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Research Article

Enhancing Productivity through Lean and Layout Redesign: A Case Study in the Frozen Fruit Industry in Peru

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Abstract: *This study addressed the persistent inefficiencies in frozen fruit processing, a sector where downtime, disorganization, and rework significantly reduce productivity. Prior research had highlighted the benefits of Lean Manufacturing, yet limited attention had been given to its application in agro-export contexts. To respond to this gap, a production model combining Lean tools—such as 5S, standardized work, and Andon—with Systematic Layout Planning was proposed and implemented in a Peruvian mid-sized company. The intervention led to a 36.4% increase in productivity, an 83.6% reduction in lost time, and a 30.1% decrease in operator displacement. These results demonstrated how tailored improvements can translate into tangible gains, especially in highly perishable environments. Beyond its academic contribution, the model presents cost-effective solutions for small agro-industrial firms seeking operational excellence. The findings encourage further exploration of integrated, people-centered Lean strategies in similar sectors, offering a path toward greater efficiency, competitiveness, and sustainable growth in developing economies.*

Keywords: *Lean Manufacturing, Systematic Layout Planning, Frozen Fruit Industry, Productivity Improvement, Operational Efficiency.*

I. INTRODUCTION

The agro-export industry focused on processing frozen fruits has become one of the most important sectors of the economy, especially in Latin America and Peru. This area has great potential for income generation and is important for sustainable development and global food security. Peru is among the top producers of frozen fruits; however, when it comes to producing lúcuma and granadilla, the country may not be as relevant as other grains or some tropical fruits. Still, the country benefits from this sector, which has been rising steadily for several decades [1],[2]. In a global environment where the healthy and sustainable product market is rapidly growing, agro-exporters need to strive to be more competitive and fully exploit their productive capacity to not be outdone in the world arena [2].

Nonetheless, agro-export companies have to deal with a host of issues pertaining to operations, with the most pressing being unproductivity and inefficiencies in the production process. These concerns impede operational productivity and the profit margins and competitive edge of the products in the global marketplace. Applying Lean Manufacturing principles has been well documented as being useful in reducing waste and optimizing processes [3], [4]. Many organizations, however, still face considerable barriers to adoption, such as reluctance to change and insufficient training of personnel [5], [6].

Addressing these problems is imperative, but action must be taken immediately. Shifts in consumer behavior and market policies require agro-export companies to perpetually seek new innovations to maintain status and excel [7]. Implementing lean methodologies seems to provide companies with enhanced operational productivity and efficiency, reducing costs and allowing businesses to elevate their product quality to meet international standards [8], [9].

In the field of research, a significant knowledge gap has been identified in the literature regarding Lean Manufacturing practices in the agro-export sector. Although studies on Lean implementation in various industries exist, specific studies related to agribusiness and, more specifically, to frozen fruit processing remain scarce [10], [11]. This research aims to fill that gap through a production model incorporating Lean Manufacturing tools such as 5S and work standardization [12]. The proposed approach seeks not only to address productivity issues but also to contribute to the existing literature by proposing an integrated framework that considers the specificity of the agro-export sector.

The contribution of this research is significant as it is contextualized within a sector that faces unique challenges and is based on the premise that improved production efficiency translates into economic and sustainable benefits [13]. Unlike previous studies that have addressed Lean in more general contexts, this specific approach offers a renewed perspective on effectively applying these principles in agribusiness [14], [15]. The research is based on the premise that process optimization will generate short-term improvements and lay the foundation for long-term sustainable development in the Peruvian and Latin American agro-export sectors [16].

II. LITERATURE REVIEW

A) Innovations in Lean Manufacturing for Frozen Fruit Processing Plants

There is a specific set of practices that comes from applying Lean Manufacturing techniques to frozen fruit production that enhances operational efficiency, reduces costs, and increases product quality. More recent research indicates that the use of Lean tools, such as value stream mapping, has made it possible to identify food industry improvement areas that could be adapted to frozen fruit processing plants [17]. The widespread integration of these tools has compelled a number of companies to incorporate waste elimination alongside an increase in production capacity, both critical in a competitive and globalized marketplace [18]. Furthermore, other research has shown that Lean principles can successfully be used in food-related areas, especially in processing and storage, improving delivery time and customer satisfaction [19].

Nevertheless, the application of Lean in the frozen fruit industry poses specific difficulties because of the fragile nature of the items and their short shelf life. It has been said that utilizing appropriate metrics and methods tailored to each sector within Lean's scope and evaluating its adaptability is essential for the sector's improvement [20]. This might mean offering SMED techniques to decrease changeover times on the processing line, where maximizing efficiency is crucial to product quality [21]. In this manner, processes are streamlined to minimize waste in the form of spoiled products.

B) Work Standardization: Key to Efficiency

Work standardization also arose as one of the primary practices aimed at helping balance production in frozen-fruit processing plants, thus preserving quality and stable processes. It has been noted that the application of standardized work practices enables organizations to reduce process heterogeneity, resulting in dependable and repeatable production outcomes [20]. A benefit of this approach for frozen fruits is the control over the maintenance of the product through uniformity in all steps of the process aided by standardized operating procedures [21].

Multiple research papers suggest that work standardization creates associations with both efficiency and employee empowerment, resulting in a more favorable and proactive workplace atmosphere [21], [22]. This is important in the food industry, where human factors significantly impact the effectiveness of implementing these practices. In addition, the standardized method assists in training new employees as all employees use the same set of instructions and standard operating procedures, resulting in enhanced continuous improvement and sustainable operations [23].

C) 5S: A Methodology for Organization and Productivity

The 5S methodology has been successfully applied for the processing of frozen fruits and has proven to be a useful tool in improving the organization and efficiency of operations. The 5S philosophy (Sort, Set in order, Shine, Standardize, Sustain) is not only useful for maintaining a safe and clean workplace but also helps to streamline operational processes by removing unnecessary workplace congestion and improving the accessibility of necessary tools and materials [24], [25]. Research shows that applying 5S practices can greatly improve the reduction of search times and work-related accidents, contributing to productivity improvements overall [25], [26].

In the frozen fruit industry, a critical part of 5S is the product's nature, which could ruin its quality if not handled with care. Thus, the organization of the workspace affects the productivity and safety of the food throughout the production process. Implementing 5S as a part of daily business processes enhances operations and strengthens the culture of improvement and commitment among employees [27], [26]. This principle eases the acceptance of other Lean practices and helps the plant become successful as a whole.

D) Use of Andon to Improve Communication and Problem Solving

In plant operations of frozen fruits, Andon as a methodology has helped integrate other elements of process improvement because of the proper internal communication and the ability to assess issues during work. Workers can report any discrepancies or concerns with production immediately using this system, something of utmost necessity in an industry that places a premium on time for product quality [28]. Companies can now respond rather than react to problems after successful implementations of Andon, significantly decreasing downtime [29].

Additionally, research indicates that adopting the Andon system enhances operational productivity and improves employee commitment, as employees are given the chance to solve workplace challenges. [30]. The implementation of the Andon system allows not only the empowerment of teams in frozen fruit processing plants, but also enables these facilities to ensure optimal quality of the products through the supervising processes in an uninterrupted manner [31].

E) Systematic Layout Planning: Efficiency in the Workspace

Lastly, systematic layout planning is another approach that frozen fruit processing plants need to incorporate to optimize workspace efficiency. Systematic spacing of machines and workstations minimizes the time spent handling materials and enhances safety and the smooth progression of workflow in the production process [32], [25]. Research indicates that the presence of an optimized workplace layout improves transport efficiency and greatly enhances workplace ergonomics. Therefore, productivity improves [33].

Systematic layout planning permits firms to evaluate operations and rearrange their facilities to assist in Lean Manufacturing practices. This approach, which incorporates workflow analysis and simulation techniques, has effectively guaranteed that each plant section is configured to deal with perishables, like frozen fruits [17], [34]. Achieving these targets improves operational productivity and aids in waste reduction and compliance with food safety regulations, which is critical in the sector.

To sum up, Lean Manufacturing principles, such as work standardization, 5S, Andon, and systematic layout planning, outline operational strategies for improving productivity in frozen fruit processing plants. These strategies improve productivity and safety and foster a long-term perception in the employees towards an organizational culture focused on continuous improvement and product quality.

III. CONTRIBUTION

A) Proposed Model

Figure 1 illustrates the production model designed using Lean Manufacturing principles alongside the SLP methodology, which was carried out in an agro-export company specializing in the processing of frozen fruits. This model sought to resolve production problems systematically, beginning from a baseline scenario with very low productivity. The model began with the planning phase, which focused on data gathering, problem recognition, and root cause determination. Lean implements such as standardized work, 5S, and Andon systems were applied in tandem with layout redesigns using SLP to mitigate workflow bottlenecks and optimize space utilization. These interventions were sufficed by a verification evaluative phase wherein outcomes were measured, and further opportunities for enhancement were determined. Proactive, responsive actions were then embarked on, which nurtured a culture of continuous improvement and operational excellence. This iterative strategy made it possible to streamline processes and drastically improve productivity.

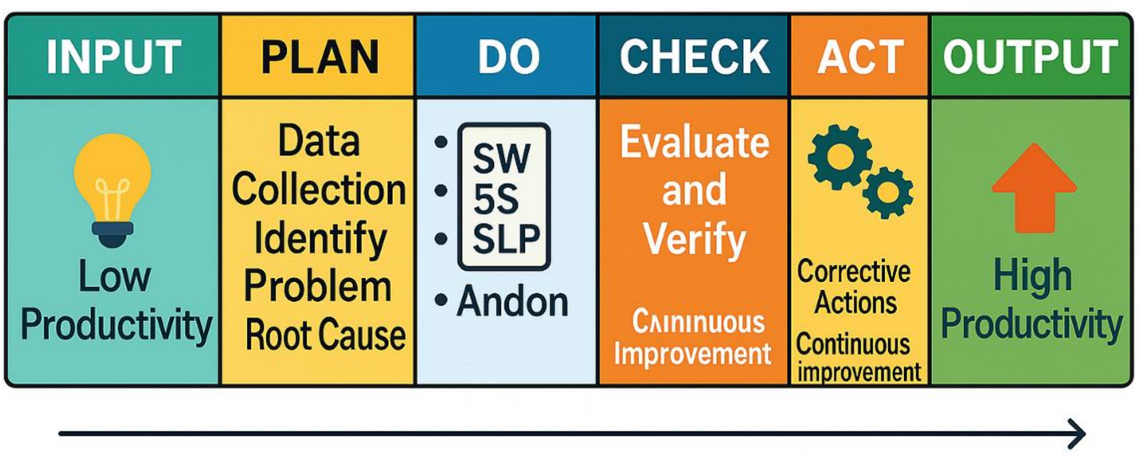


Fig. 1. Proposed Model

B) Model Components

The model presented in Figure 1 appears as an organized methodological solution to the problems confronted by most companies in highly competitive environments, in which process flexibility and operational efficiency become fundamental conditions for sustainability. Informed by the Lean Manufacturing principles and strengthened by the spatial logic of Systematic Layout Planning (SLP), this approach aims to eliminate waste, optimise assets and create a systematic dynamic of continuous improvement at all organizational levels. In contrast to isolated proposals or reactive measures, the proposed model illustrates five consecutive stages—Input, Plan, Do, Check, and Act—whose use allows initial conditions of low productivity to be transformed into more effective and sustainable operation outputs. The methodological proposal meets the necessity for improving key performance indicators and enriches technical literature concerning integrating lean tools into real environments, in this case, in the agro-export industry. Based upon this, its use is contextualized in a frozen fruit processing company. Manual process's unbalance in plant layout, and the absence of standardization were major barriers to acquiring high-performance levels.

This description of the methodology describes each of the elements of the model in detail, clarifying its internal logic, objectives, and role in the overall system of improvement.

Initial Diagnosis and Starting Point: The Challenge of Low Productivity

The suggested model is initiated by a diagnostic phase, depicted in Figure 1 under the 'Input' component, reflecting the initial stage for recognizing current operational conditions without any intervention. Such an approach is beyond basic observation of low productivity, as it entails reflectional consideration of the internal dynamics causing it. In our case study, various causes for low-performance levels were found, such as idle times, disorganized streams, repeated moves of materials, and poor visualization of bottlenecks in the plant for processing. Also, apart from low-performance levels, growing demand in the global market faced by the company necessitated greater responsiveness without sacrificing product quality or incurring disproportionate expenses.

At this stage, an understanding of the problem at the level of the system was consolidated without simplistic or superficial interpretation. Based on direct observations, operator and supervision interviews, and critical examination of production history records, the system's normal operation was defined through its behavior. This initial stage was necessary to ensure that further actions were based upon an actual knowledge of the context, so decisions could not only deal with symptoms but, at last, with the roots of underperformance. Meanwhile, this stage fixed an initial reference point for comparison of improvements achieved through the model, assuring rigorous traceability of results.

The phenomenon of 'low productivity' was dealt with as a multifaceted phenomenon, whose causes could not be explained just by referring to labor speed and machine condition but also to organizational, spatial, and methodological causes. In this sense, the model understands that efficiency is not necessarily dependent upon available technical resources but upon how they are managed, distributed, and articulated in terms of streams of continuous production. Therefore, the initial diagnosis is already an organizational threshold of awareness, in which the firm becomes aware of its weaknesses and is ready to deal with them from an organized and change-oriented approach.

a. Operational Execution of Improvement: Integration of Lean Tools and Layout Redesign

Following the planning, the model progresses to an operational implementation phase, the concrete onset of intervention in the production system. In Figure 1, such a stage is depicted by the 'DO' component, in which Lean Manufacturing instruments are systematically instituted alongside the methodical direction of Systematic Layout Planning (SLP). Such a phase constitutes the transformative core of the model, operationalizing diagnosis and planning conclusions into tangible actions in the processing plant.

Implementation in the case study started with process standardization—the cornerstone approach to guarantee consistency in executing repetitive operations. With established operating procedures, work variability was minimized, directly leading to the stabilization of the production rhythm. Standardization was followed by strict adherence to the 5S methodology, which brought in the right conditions of orderliness, cleanliness, visual organization, and discipline, creating a safe, efficient, and conducive setting for continuous production.

This was accompanied by the integrating of the Andon system as an eyes-on-the-action control and communication device for identifying and responding to any real-time deviations and interruptions in production. This practice further reinforced staff's sensitivity to unplanned events, developing an atmosphere of quick reaction and problem-solving from the shop floor. In addition, the Andon system enhanced process transparency so supervisors and operators could synchronize actions for optimal delivery of acceptable performances.

One of the cornerstones of this stage was applying Systematic Layout Planning as an aid for reconfiguring work area physical layouts. Logically sequencing analyses—such as relationship diagrams, flow analyses, spatial requirements, and operational requirements—the plant's physical layout was reorganized to consolidate highly interdependent operations in closer proximity. Redesign decreased unnecessary movement, minimized material transfer time, and optimized operations logic. For the agro-exporting firm, the new physical layout consolidated the selection, packing, and storing processes, which were earlier split and scattered across the facility.

It should be noted that this stage was not implemented independently but handled using participative and progressive measures. The model considers that operational changes must be followed through technical changes and organizational preparedness. Thus, staff training was encouraged, progress was continually checked and validated, and activities were adaptively changed to practical realities. This dynamic strategy for implementation prevented unnecessary resistance and helped staff to own the changes.

In conclusion, the execution stage involves meticulously integrating improvement tools and facility design. Merging SLP and Lean Manufacturing optimized operational efficiency and revolutionized work culture towards a disciplined, collaborative, and outcome-based approach. Therefore, this stage becomes critical to turning strategy into tangible outcomes within the production system.

b. Monitoring and Verification of Results: Evaluating the Effectiveness of the Transformed System

Following the execution of the corrective action within the production system, the model underwent a phase of checking and deep analysis of the results achieved after the intervention. This phase, which is highlighted in Figure 1 as “CHECK,” is crucial within the step of the methodological cycle because it assesses whether the change(s) made to the plant was/were fully realized, and even more, that they will be sustained in the long term. This is not a mere evaluative exercise but an evaluation of the current state against the benchmark set during the initial diagnosis exercise.

As it relates to the agro-exporting company, the result was evaluated from a holistic point of view, which included Operational conduct and organizational sentiment towards the processes. Focused were the material handling systems in the redesigned layout, interdepartmental collaboration, reduction of downtime, and the stabilizing influence of task standardization. Empirical information documented was augmented by direct field observations and routine debriefing sessions with front-line and supervisory staff to identify unanticipated over-constraining factors or blockages developed during the execution phase.

This is one of the essential aspects of the phase, which is its focus on continuous improvement processes.

For this model, evaluation is not considered an external oversight and a once-and-done activity. Instead, it is regarded as a step where internal self-evaluation systems can be honed and refined. This view promotes an organization where the analysis of results becomes routine rather than something done only during exceptional circumstances. Additionally, the operational actor’s participation in the validation of changes strengthens collective commitment towards the set targets for improvement and nurtures organizational learning.

This phase captures opportunities as well that were missing in the original plan. Discovery through systematic observation enables the identification of new opportunities for optimizing processes, re-designing small process flows, or routine tasks that could be improved through small incremental adjustments. The iterative characteristic of this model allows it to be modified on an ongoing basis, which supports its growth alongside the ever-changing production environment.

Verification in this model is treated as a moment where technical rationality and the human aspect of change meet. At this stage, it is important to highlight that metrics do not measure everything. Transformations impact processes, so qualitative evaluation with validation is performed alongside nominal measurement.

Sighted feedback about the workplace, particularly in relation to enhanced task clarity, as well as spatial order within the plant is seen as a constructive proposition that strengthens the sustainability of the system that has been improved.

The CHECK phase serves a twofold purpose: first, satisfying “confirming the implementation of corrective actions” and “evaluating the effect of actions taken.” As such, the model captures a closed-loop improvement system where evaluation is not the terminal point but a rational next step to subsequent process iterations driven by empirical evidence and factual scrutiny. This understanding allows the system to continuously adapt, strengthening its responsiveness to emerging requirements.

c. Final Adjustments and Consolidation of Change: Toward a Culture of Continuous Improvement

After the verification stage, the model progresses to a phase concentrating on consolidating milestones, institutionalizing improvements, and making necessary modifications to sustain the new production system. As depicted in Figure 1 as the "ACT" phase, this stage completes an improvement cycle and, at the same time, enables the start of new iterations formed from the insights gained during previous activities. It’s in this regard that the model captures the essence of the PDCA (Plan-Do-Check-Act) cycle, but it does so with an added organizational focus centered on embedding sustained refinement as a structural component of organizational culture.

In this stage, efforts focus mostly on tweaking optimization efforts for precise elements, rectifying systematic deviations identified during monitoring, and improving protocols that are functionally useful in the early phases of operationalization but can be streamlined through small shifts. Such changes do not emerge from a response-based logic but rather a planned approach informed by evidence and analysis. For the case of the agro-exporting company, restructurings of certain supply points, loading and unloading schedules to mitigate congestion, and work rule revisions to align with the operational workflow were all incorporated during this phase.

An important dimension of this stage is the organizational learning that can be realized.

According to the model, the value of solutions implemented in any organizational setting lies in their documentation, systematization, and dissemination for replication in other areas or advancement in the future. In this regard, it is commendable to create new operating manuals, visual instructions, training manuals, and workbooks that enable workers to reinforce already learned practices and optimization exercises.

Furthermore, the “ACT” stage also contains elements which sustain the order, discipline, and efficiency achieved in the preceding phases. The establishment of internal audit routines, daily briefings, and continuous improvement committees ensures that the system continues to function within predetermined parameters. These structures, however, are not limited to their operational role; they strive, over time, to make it possible to sustain change while preventing regressions or the return of practices aimed at the previously described progress.

Change consolidation also takes place in a symbolic and cultural dimension. Closing the improvement cycle strengthens organizational identity as one can transform, adapt, and evolve in response to environmental challenges. When this vision is constructed, it deepens staff members' commitment to operational excellence and shifts their workplace disposition towards an environment oriented towards learning. The model does not treat improvement as an exception, isolated, or special endeavor but rather includes it as a routine activity performed regularly in the organization.

At this stage, every piece of knowledge created is preserved from unnecessary loss over time or dilution and transformed into lasting organizational capabilities.

The model transforms processes and constructs technical and behavioral competencies within work teams, thus readying the organization to address future marketplace challenges with enhanced strength. In this manner, in closing, the cycle does not mean an end but rather a vantage point for greater discernment, experience, and methodical sophistication in the next processes for continuous improvement.

C) Model Indicators

The case study evaluates the production model of a frozen fruit processing company that specializes in exports. The evaluation was done using customized metrics that integrate Lean Manufacturing with SLP tools. These metrics tracked key processes like reduced production downtimes, reduced cleaning delays between different types of fruit, and elimination of freezing rework on ice build-up effectively. This system placed no limits on decision-making contrary to Lean principles owing to the need for streamlined data fostering continuous improvement, in this case, enhanced decision-making. As a result, the company improved productive time, operational disruption, and final product quality. This improved the company’s competitiveness and sustainability in the international agro-industrial market.

Productivity:

Measures production output efficiency in kilograms produced per hour, reflecting overall operational performance improvements achieved by the implemented model.

$$\text{Productivity} = \frac{\text{Total Production (kg)}}{\text{Total Hours Worked}}$$

Percentage of Lost Time:

Represents the proportion of unproductive operational time, indicating potential areas for improvement to enhance process efficiency and minimize downtime.

$$\text{Lost Time (\%)} = \frac{\text{Lost Time (hours)}}{\text{Total Scheduled Time (hours)}} \times 100$$

Reduced Waiting Time due to Tool Searching:

Quantifies the decreased time operators spend searching for tools, directly improving workflow continuity and reducing unnecessary process interruptions.

$$\text{Reduction (\%)} = \frac{\text{Initial Time} - \text{Improved Time}}{\text{Initial Time}} \times 100$$

Percentage Reduction in Distance Traveled:

Indicates the efficiency gained by minimizing operators' movement, thus optimizing the spatial layout and reducing waste associated with unnecessary travel.

$$\text{Reduction in Distance (\%)} = \frac{\text{Initial Distance} - \text{Improved Distance}}{\text{Initial Distance}} \times 100$$

Percentage of Lost Time Reduction:
Highlights improvements by showing the percentage decrease in idle and inefficient periods due to better operational practices.

$$\text{Lost Time Reduction (\%)} = \frac{\text{Initial Lost Time} - \text{Improved Lost Time}}{\text{Initial Lost Time}} \times 100$$

Percentage of Reduction in Waiting Time for Washing:
Reflects the effectiveness of process adjustments in minimizing delays specifically related to equipment washing, thereby enhancing production flow and resource utilization.

$$\text{Reduction in Washing Time (\%)} = \frac{\text{Initial Washing Time} - \text{Improved Washing Time}}{\text{Initial Washing Time}} \times 100$$

IV. VALIDATION

A) Validation Scenario

The validation scenario was conducted in a medium-sized agro-export company, referred to as the case study, located in the Callao region of Lima, Peru, dedicated to processing and exporting frozen fruits. The company faced significant productivity challenges in its production line, particularly during the fruit-freezing stage. These issues were primarily related to prolonged downtime, excessive delays during cleaning processes when switching fruit types, and recurrent reprocessing activities during the critical freezing phase. Such inefficiencies negatively impacted operational effectiveness, causing delays in meeting international customer commitments, thereby affecting market competitiveness and profitability. This problematic context motivated the study to implement substantial improvements to address and overcome these operational challenges.

B) Initial Diagnosis

The diagnostic conducted in the case study revealed that low productivity in frozen mango processing resulted from multiple interrelated operational factors. The recorded productivity reached only 620 kg/h, while the sector's average was 1100 kg/h, indicating a technical gap of 480 kg/h. This discrepancy led to a significant economic impact, with total losses estimated at 443,760.00 PEN, representing 8% of the company's annual revenue. The main contributing factor, accounting for 52%, was time lost during production. Additionally, 25% was attributed to reprocessing during the freezing stage and 23% to delays in cleaning when switching between fruit types. Among the root causes, 31% of the inefficiency was due to waiting time for tool availability and location, 23% to delays in continuing the conditioning process, and 21% to operators' continuous movement. An additional 25% of the losses were caused by delays in unloading frozen mangoes, leading to reprocessing that further disrupted the plant's operational performance.

C) Validation Design

Based on Lean Manufacturing and Systematic Layout Planning (SLP) tools, the proposed production model was validated through a pilot implementation over four months in a medium-sized frozen fruit processing company. The validation focused on improving productivity by reducing process inefficiencies, delays, and rework. Key interventions included applying the 5S methodology, standardizing work routines, and redesigning the plant layout to minimize operator movement. This structured approach was supported by quantitative performance indicators, enabling a data-driven evaluation of the model's effectiveness and operational viability within the agro-export sector.

The implementation of the proposed production model was carried out in a medium-sized company dedicated to the processing of frozen fruit for export. The model was designed to address the root causes of low productivity identified during the diagnostic phase, particularly those related to excessive process delays, prolonged tool searching times, inefficient layout, and rework in the freezing stage. By integrating Lean Manufacturing tools—such as work standardization, the 5S methodology, Systematic Layout Planning (SLP), and the Andon system—the model aimed to optimize the production process, reduce non-value-added activities, and ensure consistent quality in the final product. These tools were strategically selected to address specific inefficiencies in different stages of the production flow, and their implementation followed a structured approach. The model included the redesign of operational routines, the reorganization of workspaces, and the incorporation of visual control systems supported by a team-based training program. The solution was validated through quantitative performance indicators aligned with the objectives of increasing productivity and operational efficiency.

a. Work Standardization: Structuring Efficiency in the Packaging Process

The first stage of the solution focused on work standardization, applied specifically in the packaging area, where key tasks included unloading frozen mango cubes, separation, inspection, weighing, bagging, and sealing. The process began with a detailed analysis using a Process Analysis Diagram (DAP), identifying all activities, tools, and durations involved. Through an AVA matrix, it was determined that 6 tasks added value (VA), 4 were necessary but did not add direct value to the customer (NNVA), and 2 were classified as Non-Value-Added (NVA) and thus eliminated. Eliminating these unnecessary tasks allowed for a clearer and more streamlined workflow.

To ensure all procedures were aligned with value-adding goals, a detailed questioning technique was used based on purpose, location, sequence, personnel, and means. This analysis created a new, optimized process flowchart that reflected a logical, efficient sequence. A visual diagram was then developed to standardize the critical step of unloading frozen mango cubes, where significant reprocessing delays had been observed due to inconsistent operator methods.

After defining the new standardized method, visual instructions were posted at each workstation, ensuring all operators could easily follow the updated steps. A training plan was implemented one month before the mango harvest season, targeting production managers, supervisors, and shift leaders responsible for cascading the training to plant personnel. Attendance was recorded, and a formal control sheet was used to monitor the application of the new method.

With these sustained improvements, a control engineer was assigned to verify compliance, clarify doubts, and properly use the visual tools. This role was critical in reinforcing adherence to the new process and maintaining the quality and consistency of production. The structured deployment of work standardization reduced variability among operators and minimized the time lost due to non-standard procedures, directly contributing to an increase in productivity.

F**igure 2** presents a visual standard operating procedure for unloading frozen mango cubes. It outlines each step with corresponding images, ensuring task clarity and consistency. This standardization enhances process efficiency, reduces operator variability, and supports training by providing a clear visual guide aligned with Lean Manufacturing principles.

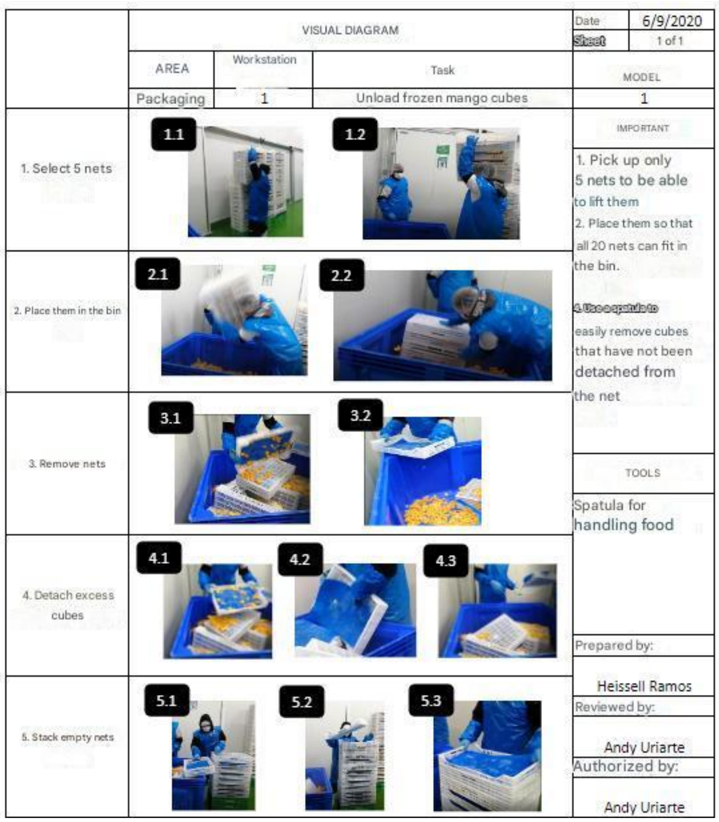


Fig. 2. Visual standardization of the unloading of frozen mangoes

b. 5S: Building a Culture of Order and Discipline

The second phase of the solution involved the implementation of the 5S methodology, with the goal of minimizing lost time caused by disorganization and the lack of proper tool and material placement in the mango production process. This phase was carried out in the raw material classification area, where inefficiencies were frequently observed due to the improper handling and storage of Personal Protective Equipment (PPE), tools, and auxiliary materials.

The first step, Seiri (Sort), began with identifying and categorising elements within the pilot area. Operators classified all materials using a colour-coded tag system—red for items that did not belong and yellow for necessary ones. This process was followed by creating a checklist to evaluate the relevance and necessity of each item, resulting in the removal or relocation of non-essential materials that cluttered workspaces and disrupted workflows.

In the second step, Seiton (Set in order), the focus was on organizing and grouping essential items. Reusable and non-reusable PPE were coded for easy differentiation, and tools were placed in individualized trays at each workstation. Custom-built storage units were designed to house categorized items, facilitating immediate access and ensuring that every operator had the required materials before starting their shift.

Seiso (Shine) emphasized cleanliness, which is critical in a food-processing environment. With the reorganization complete, the team introduced cleaning protocols that guaranteed easy access to frequently used items while reducing the risk of contamination. These measures helped reinforce hygienic practices and improved workplace safety.

During Seiketsu (Standardize), clear visual labels were introduced to assign fixed locations to each item. Labels were color-coded according to the element type and posted visibly to allow workers to quickly identify tools and spot inconsistencies or missing items. This enhanced process efficiency and reduced the time spent searching for materials.

The final step, Shitsuke (Sustain), aimed to maintain the gains through daily evaluations. An audit sheet was developed to verify compliance with the 5S principles. The control engineer used this tool to ensure that every task related to order, cleanliness, and standard placement was upheld throughout the production season. The audit revealed high adherence scores: 87% in sorting, 100% in order, 87% in cleaning, 100% in standardization, and 87% in sustainability.

As a result, operators experienced an immediate reduction in the time spent searching for tools and PPE, contributing to more fluid and uninterrupted workflows. The visual order and disciplined environment created by the 5S implementation not only supported the productivity goals of the model but also strengthened worker commitment and process ownership.

F**igure 3** illustrates a clear transformation before and after applying the 5S methodology. Initially, tools and materials were disorganized and mixed in a single container. After implementation, items were classified, labeled, and properly stored, improving visibility, accessibility, and cleanliness—key principles of Lean practices in production environments.

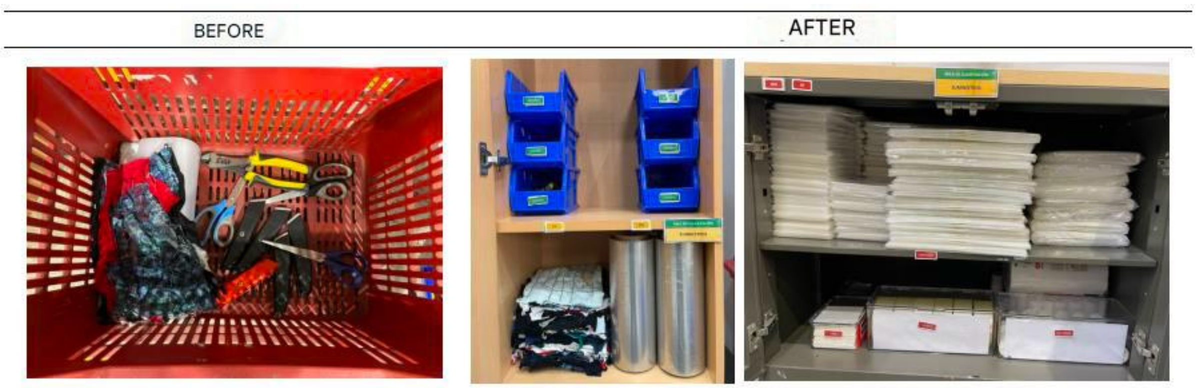


Fig. 3. Before and after the 5S model order

F**igure 4** shows designated furniture and storage spaces labeled as part of the 5S implementation. Labels ensure easy identification and promote workplace organization. This visual control strategy helps maintain order, reduces time spent searching for items, and reinforces standardization across the production area in a Lean environment.

Fig. 4. Spaces and furniture defined with their respective labels

c. Systematic Layout Planning: Optimizing the Flow of Materials and People

The third phase of the solution addressed the root cause of continuous and inefficient operator movement in the raw material classification area. Implementing the Systematic Layout Planning (SLP) method was designed to reduce unnecessary transportation, minimize wasted time, and ultimately enhance productivity in the frozen mango processing line. The methodology was structured in accordance with four fundamental layout principles: safety, integration, minimum distance, and flow continuity.

The initial step consisted of thoroughly mapping the current plant layout, supported by AutoCAD-based floor plans and material flow diagrams. This allowed the team to visualize the sequence of activities and identify spatial constraints, bottlenecks, and areas with high levels of operator traffic. The analysis revealed that key areas such as the raw material warehouse, clean crate storage, and classified product storage were misaligned with the logical sequence of operations, forcing operators to travel long distances and interrupt the flow of tasks.

So as to quantify these inefficiencies, a detailed activity relationship chart was developed, classifying the importance of adjacency between process areas using a ranking system (A, E, I, O, U). The findings indicated a mismatch between the actual physical layout and the ideal proximity required by the process sequence. A relational diagram was then created to graphically represent these relationships and support the diagnosis of layout inconsistencies.

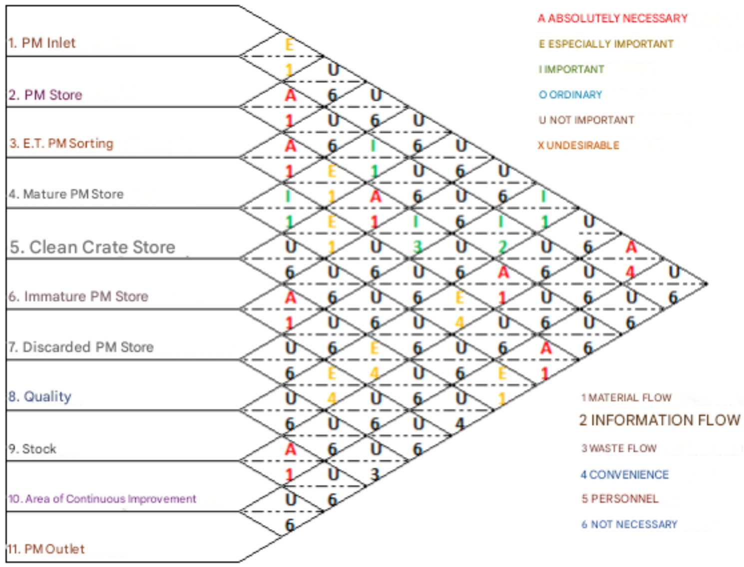
The design team defined the spatial requirements for each workstation and storage area based on observed operational needs. This included calculating minimum aisle widths (no less than 1.50 meters) to accommodate pallet movement and identifying the optimal dimensions for new and existing zones. The design incorporated additional areas introduced during earlier improvement phases, such as the standardized tool station (estoca) and a dedicated continuous improvement area for tool and PPE organization.

With this information, a proposed layout was developed to optimize the flow of materials and operators. A new relationship chart and relational diagram were constructed to evaluate and validate the proposed layout. The final design included segregated storage for ripe, unripe, and discarded raw materials, clearly defined workstations and direct pathways that eliminated unnecessary movement between activities.

With these, a comparative analysis of travel distances was conducted to evaluate the effectiveness of the redesigned layout. The original layout required a distance of 25.99 meters for completing a standard task cycle, while the new layout reduced this to 18.16 meters. This translated into a 30.13% reduction in operator travel distance. The reduction aligned with sector benchmarks that suggest a minimum 24% improvement in spatial efficiency when applying SLP in industrial settings.

Following the redesign, the plant area was physically restructured to match the proposed layout, with clearly marked zones, reorganized storage areas, and streamlined paths for material handling. This restructuring ensured that tasks were performed logically and sequentially, reducing delays and improving spatial ergonomics.

In the final stage, a monitoring and control system was implemented to track adherence to the new layout and measure its impact on productivity. Indicators focused on travel time, distance, and delays. The results confirmed a significant decrease in unnecessary movement and time loss, validating the model’s contribution to the company's productivity goals. The systematic application of the SLP method enhanced process flow and created a safer and more organized work environment.



Fig, 5. Relational table of activities of the proposed model

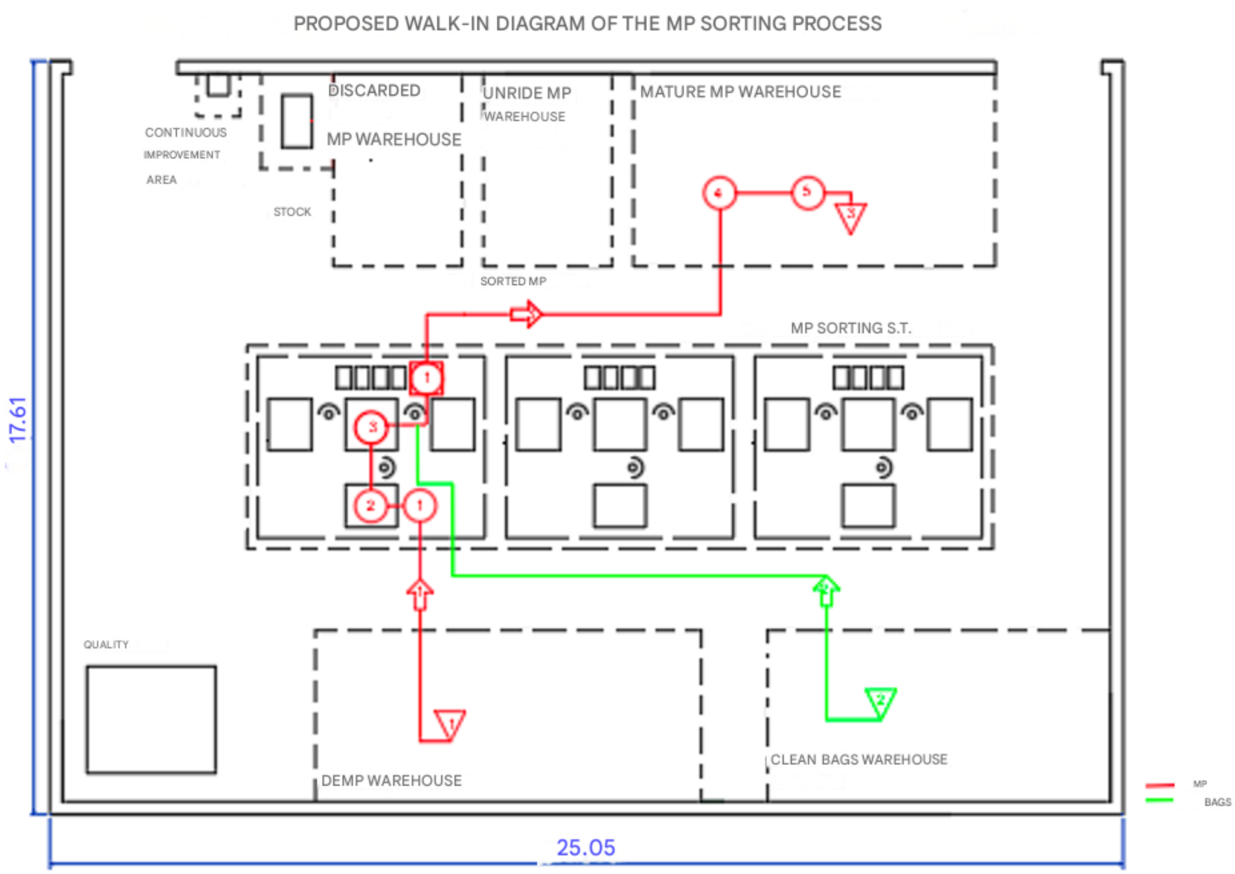


Fig. 6. Proposed route diagram of the redistribution of the sorting area

d. Andon System: Visual Control for Immediate Action

The fourth phase of the solution involved implementing the Andon system, aimed at reducing delays caused by cleaning transitions during fruit changeovers in the frozen mango production process. This phase targeted a critical bottleneck in the conditioning and enmeshment area, where prolonged waiting times during sanitation activities were responsible for considerable productivity loss. Prior to the intervention, operators experienced an average delay of 7200 seconds per pallet, equivalent to a standard loss of 9 seconds per kilogram, which directly impacted production continuity and output volume.

The analysis of the existing process revealed that the cleaning request protocol was bureaucratic and slow, involving multiple steps and approvals before action could be taken. This lack of immediate communication between operators and the sanitation team delayed the cleaning process and caused idle time in adjacent work areas. An address this inefficiency, a visual and audible signaling system was proposed, enabling operators to directly trigger an alert when the production of one fruit type ended, and cleaning was required before switching to another.

The Andon system was designed with simplicity and visibility in mind. Strategically placed alarm buttons (pushers) were installed at key points near the enmeshment and conditioning stations. Once pressed, the system would activate an audible and visual alert (e.g., sirens and light beacons) at the sanitation control center, prompting an immediate response from the cleaning staff. This eliminated the need for manual reports or verbal communication, reducing the transition time and ensuring that sanitation activities began without delay.

A standardized operating procedure was developed to support the system. This procedure established clear responsibilities for activating and responding to the Andon signals and rules to avoid false alarms. Operators were trained to press the button 7 minutes before completing their task, giving the sanitation team time to prepare and arrive promptly. A parallel checklist was implemented to track all Andon activations and record the time elapsed from signal to intervention. These data were used to evaluate system performance and guide continuous improvement.

In terms of materials, the system required alarms, pushers, electric boxes, megaphones, and accessories for installation. The setup was designed to be robust yet cost-effective and adaptable to the existing infrastructure without disrupting daily operations. All materials were listed in a detailed inventory to facilitate implementation and future maintenance.

The training program included sessions for both operators and cleaning staff. Emphasis was placed on the importance of timely activation, appropriate use of the signal, and rapid response. Additionally, selected personnel were trained to perform first-level troubleshooting of the Andon equipment in case of failure, ensuring system reliability.

Once in operation, the Andon system significantly reduced idle times during cleaning-related transitions. Operators no longer had to wait for clearance or locate supervisors to initiate sanitation; instead, a single action ensured immediate visibility of the need for intervention. The process became more fluid, and coordination among departments improved. The integration of Andon into the production model reinforced the company's Lean culture by fostering visual control, quick feedback loops, and standardized responses to disruptions.

The system's effectiveness was monitored using a dedicated dead time tracking format, which recorded the cause, duration, and area affected by any unexpected downtime. These records served as input for performance audits and were reviewed weekly to identify trends and prevent the recurrence of delays.

Overall, the introduction of the Andon system contributed to reducing cleaning delays, avoiding rework, and restoring process rhythm. The clarity and speed provided by the visual alerts empowered operators and ensured that issues were addressed before they could escalate, playing a key role in sustaining the productivity gains envisioned by the proposed model.

Figure 7 illustrates the improvement achieved through the implementation of the Andon system. Initially, operators followed manual procedures to request cleaning support. After implementation, a push-button triggered a visual and audible alarm in the cleaning office, enabling immediate response and reducing waiting times during cleaning transitions in the production process.

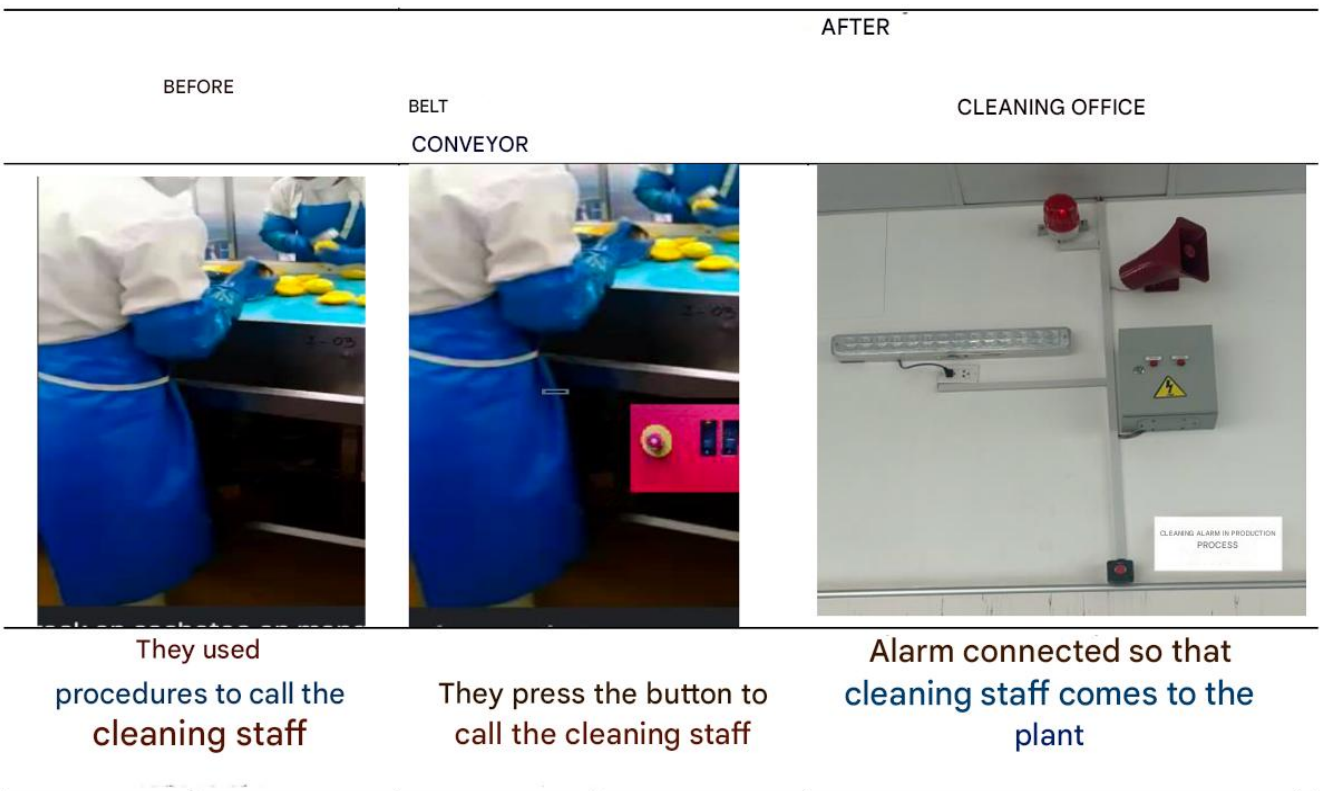


Fig. 7. Andon system before and after comparison

e. Implementation, Monitoring, and Sustainability of the Production Model

After completing the design and individual implementation plans for each tool—work standardization, 5S, SLP, and Andon—the final step was integrating them into a unified model to improve frozen mango production. This phase involved the physical transformation of workspaces, training of personnel, allocation of resources, and the establishment of evaluation mechanisms to ensure the sustainability of the improvements.

The implementation began with restructuring the layout based on the SLP methodology. The physical space was adjusted according to the new plan, incorporating two additional areas: a continuous improvement station for PPE and tool organization and a standardized tool-handling area ("estoca"). Additionally, previously undifferentiated spaces for raw material storage were subdivided into three zones: ripe, unripe, and discarded fruit, based on proximity to their next use. These changes ensured logical sequencing and minimized backtracking, a common source of inefficiency in the original layout.

All improvements were consolidated into a comprehensive rollout plan, executed staged to allow teams to adapt gradually. Leadership from the production manager and supervisors was key, as they oversaw the dissemination of information and ensured frontline staff understood and adhered to the new methods. One month before peak production season, training sessions focused on proper tool handling, process discipline, hygiene protocols, and visual control systems.

A performance monitoring system was implemented to assess the effectiveness of the changes. Operator travel time, waiting time, tool search time, and rework quantity were tracked regularly. Compliance audits were conducted using standardized checklists and scoring systems, while productivity was measured in terms of kilograms produced per hour. After full implementation, the company recorded a productivity increase from 621 kg/h to 847 kg/h, representing a 36.4% improvement.

One of the most notable results was reducing operator travel distance in the classification area from 25.99 meters to 18.16 meters, translating to a 30.13% decrease in unnecessary movement. Additionally, the time lost due to tool searching fell from 650 seconds to 465 seconds per task cycle, and the cleaning transition delay was minimized by nearly 80% with the implementation of the Andon system.

In order to ensure long-term sustainability, a follow-up strategy was developed, assigning a control engineer responsible for validating compliance and assisting in ongoing improvement efforts. This engineer served as the link between management and operators, ensuring the continuity of the Lean culture. Control formats were designed to capture deviations in real time and generate weekly performance reports, allowing proactive decision-making.

The combined implementation of Lean and SLP tools fostered a culture of discipline, visibility, and continuous improvement. Operators became more engaged with process standards, delays were rapidly addressed, and the production environment became cleaner and more organized. These outcomes positioned the company to better meet international demand, minimize waste, and strengthen its market competitiveness.

D) Results

Table 1 illustrates the results obtained while validating the production model incorporating Lean and SLP tools. The productivity increase from 621 kg/hour to 847 kg/hour reflects a 36.39% improvement. Also, the percentage of time lost decreased remarkably from 67% to 11%, an 83.58% reduction. In the same manner, the waiting time related to tool searching was reduced from 650 seconds to 465 seconds, a decrease of 28.46%. Reduction in the distance traveled was achieved by 30.13%, resulting in a total of 70%. In addition, the total reduction in the lost-time value was 72%, an improvement of 28.48%. Moreover, the significant reduction in washing waiting time to 20.01% was almost 80%. All these results confirmed the effectiveness of the model toward the research problem.

Table 1. Results of the pilot

Indicator	Unit	Measurement Frequency	As-Is	To-Be	Results	Variation
Productivity	Kilos/hour	Daily	621	890	847	36.39%
Percentage of Lost Time	Percentage	Daily	67%	6%	11%	-83.58%
Reduced Waiting Time due to Tool Searching	Seconds	Daily	650	470	465	-28.46%
Percentage Reduction in Distance Traveled	Percentage	Daily	100%	24%	70%	-30.13%
Percentage of lost time reduction	Percentage	Daily	100%	34%	72%	-28.48%
Percentage of reduction in waiting time for washing	Percentage	Daily	100%	20%	20.01%	-79.99%

V. DISCUSSION

The outcomes of this study reaffirm the strategic value of Lean Manufacturing when adapted to the specific dynamics of the frozen fruit processing industry. Compared to existing studies, this research validates the relevance of tools like 5S and work standardization [18], [21] and advances prior findings by demonstrating measurable improvements in productivity and waste reduction through a hybrid model that integrates Systematic Layout Planning. Similar to the findings by Randhawa and Ahuja [19], implementing standardized procedures enhanced workflow consistency and employee engagement. Furthermore, the reduction in tool-search time and operator displacement aligns with the improvements observed in layout-focused interventions reported by Karim and Arif-Uz-Zaman [20]. However, this study extends those contributions by applying Lean-SLP synergies in a highly perishable context, achieving a 36.4% increase in productivity and up to 80% reduction in downtime.

Despite the promising results, the model's validation occurred in a single mid-sized company, which may limit generalizability. The seasonal nature of mango production and reliance on manual labor also introduce contextual constraints. Moreover, the effectiveness of the implemented changes heavily depended on leadership involvement and operator participation, which may vary across firms. Time constraints also restricted the evaluation of long-term sustainability beyond one production cycle.

This study offers a scalable roadmap for agro-industrial companies seeking to enhance efficiency through structured process improvement. Integrating Lean and SLP tools provides a replicable framework for managing workspace organization, visual control, and waste elimination. It empowers frontline teams and strengthens operational discipline without requiring major technological investments.

Future studies should replicate the model in agro-export contexts, including automated or semi-automated environments. Longitudinal analyses could examine the durability of gains over multiple production seasons. It is also recommended to explore digital integrations, such as IoT-based Andon systems, to improve real-time responsiveness and reduce non-value-added activities.

IV. CONCLUSION

The study confirms the effectiveness of a production model that integrates Lean Manufacturing principles with Systematic Layout Planning (SLP) to improve productivity in a frozen fruit processing company. Implementing tools such as 5S, standardized work, Andon systems, and layout redesign led to substantial operational improvements. The most notable results include a 36.4% increase in productivity, an 83.6% reduction in lost time, and a 30.1% decrease in operator travel distance. These achievements demonstrate that targeted interventions based on structured methodologies can directly address inefficiencies linked to disorganization, excessive motion, and long cleaning delays in agro-export contexts.

This research gains importance because of its quantitative results and because it responds to a real and persistent problem in Latin American agro-industrial companies. The paper illustrates how operational models, when adapted to the characteristics of perishable product processing, can produce sustainable and scalable outcomes. The proposed model stands out by not relying on high-cost technology but on a clear logic of problem identification, human-centred implementation, and continuous feedback. As such, it presents a realistic approach for small and medium-sized enterprises facing resource constraints.

The study contributes to the field of Industrial Engineering by demonstrating a practical application of Lean-SLP integration in an underexplored sector. Unlike theoretical analyses, this research is grounded in a field-based implementation that links technical tools with behavioral and organizational change. Furthermore, it enriches the academic dialogue by offering validated indicators that can serve as benchmarks for future evaluations in similar environments.

Although the model demonstrates strong performance, further studies are necessary to replicate its application across diverse processing conditions and fruit types. Future research should also explore its adaptability to higher levels of automation and its resilience across multiple production cycles and seasons to validate its long-term effectiveness.

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