cleaning and inspection routines of the injection machine were fully standardized by defining specific criteria, frequencies, tools, and responsibilities for each component. This standardization ensures that all operators perform the same maintenance routine, reducing process variability, and preventing quality defects in the final product.

5.4 Validation

For the validation of the integrated tools, the Arena software was used, starting with the definition of the unit of analysis, which was established as a production order representing the entire operational cycle of a batch. The sample consisted of 78 production orders, a size determined using the finite population formula. The recorded times for each activity in the process were processed using the Input Analyzer to obtain the time distributions for the simulation model. Based on this information, two simulation models were developed: the current-state model and the improved-state model. Each model was executed with 30 replications, and their results were evaluated using 95% confidence intervals and a paired t-test, statistically validating the improvements in the OEE indicators. Table 6 presents the comparative results obtained from both models, statistically validating the improvements in the OEE indicators.

Table 6. Comparative results obtained from models

Indicator	After Implementation	Simulation Result
Availability	82%	87%
Performance	86%	90%
Quality	93%	98%
Total OEE	**66%**	**77%**

The economic impact of the improvement model was assessed using a projected cash flow analysis. To account for market and operational uncertainty, a sensitivity analysis of the Net Present Value (NPV/VAN) and Internal Rate of Return (IRR/TIR) was conducted using Risk Simulator in Excel. This simulation-based approach allowed for the evaluation of the financial robustness of the proposal under different risk scenarios, providing a comprehensive view of its economic feasibility. The Net Present Value (NPV) at a 12% discount rate was positive (S/ 25,398), and the Internal Rate of Return (IRR) reached 31%, indicating that the proposed improvements generate value for the company over a five-year planning horizon. In addition, the payback period was approximately 2.5 years, confirming the economic viability of the project under the evaluated scenarios.

6. Conclusion

This study evaluated the operational performance of a cosmetic container injection line in a Peruvian plastic manufacturing company, focusing on equipment effectiveness. The diagnostic stage identified low equipment availability caused by inefficient set-up procedures and high defect rates as the main operational problems affecting Overall Equipment Effectiveness (OEE).

To address these issues, an integrated improvement proposal based on Preventive Maintenance, SMED, and Autonomous Maintenance was implemented. As a result, OEE increased from 66.71% to 77%, and downtime hours were reduced by 34%. In addition, improvements in process control and mold management reduced the defect rate from 6.79% to 1.8%, achieving a 73% reduction. The validity of the production data was supported through statistical analysis using Arena Input Analyzer.

The economic evaluation, performed with Risk Simulator, confirmed the feasibility of the proposal, obtaining a positive Net Present Value, an Internal Rate of Return of 31%, and a payback period of 2.45 years, even under unfavorable scenarios. The final proposal prioritizes production stability, with operators and maintenance personnel playing a key role. The solution is based on standardized set-up procedures and structured autonomous maintenance activities, supported by monitoring indicators and documented work instructions. These elements provide a practical framework to sustain the improvements achieved.

Finally, the proposed approach can be adapted to other high-precision plastic manufacturing sectors, such as medical or automotive components. Future studies should incorporate predictive analytics and real-time monitoring tools to further improve equipment reliability and decision-making accuracy.

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