IMPROVING PRODUCTIVITY IN A BAKERY SME BY APPLYING 5S, SLP, AND POKA YOKE IN THE PACKAGING AREA

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Abstract— Bakery small and medium-sized enterprises (SMEs) often experience nonproductive time, limited standardization, and losses associated with nonconforming products, all of which may reduce operational performance. This study was conducted in an SME that produces panettone; its packaging area had a labor productivity of 32.89 units/labor-hour, below the company's target of 37.32 units/labor-hour. The diagnosis identified errors in manual weight inspection, lengthy setup during shift changes, material-replenishment stoppages caused by flow obstructions, and time spent searching for unidentified or misplaced utensils. Based on these findings, an improvement model integrating 5S, Systematic Layout Planning (SLP), and Poka Yoke was designed and evaluated through statistical tests and discrete-event simulation in Arena. Labor productivity increased to 34.76 units/labor-hour, closing approximately 42.3% of the technical gap. The study's main contribution is the integration, within a single intervention for panettone packaging, of workplace organization and standardization, material-flow redesign, and weight control through a Poka Yoke prototype. The results show that combining low-cost Lean tools is a practical alternative for improving the operational performance of bakery SMEs under similar conditions.

Keywords—Productivity, 5S, Systematic Layout Planning (SLP), Poka Yoke, Lean Manufacturing.

I. INTRODUCTION

The Peruvian bakery industry is part of the food and beverage sector, an activity that is relevant to national manufacturing because of its productive contribution and job creation [1]. Industrial activity also continues to play an important role in the country's manufacturing growth [2]. Small and medium-sized bakery enterprises (SMEs) frequently depend on manual operations and limited process standardization, conditions that may generate nonproductive time, unnecessary movement, quality variability, and losses in labor productivity [3].

Lean approaches have been increasingly applied in food manufacturing to reduce waste, standardize operations, and improve process efficiency. Previous applications combining Lean tools and Systematic Layout Planning (SLP) have shown the relevance of layout-focused interventions for labor productivity in food manufacturing [4]. A recent systematic review of food-manufacturing studies found frequent applications of 5S, visual management, Value Stream Mapping, and other improvement tools, while also identifying a continuing need for structured integration frameworks, particularly in SMEs [5]. In a ready-meal factory, Lean-based changeover improvement reduced changeover time by nearly 30% and labor costs by 10% [6]. Layout design and material-flow analysis have also been applied in food production to improve flow continuity and production-line efficiency [7].

Preventive quality control and simulation provide complementary mechanisms for evaluating operational improvements. In a Peruvian nectar manufacturer, an integrated Green Lean Six Sigma model incorporating Poka Yoke and statistical testing reduced raw-material waste by 2.23% and increased productivity by 2.40% [8]. In the Thai food industry, Lean-Kaizen principles combined with simulation modeling, Internet of Things (IoT), and automation were used to evaluate improvements involving weighing, sealing, and packaging, with the selected intervention increasing productivity by 7.8% [9]. Discrete-event simulation has also been incorporated into a bakery production system to evaluate AS-IS and alternative configurations through repeated stochastic simulation [10], while food-processing research has used multiple replications and historical production data to validate simulation-based production scenarios [11].

Comparative evidence from food-processing companies also suggests that the sequencing of Lean interventions may influence implementation performance, with phased approaches outperforming simultaneous deployment in the analyzed cases [12]. Accordingly, this article evaluates an integrated but sequential model based on 5S, Systematic Layout Planning (SLP), and Poka Yoke to improve labor productivity in the packaging area of a panettone-producing SME. The model links 5S to workplace organization and standardization, SLP to internal material-flow redesign, and Poka Yoke to preventive weight control, combining direct pilot measurements, statistical testing, and discrete-event simulation to compare the AS-IS and TO-BE scenarios.

II. Methodology

A. Conceptual model

Based on the plant diagnosis, the conceptual model was designed to reduce nonproductive time, eliminate obstructions in material flow, and decrease manual weight-inspection errors. The solution therefore integrates three complementary components: 5S as the foundation for organization, cleaning, and operational discipline; SLP as a methodology for redesigning the physical layout and replenishment routes; and Poka Yoke as an error-prevention mechanism for weight control. Fig. 1 shows the relationship between the AS-IS situation, the root causes, the selected tools, and the expected TO-BE scenario.

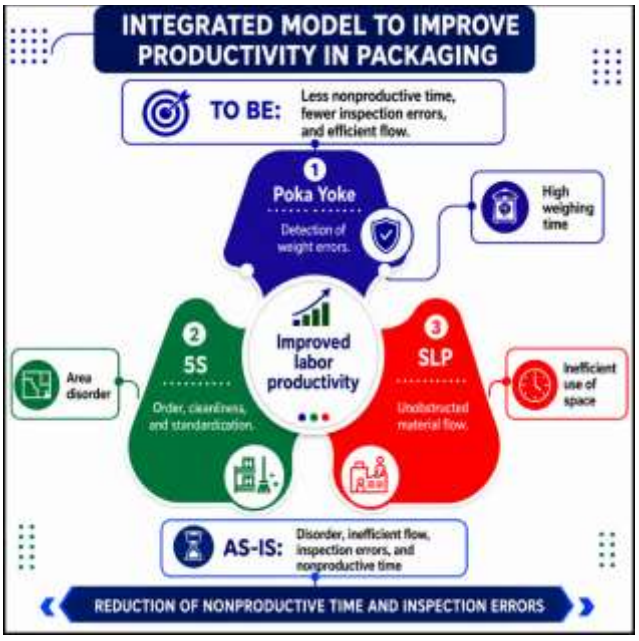


Fig. 1 Integrated improvement model.

The model assumes that labor productivity is affected by the accumulation of several operational losses rather than by a single isolated constraint. For this reason, the proposal establishes a sequential relationship among the three components. First, 5S establishes the organizational conditions required to keep materials, utensils, and work areas in defined locations. Second, SLP modifies the physical arrangement and circulation routes to prevent the recurrence of obstructions. Third, Poka Yoke strengthens the control stage by reducing the dependence on manual judgment during weight inspection.

The expected productivity improvement is therefore generated by the combined reduction of setup time, searching activities, replenishment interruptions, manual inspection time, and rejected products.

B. Components and implementation sequence

The model was organized as a sequential implementation process, as shown in Fig. 2.

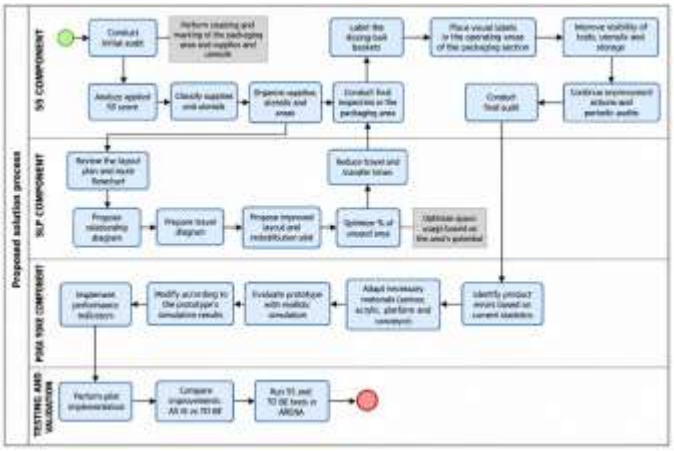


Fig. 2 Proposed solution flowchart.

The 5S component begins by classifying and removing unnecessary items, continues by assigning fixed locations for boxes, bags, tape, and cleaning utensils, and is sustained through cleaning routines, checklists, and periodic audits. This sequence reduces operational variability and decreases the time spent searching for items and setting up the area.

The SLP component is developed by surveying the current layout, identifying replenishment routes, preparing the closeness relationship chart, analyzing alternatives, and selecting the layout that reduces interference among pallets, materials, and operators. The objective is to improve physical flow, clear aisles, and eliminate replenishment-related stoppages.

The Poka Yoke component focuses on preventive weight control. The weighing procedure is standardized, a prototype is incorporated to support weight control, and separate flows are defined for conforming products, products requiring review, and scrap. This component is intended to reduce inspection errors, rejected products, and operating time devoted to manual control.

C. Indicators evaluated

The indicators were defined according to the identified root causes and the expected effects of the tools. Table I summarizes the indicators, measurement units, and interpretation criteria used to evaluate the proposed model. Labor productivity was calculated using (1):

$$Labor\ Productivity = \frac{Q}{LH} \quad (1)$$

Q = number of conforming units produced.

LH = labor-hours used.

TABLE I
INDICATORS USED TO EVALUATE THE MODEL

Indicator	Measure	Interpretation
Labor productivity	Q / LH	Higher values indicate better use of labor.
Finished boxes	Arena model output	Higher values indicate greater output capacity.
Setup	min/day	Lower values indicate less nonproductive time.
Utensil search	min/day	Lower values indicate better organization and availability.
Replenishment stoppages	min/day	Lower values indicate better material flow.
Manual weight inspection	s/obs.	Lower values indicate less manual control time.
Weight-rejected products	units/year	Lower values indicate better quality control.

D. *Validation design*

Validation was structured at three levels. First, the AS-IS baseline was established using historical production records, plant observations, and time measurements. Second, the 5S and Poka Yoke improvements were evaluated through pilot tests. For the 5S component, 30 observations per scenario were collected for setup and utensil-search times. For the Poka Yoke component, 150 observations per scenario were analyzed for manual weight inspection. AS-IS and TO-BE measurements were compared in RStudio using independent two-sample Student's t-tests at a 5% significance level after verifying normality and homogeneity of variances. The replenishment-stoppage indicator associated with SLP was evaluated through discrete-event simulation because the proposed layout was not fully implemented in the plant.

Third, the integrated packaging flow was modeled in Arena over a 900-minute horizon. Processing-time distributions were fitted in Input Analyzer using 112 observations per activity. Both AS-IS and TO-BE scenarios were evaluated through 30 independent replications, and 95% confidence intervals were obtained using Output Analyzer. The TO-BE model incorporated the pilot-test results and the modifications arising from the proposed layout.

III. RESULTS

A. *AS-IS situation*

The initial diagnosis used historical production data from 2023-2024, plant observations, and time studies performed in the packaging area. The unit of analysis comprised two production shifts with 30 operators distributed across the selection, dosing, packaging, coding, case-packing, and final-packing stations. Initial labor productivity was 32.89 units per labor-hour against a company target of 37.32 units per labor-hour, revealing a technical gap of 4.43 units per labor-hour.

The main causes identified were errors in manual weight inspection, lengthy setup activities during shift changes, replenishment stoppages caused by material-flow obstructions, and searches for unidentified or misplaced utensils.

The productivity gap was not attributed exclusively to the speed of a particular machine or operator. Plant observations showed that short and recurrent interruptions accumulated throughout the operating day. Setup activities delayed the effective start of operations, material obstructions generated temporary stoppages, and the absence of clearly identified locations increased unnecessary movement. At the same time, manual weight inspection introduced variability because the classification of the product depended on the operator's response and the time required to verify each observation. These findings supported the use of a multi-component solution.

Table II summarizes the main AS-IS indicators identified in the packaging area.

TABLE II
AS-IS SITUATION IN THE PACKAGING AREA

Indicator	Unit	AS-IS
Labor productivity	units/labor-hour	32.89
Finished boxes	boxes	1,939.5
Finished panettones	units	11,730
Setup	min/day	60.76
Utensil search	min/day	2.50
Replenishment stoppages	min/day	37.92
Manual weight inspection	s/obs.	8.52
Weight-rejected products	units/year	3,800

B. *Implementation evidence by component*

The 5S component included classification, organization, cleaning, standardization, and discipline actions. The comparative audit showed visual and quantitative improvement in the evaluated dimensions due to area demarcation, utensil identification, the creation of checklists, and the assignment of operating responsibilities. Fig. 3 summarizes the change between the initial audit and the TO-BE audit.

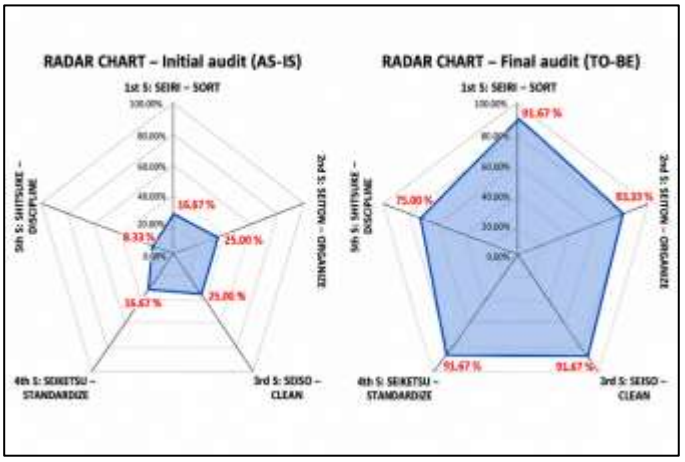


Fig. 3 5S radar chart: initial and final audits.

For the SLP component, the current layout was reviewed and an improved arrangement was proposed. Packaging materials were brought closer to their points of use, inbound and outbound flows were differentiated, and the main aisle was cleared to avoid interference between replenishment and production activities. Figs. 4 and 5 compare the current and improved layouts.

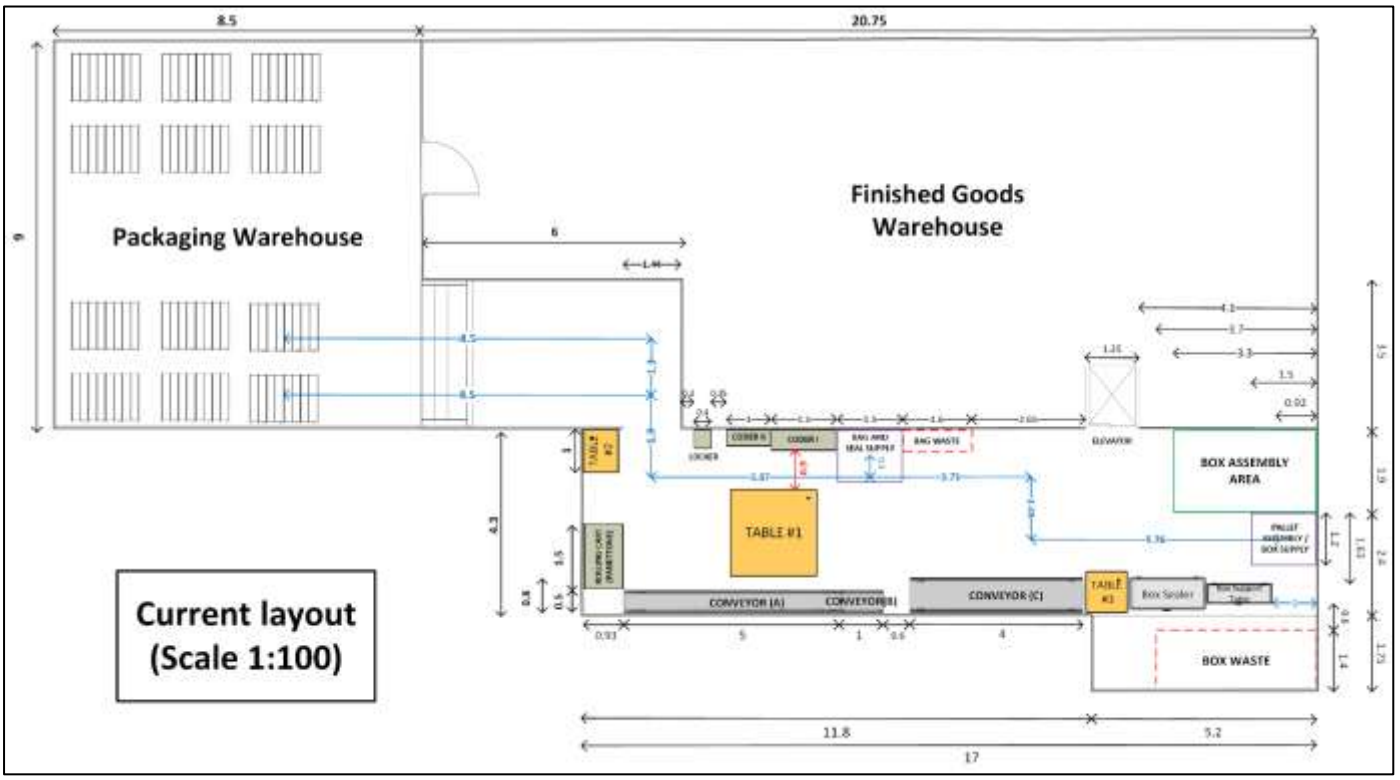


Fig. 4 Current layout.

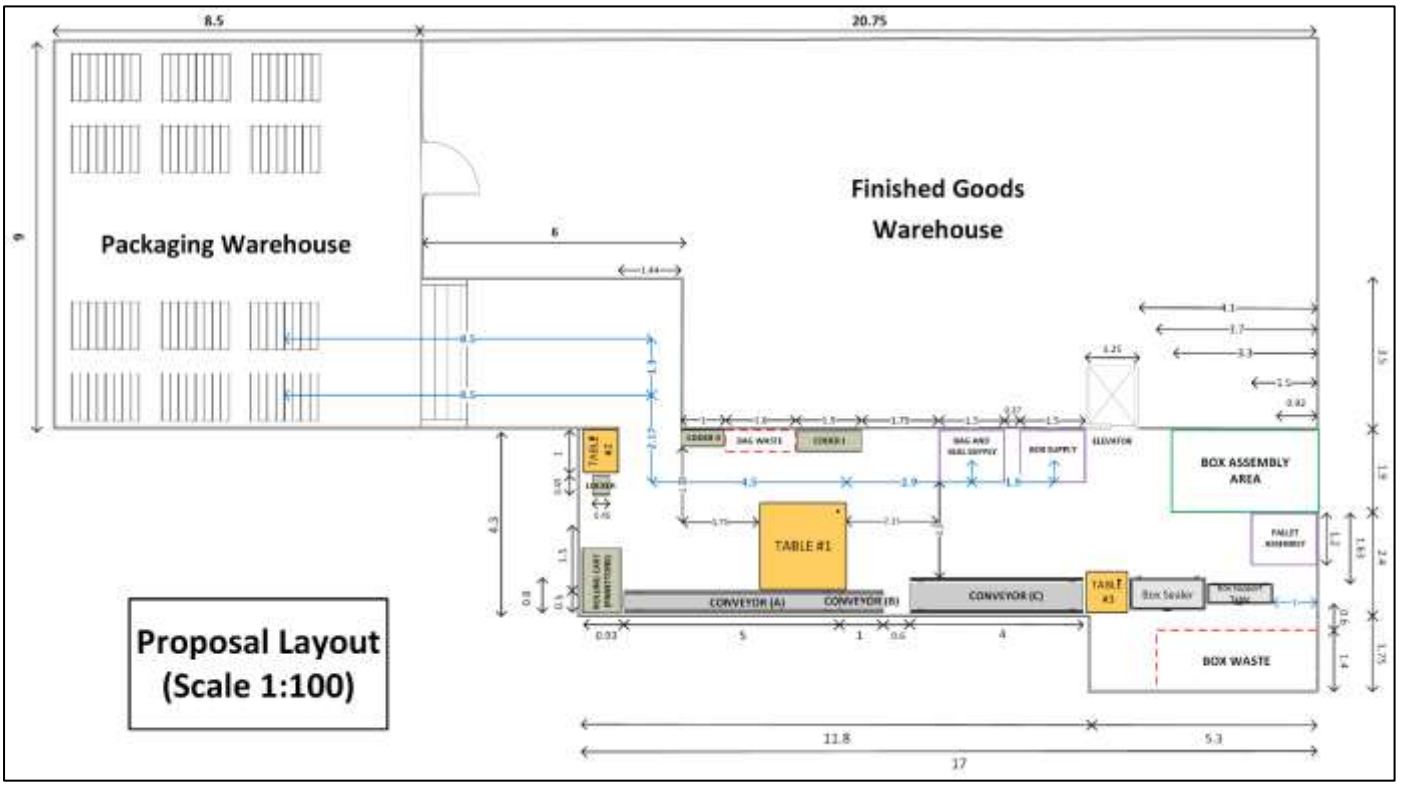


Fig. 5 Improved layout.

For the Poka Yoke component, a weight-control support prototype was incorporated to reduce dependence on manual inspection and promptly separate conforming products, products requiring review, and scrap. Fig. 6 shows the device used as part of the solution design.

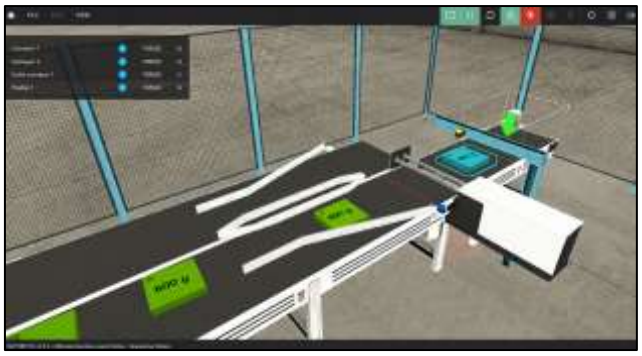


Fig. 6 Poka Yoke prototype.

C. TO-BE situation and integrated validation

Validation combined statistical tests for the time indicators with discrete-event simulation in Arena to evaluate the system's overall behavior. The discrete-event simulation model developed in Arena to represent the integrated packaging flow and evaluate the AS-IS and TO-BE scenarios is shown in Fig. 7. The AS-IS model was compared with average actual production in high-demand months and showed a relative difference of 3.22%, so it was considered representative. In the TO-BE scenario, box output increased from 1,939.5 to 2,050.0 per simulated horizon, while panettone output increased from 11,730 to 12,397 units.

Based on the 30 independent replications, the TO-BE scenario produced an average of 2,050.03 finished boxes per simulated horizon, with a standard deviation of 9.29 boxes and a 95% confidence interval of 2,046.56–2,053.50 boxes. The reductions in setup, utensil-search, and manual weight-inspection times were statistically significant in the corresponding two-sample t-tests ($p < 0.05$).

Estimated productivity increased from 32.89 to 34.76 units/labor-hour, equivalent to a 5.70% improvement and the closure of approximately 42.3% of the technical gap. Table III compares the AS-IS and TO-BE results for the evaluated indicators.

TABLE III
COMPARISON OF AS-IS AND TO-BE INDICATORS

Indicator	Unit	AS-IS	TO-BE	Change
Labor productivity	units/labor-hour	32.89	34.76	+5.70%
Finished boxes	boxes	1,939.5	2,050.0	+5.70%
Finished panettones	units	11,730	12,397	+5.69%
Setup	min/day	60.76	29.80	-50.95%
Utensil search	min/day	2.50	1.01	-59.60%
Replenishment stoppages	min/day	37.92	0.00	-100.00%
Manual weight inspection	s/obs.	8.52	3.57	-58.10%
Weight-rejected products	units/year	3,800	1,000	-73.68%

The results indicate that the productivity improvement was accompanied by reductions in each of the operational losses included in the model. Setup time decreased by 50.95%, which reflects a more organized preparation of the area at the beginning of operations and during shift transitions. Utensil-search time decreased by 59.60% as a consequence of fixed locations, visual identification, and standardized storage practices. Replenishment stoppages associated with the identified obstructions were eliminated in the simulated TO-BE scenario after modifying material locations and circulation routes.

Manual weight-inspection time decreased by 58.10%, while weight-rejected products decreased by 73.68%. These results indicate that the Poka Yoke component influenced both process continuity and the consistency of quality control. The increase in finished boxes and finished panettones was therefore not produced by a single modification, but by the combined recovery of operating time across different activities in the packaging system.

Although productivity increased by 5.70%, the TO-BE value remained below the target established by the company. This result suggests that the model addressed relevant causes of productivity loss but did not include all possible restrictions affecting the packaging line. The remaining gap may be associated with differences in workload among stations, variability in processing times, coordination between consecutive operations, and limitations in the current level of automation.

From an economic perspective, the integrated proposal required an estimated initial investment of S/6,321.26, comprising S/1,042.60 for 5S, S/1,264.00 for SLP, S/3,440.00 for the Poka Yoke component, and S/574.66 as a contingency. Annual incremental savings were estimated at S/51,735.43, comprising S/10,855.43 from reduced nonproductive time through 5S and SLP and S/40,880 from the reduction in weight-rejected products. Under a five-year evaluation horizon and a 9.84% annual discount rate, the proposal generated a net present value (NPV) of S/188,215, a benefit-cost ratio of 22.57, and a discounted payback period of approximately 0.14 years, supporting the economic feasibility of the integrated improvement model.



Fig. 7 Arena Simulation Model.

IV. Discussion

The integrated model increased labor productivity by 5.70%, from 32.89 to 34.76 units/labor-hour. This result can be contrasted with recent food-manufacturing applications, although the intervention scopes and performance measures differ. In a Peruvian nectar manufacturer, an integrated model incorporating Poka Yoke increased productivity by 2.40% and reduced raw-material waste by 2.23% [8]. In a Thai food-production process, Lean-Kaizen, simulation, IoT, and automation increased productivity by 7.8% [9]. The larger improvement reported in the latter study should be interpreted considering its broader technological scope, whereas the present proposal relied primarily on organizational, layout, and preventive-control interventions.

Regarding workplace organization, setup time decreased by 50.95% and utensil-search time by 59.60%. These results can be contrasted with the nearly 30% reduction in changeover time reported in a ready-meal manufacturing facility [6]. Although setup and changeover are not identical indicators, both capture nonproductive time associated with preparing the production system. In a Latin American food-processing context, a Colombian panela operation reported a 63% improvement in order and cleanliness and a 10% reduction in manufacturing time after applying 5S and standardization [13]. These results reinforce the relevance of organization and standardized practices for reducing recurring losses in food-processing environments.

The SLP-based redesign eliminated the 37.92 min/day of replenishment stoppages associated with the diagnosed flow obstructions in the simulated TO-BE scenario. This result is consistent with the importance of production layout and material-flow continuity reported in food-manufacturing applications [7] and with previous Lean–SLP applications in the food industry [4]. However, the result should not be interpreted as the elimination of all potential material-flow losses, because the simulated indicator represents only the replenishment interruptions associated with the obstructions identified during the diagnosis.

The Poka Yoke component reduced manual weight-inspection time by 58.10% and projected annual weight-rejected products from 3,800 to 1,000 units, equivalent to a 73.68% reduction. A previous Peruvian food-manufacturing study also incorporated Poka Yoke within an integrated improvement model and reported reductions in material waste together with higher productivity [8]. The indicators are not directly equivalent because their intervention focused on raw-material waste rather than finished-product rejection by weight; nevertheless, both cases illustrate the role of preventive controls in reducing process losses in food manufacturing.

The validation strategy constitutes another relevant aspect of the model. The present study combined direct pilot measurements with discrete-event simulation, using 30 independent replications and 95% confidence intervals for the integrated TO-BE scenario. A bakery production system was evaluated using 50 simulation replications and 95% confidence intervals [10], while a processed-cheese production study used 100 replications for each original and modified production plan and validated simulation outputs against historical production data [11]. These studies use different platforms, model boundaries, and replication requirements; therefore, their replication counts should not be interpreted as fixed benchmarks, but they support the explicit reporting of replication design and uncertainty in simulation-based production studies.

The integration logic should also be considered. A comparative analysis of four food-processing companies found stronger performance under phased Lean implementation than under simultaneous deployment [12]. The present model follows a compatible logic: 5S, SLP, and Poka Yoke are assigned to distinct prioritized root causes and implemented through a defined sequence before their combined effect is assessed at system level. Thus, integration in this study does not imply applying all tools indiscriminately at the same time, but coordinating complementary interventions within a common improvement model.

Despite the favorable results, the model closed only 42.3% of the technical gap. This indicates that the prioritized causes explain an important part, but not the entirety, of the productivity problem. The remaining difference may be associated with workload imbalance among stations, variability in processing times, coordination between consecutive operations, and limitations in the current level of automation.

The results should also be interpreted considering the study limitations. Validation was conducted under conditions representative of the high-demand season and assumed stable operating conditions. The model did not incorporate major equipment failures, personnel turnover, significant changes in the product mix, or ergonomic constraints. Consequently, the obtained results may vary during lower-demand periods or under different operating conditions.

V. Conclusions and Recommendations

The integrated 5S–SLP–Poka Yoke model improved labor productivity in the packaging area from 32.89 to 34.76 units/labor-hour, equivalent to a 5.70% increase and the closure of approximately 42.3% of the gap relative to the company target of 37.32 units/labor-hour. The results therefore indicate a meaningful but partial improvement, since the intervention addressed the prioritized operational losses without eliminating all constraints affecting the packaging system.

The three components generated complementary effects. The 5S actions reduced setup time from 60.76 to 29.80 min/day and utensil-search time from 2.50 to 1.01 min/day. The SLP redesign eliminated the 37.92 min/day of replenishment stoppages associated with the diagnosed flow obstructions in the simulated TO-BE scenario, while the Poka Yoke component reduced manual weight-inspection time from 8.52 to 3.57 s/obs. and projected annual weight-rejected products from 3,800 to 1,000 units.

The hybrid validation strategy combined pilot measurements, statistical testing, and discrete-event simulation. The TO-BE simulation increased output from 1,939.5 to approximately 2,050 finished boxes per simulated horizon, while the 30-replication analysis yielded a 95% confidence interval of 2,046.56–2,053.50 boxes. The economic evaluation also supported the feasibility of the proposal, with an estimated initial investment of S/6,321.26, an NPV of S/188,215, a benefit-cost ratio of 22.57, and a discounted payback period of approximately 0.14 years.

The results should be verified through prolonged implementation because validation was conducted under high-demand conditions and stable operating assumptions. Future work should evaluate line balancing, progressive automation, equipment variability, and longitudinal monitoring to determine whether the remaining productivity gap can be further reduced and whether the improvements are sustained under different demand conditions.

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