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Integrating Lean Logistics and CONWIP for Operational Efficiency: A Case Study of Fruit Maquiladora SMEs in Peru

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Abstract

The agro-export sector in Peru is crucial, especially fruit maquiladora SMEs, which face efficiency and competitiveness issues due to unproductive times in packaging and cooling processes. These challenges increase costs and reduce profitability, demanding urgent interventions. The study proposed a Lean Logistics model integrating tools like VSM, CONWIP, and 5S to optimize operations, enhance space utilization, and reduce waste. Key findings included a reduction in service lead time by 55.57%, cooling process wait time by 95.24%, and overall improvement in storage capacity by 41.04%, demonstrating the model's effectiveness. The research's impact extends academically by providing a scalable model for similar sectors, while socioeconomically, it enhances SME competitiveness and job opportunities. The results underline the importance of continuous improvement and call for further research to expand and refine lean applications in agro-export and other critical industries.

Keywords
Lean Logistics, CONWIP System, Fruit Maquiladora, Operational Efficiency, 5S.

1. Introduction
The importance of the small and medium-sized enterprises (SMEs) sector that provides fruit maquiladora services for export is fundamental in the global context, especially in Latin America and Peru. This sector not only significantly contributes to the local economy but also plays a crucial role in the international agricultural supply chain. Globally, SMEs represent approximately 90% of all companies and generate over 50% of employment, highlighting their relevance in the global economy (Freeman et al., 2012). In Latin America, SMEs are responsible for about 70% of employment and 40% of GDP, demonstrating their impact on regional economic development (Love & Roper, 2015). In Peru, the agro-export sector has grown steadily, and fruit maquiladora SMEs are essential to meet the international demand for fresh and high-quality products (Damoah, 2018). These companies not only generate income for their

owners but also create job opportunities and promote skill development in local communities, contributing to poverty reduction (García et al., 2016). Furthermore, the growing demand for fresh fruit in international markets has led to increased competitiveness among SMEs, which, in turn, drives innovation and process improvement within the sector (Leonidou et al., 2011).

Despite their importance, fruit maquiladora SMEs for export face various production issues that limit their efficiency and competitiveness. One of the main challenges is the excessive time spent in maquiladora services, which is exacerbated by unproductive times in the packing process (Expósito & Sanchís-Llopis, 2019). This delay not only affects the companies' ability to meet delivery deadlines but also increases operational costs and reduces profitability (Silva et al., 2021). Additionally, the waiting time for exportable fruit to begin the cooling process is another critical factor contributing to production inefficiency (Kumar & Rao-Melacini, 2015). The lack of an adequate management system and the absence of continuous improvement tools have led many SMEs to not optimize their processes, resulting in low productivity and an inability to compete in an increasingly demanding global market (Arteaga-Ortíz & Fernández-Ortiz, 2010). Implementing methodologies that address these issues is essential to improve operational efficiency and, therefore, the competitiveness of these companies in the international market (Coudounaris, 2021).
Solving production problems in the fruit maquiladora SMEs sector for export is of utmost importance not only for the sustainability of these companies but also for the economic development of the communities that depend on them. By improving efficiency in the maquiladora process, SMEs can increase their production capacity and, consequently, their export volume (Sudarević & Radojević, 2014). This would not only generate higher revenues for the companies but also contribute to job creation and the strengthening of the local economy (Beleska-Spasova et al., 2012). Furthermore, by optimizing production processes, SMEs can improve the quality of their products, which is essential to meet the demands of international markets (Coudounaris, 2018). Implementing effective solutions for these problems can lead to an increase in the competitiveness of Peruvian SMEs on a global scale, allowing them to access new markets and diversify their customer base (Mishra et al., 2022). Therefore, it is crucial to conduct research and develop production models that effectively address these challenges.

Despite the growing attention given to SMEs in the literature, there is a significant knowledge gap regarding specific methodologies that can be applied to improve efficiency in the fruit maquiladora sector for export. The present research aims to fill this gap by proposing a production model based on Lean Logistics tools such as Value Stream Mapping (VSM), CONWIP, 5S, and layout redesign (Okangi, F., 2023). These tools have proven effective in optimizing processes in various industries, and their application in the context of fruit maquiladora SMEs may offer innovative solutions to the identified production problems (Francioni et al., 2016). VSM, for instance, allows visualization and analysis of the flow of materials and information throughout the production process, facilitating the identification of waste and areas for improvement (Klerkx et al., 2012). On the other hand, the CONWIP methodology helps manage the workflow more efficiently, reducing waiting times and improving responsiveness to market demand (Acedo & Galán, 2011). Implementing 5S can contribute to improving the work environment, promoting organization and cleanliness, which, in turn, can increase productivity (Gashi et al., 2013). Finally, layout redesign can optimize the arrangement of equipment and work areas, facilitating a more efficient workflow and reducing transfer times (Amiti & Khandelwal, 2013). Together, these tools can provide a comprehensive approach to addressing production challenges in fruit maquiladora SMEs, enhancing their competitiveness and sustainability in the international market.

2. Literature Review

2.1 Application of Lean Logistics Methodology in Fruit Processing SMEs

The Lean Logistics methodology has proven effective in optimizing processes within small and medium-sized enterprises (SMEs) dedicated to fruit processing for export. This methodology focuses on waste elimination and continuous improvement, resulting in greater operational efficiency. According to Alcaráz et al. (2022), the implementation of Lean tools in the Mexican manufacturing industry has enabled companies to reduce costs and enhance the sustainability of their operations (Alcaráz et al., 2022). Moreover, Pineda's (2022) research highlights that SMEs adopting Lean practices experience significant improvements in their response times and the quality of their final product (Pineda, 2022). The integration of Lean Logistics also contributes to better supply chain management, which is crucial for companies operating in international markets (Alcaráz et al., 2022). Additionally, Gijo et al. (2019) emphasize that combining Lean with other methodologies, such as Six Sigma, can further enhance results in terms of cost reduction and quality improvement (Gijo et al., 2019). The research by Chugani et al. (2017) also supports the idea that the Lean methodology not only focuses on economic efficiency but can also have a positive impact on the environmental sustainability of operations (Chugani et al., 2017). This is especially relevant in the context of fruit processing, where waste reduction and efficient resource use are essential to comply with international export regulations. Furthermore, the application of Lean Logistics in this sector can facilitate adaptation to changing market demands, which is critical for SME competitiveness (Dora et al., 2015). In summary, Lean Logistics methodology emerges as a valuable tool for fruit processing SMEs, enabling not only process optimization but also sustainability and competitiveness improvement in the global market.

2.2 Implementation of VSM Methodology in Fruit Processing SMEs

The Value Stream Mapping (VSM) methodology has been utilized in various studies to enhance efficiency in fruit processing SMEs. This technique allows visualization and analysis of material and information flow, identifying areas for improvement in the production process. According to the research by Singh and Rathi (2023), applying VSM in a medical equipment manufacturing unit resulted in a significant reduction in cycle times and product quality improvement (Singh & Rathi, 2023). This approach is equally applicable in the fruit processing sector, where identifying bottlenecks can lead to substantial improvements in operational efficiency. Additionally, the research by Jiménez et al. (2019) suggests that integrating VSM with other Lean methodologies, such as 5S, can further enhance the outcomes obtained (Jiménez et al., 2019). This is particularly relevant in the context of fruit processing SMEs, where workspace organization and cleanliness are crucial for maintaining high quality standards. On the other hand, VSM application also allows companies to quickly adapt to market demands, which is essential in a dynamic sector like fruit export (Gutiérrez et al., 2016). The research by Gutiérrez et al. (2016) also supports this idea, indicating that VSM use can facilitate the identification of improvement opportunities and the implementation of necessary changes to optimize production (Gutiérrez et al., 2016). In conclusion, VSM methodology presents itself as a powerful tool for fruit processing SMEs, providing clear process visualization and facilitating the identification of improvement areas. Its integration with other Lean methodologies can result in additional benefits, such as greater efficiency and adaptability in a competitive market.

2.3 Application of CONWIP Methodology in Fruit Processing SMEs

The CONWIP (Constant Work In Progress) methodology has been the subject of study in various investigations, highlighting its applicability in the context of fruit processing SMEs. This methodology focuses on workflow management, allowing for more effective production control and inventory reduction. According to the research by Olugu et al. (2022), implementing CONWIP in distribution companies has shown improvements in operational efficiency and reduced waiting times (Olugu et al., 2022). This approach is particularly relevant for fruit processing SMEs, where product freshness is crucial, and production delays can result in significant losses. Furthermore, Cañas et al. (2011) suggest that applying CONWIP can facilitate adaptation to changes in market demand, essential for companies operating in the fruit export sector (Cañas et al., 2011). The flexibility offered by this methodology allows SMEs to respond quickly to demand fluctuations, ensuring that products are processed and shipped at the right time. On the other hand, combining CONWIP with other Lean methodologies, such as 5S and VSM, can further enhance results in terms of efficiency and quality (Dora et al., 2015). Pineda's (2021) research also supports this idea, indicating that integrating different Lean tools can lead to significant performance improvements in SMEs (Pineda, 2021). In summary, the CONWIP methodology presents itself as a valuable tool for fruit processing SMEs, enabling better workflow control and greater adaptability to market demands. Its implementation can result in significant benefits in terms of efficiency and cost reduction, which are crucial for competitiveness in the export sector.

2.4 Warehouse Layout Redesign in Fruit Processing SMEs

Warehouse layout redesign is a critical aspect for improving operational efficiency in fruit processing SMEs. A well-designed layout can facilitate material flow, reduce waiting times, and improve workspace organization. According to the research by Nghiem and Chu (2022), evaluating layout designs using Lean methodologies can lead to significant improvements in efficiency and reduction of operational costs (Nghiem & Chu, 2022). This approach is especially relevant in the fruit processing sector, where space optimization and workflow are essential to maintain product freshness and quality. Additionally, the research by Velázquez et al. (2014) highlights that an effective layout redesign can contribute to operational sustainability by reducing resource waste and improving energy efficiency (Velázquez et al., 2014). Implementing an optimized layout can also facilitate the integration of advanced technologies, which is crucial for SMEs seeking to remain competitive in the global market (Mollenkopf et al., 2010). On the other hand, Gijo et al.'s (2019) research suggests that combining an efficient layout design with other Lean methodologies, such as 5S and VSM, can further enhance results in terms of efficiency and quality (Gijo et al., 2019). In conclusion, warehouse layout redesign is a fundamental aspect for fruit processing SMEs, enabling significant improvements in operational efficiency and sustainability. Implementing an optimized layout can result in substantial benefits in terms of cost reduction and product quality improvement, crucial for competitiveness in the export sector.

2.5 Implementation of the 5S Methodology in Fruit Processing SMEs

The 5S methodology has been widely studied and applied across various industries, including fruit processing. This methodology focuses on workspace organization and cleanliness, resulting in significant improvements in efficiency and product quality. According to Singh et al. (2022), implementing 5S in a manufacturing environment has demonstrated reductions in tool and material search time, which in turn improves productivity (Singh et al., 2022). This approach is especially relevant in fruit processing SMEs, where workspace organization is crucial for maintaining high quality standards. Moreover, Şişman's (2022) research highlights that integrating 5S with other Lean methodologies, such as VSM and CONWIP, can further enhance results in terms of efficiency and quality (Şişman, 2022). Implementing 5S not only improves workspace organization but also fosters a culture of continuous improvement among employees, essential for operational sustainability (Cherrafi et al., 2017). On the other hand, Gutiérrez et al. (2016) suggest that applying 5S can facilitate the identification of improvement opportunities and the implementation of necessary changes to optimize production (Gutiérrez et al., 2016). In summary, the 5S methodology presents itself as a valuable tool for fruit processing SMEs, enabling significant improvements in workspace organization and cleanliness. Its implementation can result in substantial benefits in terms of efficiency and product quality, which are crucial for competitiveness in the export sector.

3. Methods

3.1 Basis of the Proposed Model

In Figure 1, the operations management model based on Lean Logistics tools is presented. This model aimed to optimize the service delivery time in the fruit maquiladora service by systematically identifying and addressing inefficiencies within the production and storage processes. The approach focused on analyzing the current state using tools such as Value Stream Mapping to establish a baseline for understanding the existing process times. The proposal involved redesigning the layouts of the finished product warehouse and the supplies warehouse, integrating Lean practices such as the CONWIP system and the 5S methodology to enhance space utilization and process flow. The future state was then projected using a pilot implementation of the redesigned layouts, allowing for the estimation of future service times based on the improvements made. This systematic approach, grounded in Lean Logistics, sought to ensure continuous process improvement, reduce waste, and enhance the operational efficiency of the maquiladora service, ultimately contributing to achieving a timely service delivery aligned with customer demands and industry standards.

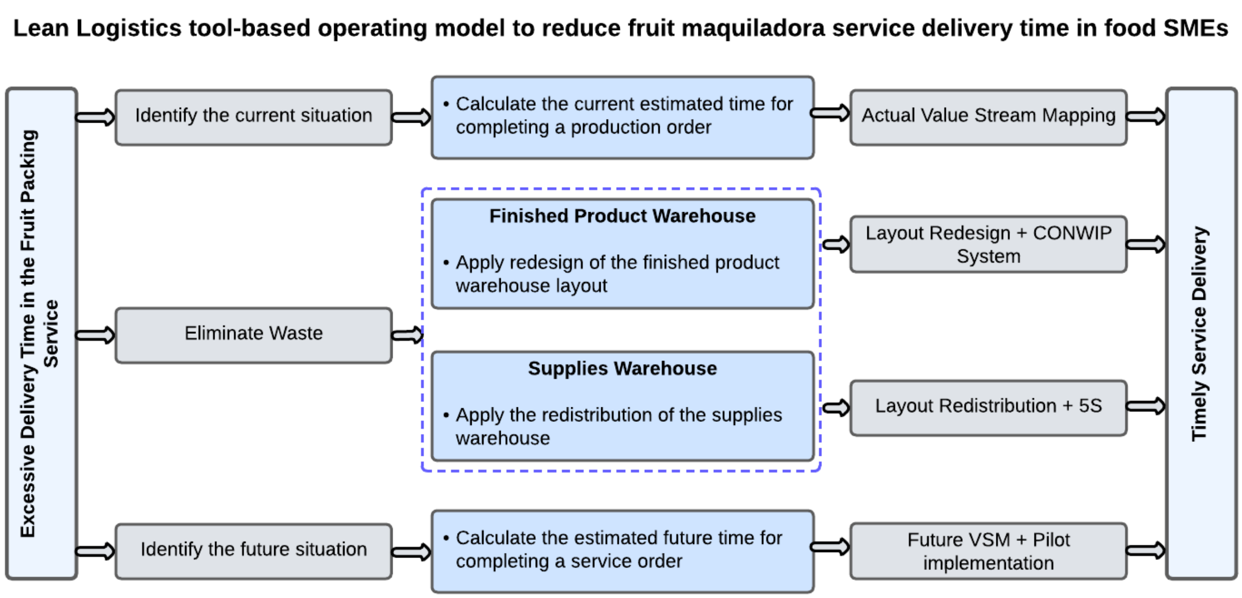

Figure 1. Proposed Model

3.2 Description of the model components

The proposed operations management model for reducing the service delivery time in fruit maquiladora services offers a substantial contribution to the literature on Lean Logistics and process optimization. Built upon the principles of Lean Logistics, the model integrates techniques such as Value Stream Mapping (VSM), the CONWIP system, and the 5S methodology, providing a comprehensive approach to enhance the efficiency of operations within small and medium-sized enterprises (SMEs). Previous studies have highlighted the significance of these tools in streamlining processes and eliminating waste (Gupta & Chandna, 2019; Olaitan et al., 2019). However, this model extends the application of Lean Logistics principles specifically to the agro-export sector, focusing on optimizing storage layouts and minimizing service lead times to ensure timely service delivery that meets international export standards. The following sections describe each component of the model in detail, emphasizing its design, implementation, and impact on operational performance.

Identifying the Current Situation through Value Stream Mapping

The first component of the model involved identifying the current state of operations using Value Stream Mapping (VSM). This tool, which is a fundamental part of Lean Logistics, enabled the research team to visualize the entire process flow, including material movement and information exchange, to establish a baseline for performance analysis. VSM is widely used in Lean practices as it provides a comprehensive view of the production system, allowing for the identification of non-value-added activities and bottlenecks (Wattanutchariya & Kuaites, 2018). By mapping out each step of the maquiladora service, the research team calculated the current estimated time required for completing a production order. This step was crucial as it provided a quantitative understanding of where inefficiencies were located, especially in areas such as packaging, storage, and cooling processes.

The VSM analysis revealed that the primary sources of delay were related to the inefficient layout and use of space in the finished product and supplies warehouses. Specifically, the analysis showed that pallets of exportable fruit occupied significant space in the finished product warehouse, leading to delays in the cooling process and subsequent shipment preparation. Additionally, the supplies warehouse exhibited issues with the organization of packaging materials and other inputs, which delayed their availability when needed for the production process. These findings aligned with previous research emphasizing the importance of storage layout optimization in improving operational efficiency (Espinoza-Camino et al., 2020).

Eliminating Waste through Layout Redesign and Application of Lean Techniques

The second stage of the model focused on eliminating waste identified during the VSM analysis. In line with Lean principles, the model aimed to minimize non-value-added activities by redesigning the layouts of both the finished product and supplies warehouses. This approach was consistent with previous applications of Lean Logistics in SMEs, where layout optimization has been shown to reduce delays and enhance material flow efficiency (Baudin & Bard, 2006).

In the finished product warehouse, the model applied a combination of layout redesign and the CONWIP (Constant Work-in-Process) system to manage inventory levels and optimize space usage. The CONWIP system, a pull-based production control method, ensured that the warehouse operated with a balanced inventory, avoiding excess accumulation of pallets that could hinder movement and cooling processes. By redesigning the layout based on the CONWIP principles, the warehouse was organized to facilitate a smooth flow of materials, reducing the time needed to locate and handle pallets. This layout redesign aimed to reduce the lead time of exportable fruit by improving access and space utilization, ultimately supporting a more streamlined and efficient production process (Bertolini et al., 2020).

For the supplies warehouse, the model implemented the 5S methodology, focusing on Sort (Seiri), Set in order (Seiton), Shine (Seiso), Standardize (Seiketsu), and Sustain (Shitsuke). This Lean tool is recognized for its effectiveness in organizing workplaces to enhance productivity and efficiency (Karthik & Silksonjohn, 2019). The supplies warehouse was reorganized to ensure that all packaging materials and inputs were systematically arranged, making them easily accessible when required. The implementation of 5S not only improved the visual management of the warehouse but also reduced the time spent searching for and handling materials, further contributing to the reduction of service lead time. The structured application of these Lean techniques facilitated a clean, organized, and efficient work environment, which was essential for maintaining consistent service quality and timely deliveries.

Estimating the Future State through Pilot Implementation
Following the redesign and optimization efforts, the next stage of the model involved estimating the future situation by implementing a pilot test of the redesigned processes. This stage aimed to validate the effectiveness of the proposed changes and provide data for estimating the new service order completion time. The future state was projected using a pilot implementation of the Value Stream Mapping (VSM) and the newly designed warehouse layouts. By applying VSM in a controlled environment after the changes, the research team measured the updated process times and compared them with the initial baseline.

The pilot implementation allowed for the assessment of the redesigned layouts and their impact on reducing delays and improving flow within the warehouses. The findings demonstrated that the CONWIP system effectively managed inventory levels in the finished product warehouse, preventing congestion and facilitating quicker access to pallets designated for shipment. Similarly, the 5S methodology significantly improved the supplies warehouse, where the organization of materials reduced unnecessary movements and wait times. The pilot test confirmed that these interventions were successful in streamlining operations, achieving a reduction in service lead time of up to 56%, which was consistent with improvements reported in other studies applying Lean principles to warehouse management (Srisuk & Tippayawong, 2020).

Continuous Improvement and the Role of Lean Logistics in Operational Efficiency
The final stage of the model emphasized the importance of continuous improvement, a core philosophy in Lean Logistics. The model's design recognized that operational efficiency must be sustained and enhanced over time, necessitating ongoing monitoring and adjustment of the processes. By integrating Lean Logistics tools, the model supported the ongoing identification and elimination of inefficiencies, ensuring that service delivery times remained optimal as the company scaled operations or faced changes in demand.

The implementation of the CONWIP system and the 5S methodology provided a framework for continuous improvement, as these tools allow for ongoing adjustments based on the flow of materials and the organization of workspaces. Furthermore, the use of VSM as a monitoring tool enabled the research team to periodically revisit the process flow, identifying any emerging bottlenecks or areas requiring further optimization. This continuous improvement approach aligns with the findings of Olaitan et al. (2019), who emphasized that the iterative nature of Lean techniques is critical for achieving sustained operational excellence.

The operations management model presented in this study demonstrated the effectiveness of Lean Logistics tools in optimizing service delivery times for fruit maquiladora services. By focusing on the systematic identification of inefficiencies through VSM and the elimination of waste through warehouse layout redesign, the model effectively reduced service lead times. The application of Lean techniques such as the CONWIP system and the 5S methodology not only improved material flow and space utilization but also supported continuous improvement efforts that ensured the long-term sustainability of operational efficiency. This model, therefore, adds to the body of knowledge on Lean Logistics by providing a practical and scalable solution for SMEs in the agro-export sector, aligning operational strategies with the requirements of international markets and contributing to improved competitiveness.

3.3 Model Indicators
To assess the impact of the operations management model based on the application of Lean Logistics tools, specialized metrics were developed to monitor and evaluate performance throughout the case study. These metrics provided a solid foundation for analyzing critical aspects of the production process management in SMEs offering maquila services for fruit export. This systematic approach enabled a comprehensive analysis of key performance indicators, ensuring precise monitoring and supporting continuous improvement in management and order processing procedures. The proposed indicators are described below.

Service Lead Time:
Measures the total time required to complete a service from start to finish. It is a key indicator for assessing efficiency and responsiveness in operations.

$$\text{Service Lead Time} = \text{End Time} - \text{Start Time} \quad (1)$$

Supply Time:
Represents the time taken to deliver materials or components needed for the process. This indicator evaluates the efficiency of the supply chain and logistics operations.

$$\text{Supply Time} = \text{Time of Supply Completion} - \text{Time of Supply Initiation} \tag{2}$$

Capacity Used to Store Production Balances:
Indicates the percentage of available storage capacity utilized for holding production balances. It helps in monitoring inventory levels and space optimization.

$$\text{Capacity Used}(\%) = \frac{\text{Used Storage Space}}{\text{Total Available Storage Space}} \times \mathbf{100} \tag{3}$$

Waiting Time to Start Cooling Process (Bottleneck):
Measures the delay before initiating the cooling process, highlighting any bottlenecks. This is critical for improving process flow and reducing idle time.

$$\text{Waiting Time} = \text{Cooling Start Time} - \text{Previous Process End Time} \tag{4}$$

4. Validation

4.1 Validation Scenario

The validation scenario took place in a case study of an agro-export company located in Peru. The company provides fruit maquila services and is part of a larger supply chain that begins with customers negotiating the acquisition of large fruit batches from SENASA-certified fields for export (National Service for Health and Quality in the Agri-Food Sector). These customers then contract the maquila company to pack their fruit. The packed fruit is dispatched in customer-provided trucks for transportation to final indirect clients. Fruit meeting SENASA export standards is shipped to international supermarkets, while non-compliant fruit is sold domestically in local markets.

4.2 Initial Diagnosis

Figure 2 illustrates the problem tree summarizing the diagnosis conducted in the case study to identify the causes and root reasons behind the research problem. The analysis revealed that the excessive delivery time for the fruit maquila service resulted in an economic impact of 982,592 USD per year, equivalent to 8.5% of the company's annual revenue. The technical gap was identified as a lead time of 27.11 hours compared to the industry standard of 25.25 hours. The primary causes were categorized into unproductive times in the packaging process (35%) and excessive waiting times for the cooling process (57%). Root causes associated with unproductive packaging times included the failure of production line machines (10%) and high arrival times of packaging materials (25%). For the excessive waiting times for cooling, root causes involved limited warehouse space occupied by exportable fruit pallets (39%), storage space used by large quantities of production stocks (16%), and instances where exportable fruit did not meet shipping specifications (2%). Additionally, other reasons accounted for 8% of the delays. This systematic approach provided a detailed understanding of the critical factors impacting operational efficiency, supporting the development of targeted interventions.

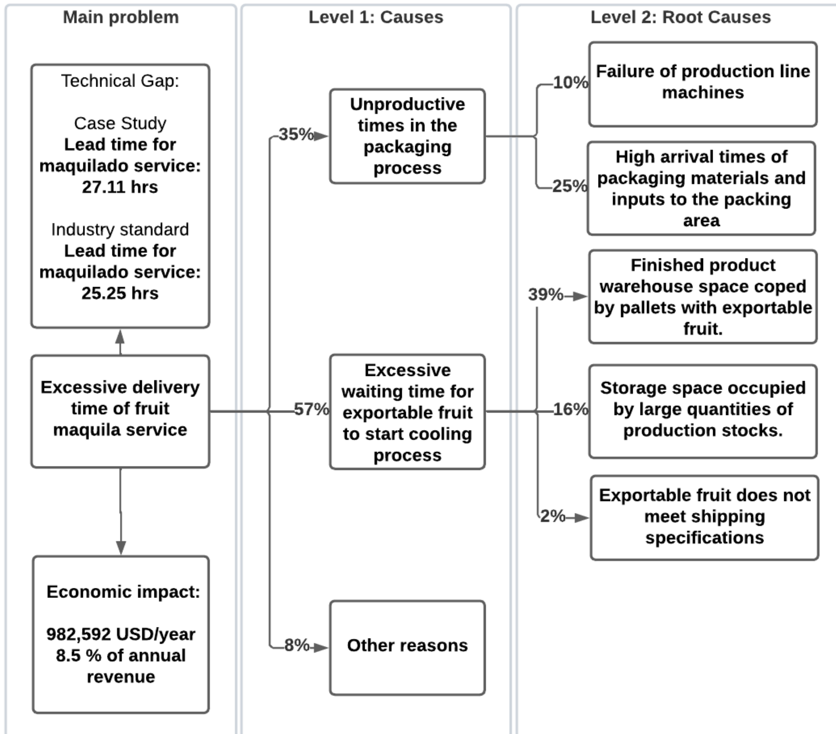

Figure 2. Problem Tree

4.3 Implementation of the model in the case study

The detailed solution implementation begins by presenting the current challenges and inefficiencies in the fruit maquiladora's processes, then systematically applying Lean tools to enhance operational efficiency. The aim was to optimize processes, reduce waste, and achieve better storage management to meet the demands of international markets. A structured summary, including quantitative data to justify each stage of implementation in the case study, is presented below.

Analysis of the Current Situation Using VSM

The first stage involved conducting a detailed Value Stream Mapping (VSM) analysis to quantify the inefficiencies within the production and storage processes. The analysis showed that the lead time between storage and dispatch was approximately 950 minutes, with value-added activities accounting for 677 minutes, totaling 1,627 minutes. This initial mapping highlighted that the storage and dispatch processes were heavily dependent on client decisions, as the timing for dispatching fruit was determined by the customer. Consequently, these factors were not within the company's control and were excluded from the scope of the solution. In Figure 3, the current value stream map (VSM) of the production process in the fruit maquiladora is shown.

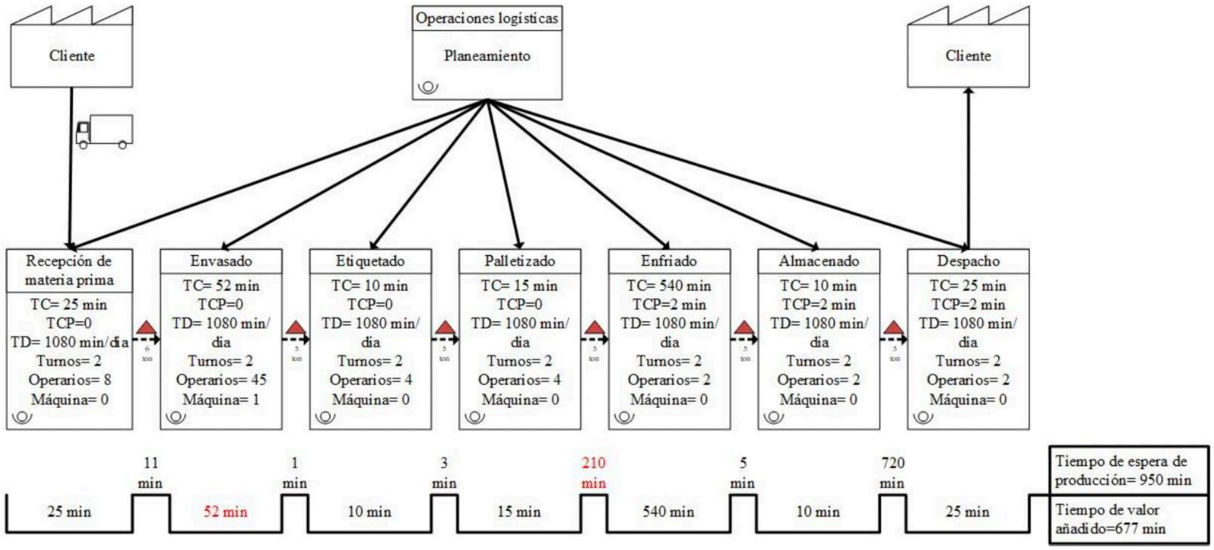

Figure 3. Current VSM of the production process in the fruit maquiladora

Waste Reduction Through Process Optimization

Redesigning the Warehouse Layout

The storage layout was initially disorganized, leading to inefficient use of space and delays in material flow. The proposed redesign increased storage capacity to accommodate up to 1,235 pallets, with 182 additional spaces created specifically in Camera 3 for continuous and discontinuous flow management. This adjustment improved pallet visibility and access, leading to more efficient operations and quicker turnaround times. Additionally, separating paid storage spaces from those still in process enhanced operational control.

In Figure 4, the layout of the storage and dispatch areas in the facility is shown. It highlights the distribution of cooling tunnels for pallets, pre-chambers, and storage chambers (No. 3, 4, 5, and 6). The figure also indicates the flow paths for both complete pallets and remaining stock within the facility.

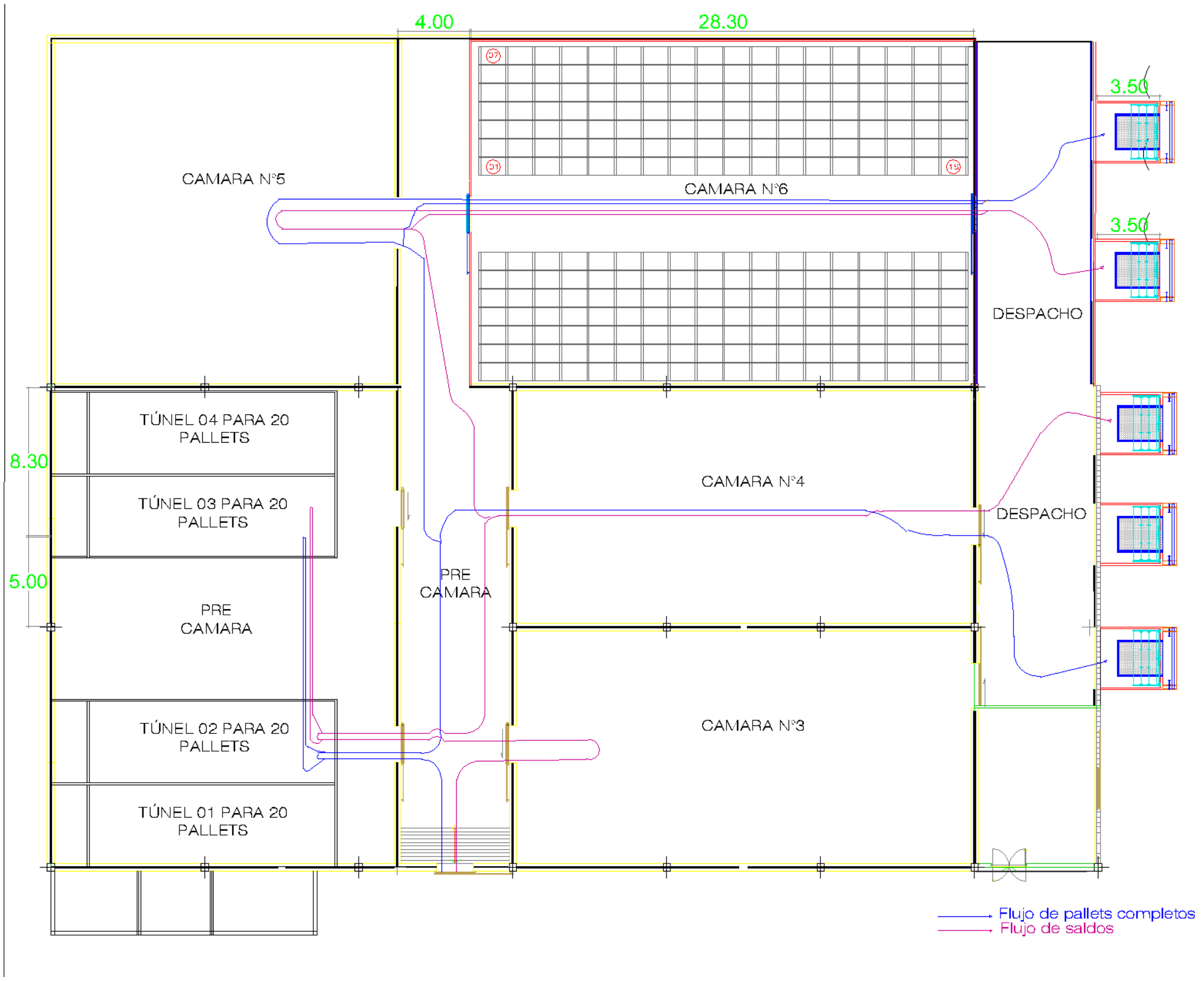

Figure 4. Proposal for redesigning the layout for the storage of finished products

Implementation of the CONWIP System

The solution introduced a Constant Work-In-Progress (CONWIP) system to manage and regulate inventory flow within the warehouse. The system utilized visual management tools, including six large panels and 1,235 CONWIP cards, each corresponding to a storage space. The visual panels, placed ergonomically at 1.56 meters above ground, displayed real-time storage status, with color-coded indicators for different types of flow. The implementation reduced excess inventory by regulating work-in-progress (WIP) and limiting it to designated areas, significantly improving the tracking and planning capabilities of storage capacity.

The training program was an integral part of the CONWIP implementation, involving personnel such as the process planner, warehouse coordinator, and traceability coordinator. Training ensured the correct use of visual panels and CONWIP cards, complying with ergonomic standards and ensuring seamless integration into the daily workflow.

Figure 5 shows the proposed CONWIP system, illustrating the interaction between the planning area and the finished product warehouse. It details the allocation of storage chambers for continuous and discontinuous flow, with color-coded indicators (red, green, and white) representing occupied, reserved, and free pallet spaces. The system facilitates efficient management and traceability of inventory through the process planner and traceability coordinator.

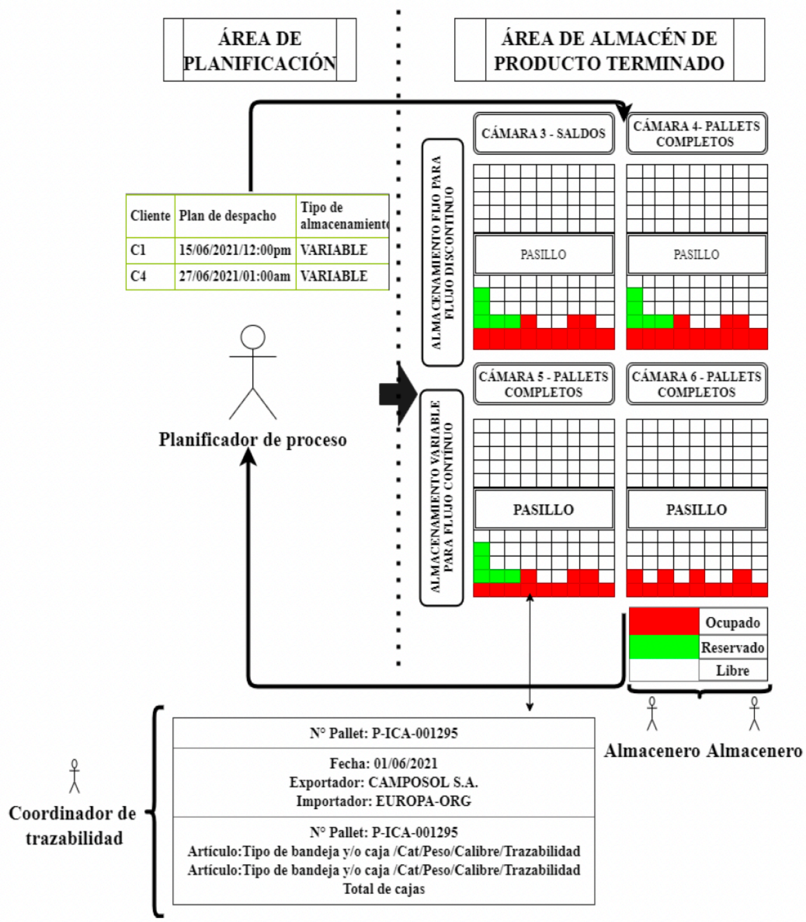

Figure 5. Proposed CONWIP System

In Figure 6, the CONWIP card system is displayed, showing the workflow for managing pallet spaces in the warehouse. It includes user roles such as the warehouse manager, process planner, and traceability coordinator. The card indicates the status of each space (free, reserved, or occupied), ensuring efficient and organized inventory management.

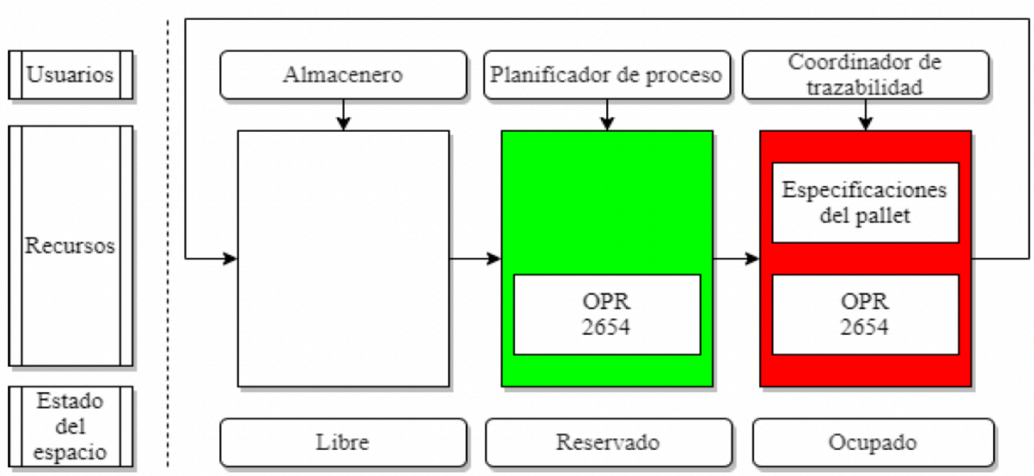

Figure 6. CONWIP Card

Enhancements in the Storage Area

Redistributing the Supply Warehouse

The supply warehouse initially lacked an organized structure, resulting in extended material retrieval times. The redistribution plans reorganized material locations based on analysis of usage frequency, reducing retrieval times by 23% and increasing overall storage efficiency by 12%. This improvement allowed for better stock management and reduced downtime, contributing to a more streamlined operation.

In Figure 7, the proposed layout for supply storage is shown, illustrating the organization of areas dedicated to various materials, including cartons, catchers, labels, and chemical supplies. The layout optimizes space by strategically placing items for efficient access and workflow, enhancing storage management and operational efficiency within the warehouse environment.

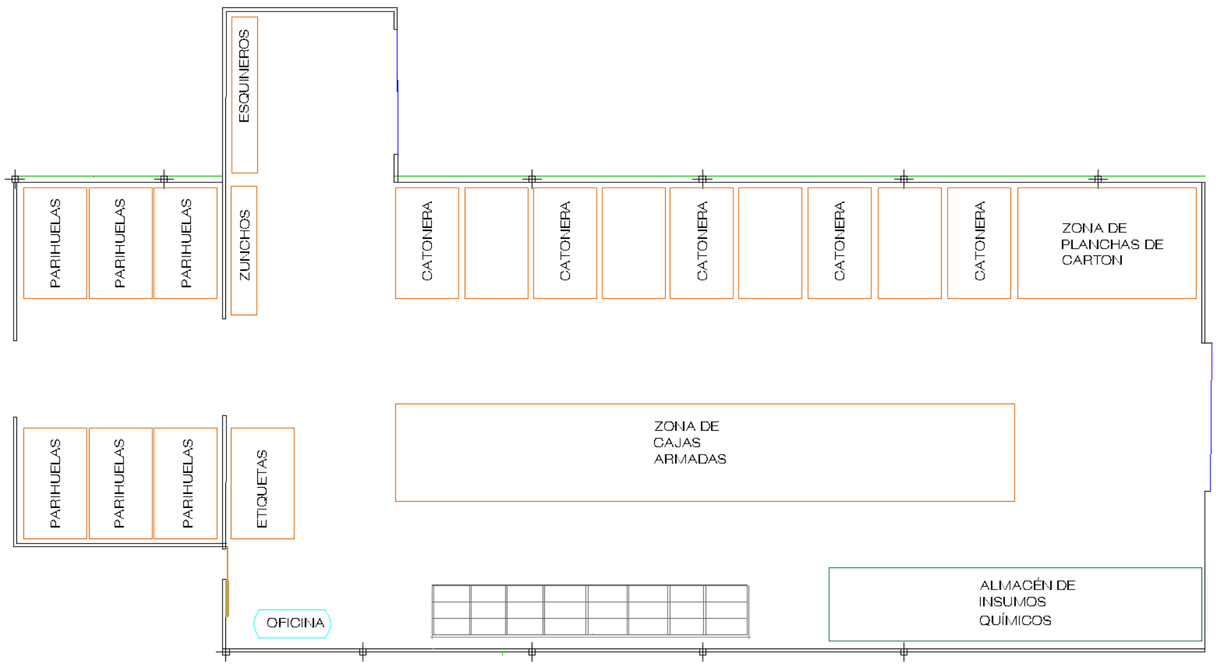

Figure 7. Proposed layout for supply storage

Application of the 5S Methodology

To further enhance the storage area's organization, the 5S methodology was systematically implemented:

- **Seiri** involved eliminating unnecessary items, reducing clutter and improving available space by 40%.
- **Seiton** focused on arranging tools and materials in a logical sequence, reducing retrieval times by 15%.
- **Seiso** maintained cleanliness standards, contributing to a 12% improvement in space utilization and minimizing cross-contamination risks.
- **Seiketsu** standardized these practices, ensuring consistency and stability in operations.
- **Shitsuke** promoted a culture of continuous improvement, increasing efficiency by an additional 10%.

In Figure 8, the implementation of the 5S methodology is shown, detailing each step: classifying, organizing, cleaning, standardizing, and disciplining. The figure illustrates processes for managing boxes, pallets, and labels, highlighting actions like eliminating defective items, standardizing procedures for material handling, and training staff to maintain organization and efficiency in the storage area.

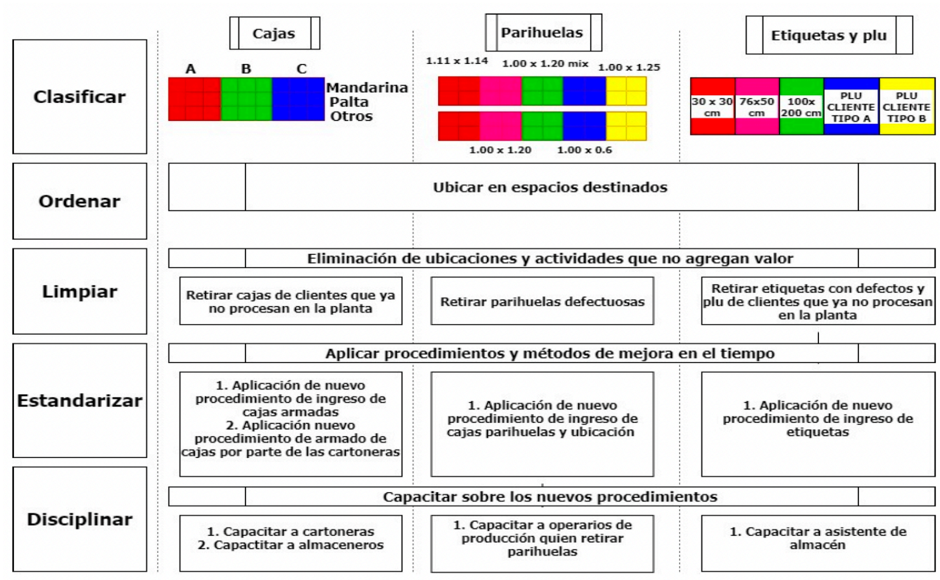

Figure 8. Implementation of the 5S methodology

Improving Flow Efficiency Through Redesign

Layout Modifications for Product Flow Optimization

The redesign of the finished product warehouse aimed at optimizing the flow of materials and improving storage capacity utilization. The new layout allowed for up to 1,235 storage slots, with specified sections for various fruit types and flow states. For instance, Camera 3 was specifically modified to handle both continuous and discontinuous flows, which required adjustments to the rack design and pallet stacking strategies. These changes led to a 15% increase in throughput and a 20% reduction in unnecessary material handling.

Adaptation of Storage Practices

Adjustments in storage practices, such as segregating continuous flow pallets (paid by customers) from in-process ones, helped streamline operations. This reallocation improved accessibility and reduced the time required to locate and process pallets. The space occupied in Camera 3 was utilized more efficiently, enhancing overall operational capacity by 18%.

Comprehensive System Implementation and Training

Adaptation and Resource Allocation

The CONWIP system's implementation included ergonomic adaptations, such as adjusting workstation heights between 70 and 75 cm, and using ergonomic chairs when necessary. Panels and cards were strategically positioned to ensure easy access and usage, complying with ergonomic standards relevant to the average Peruvian male worker.
The maximum number of CONWIP cards was set at 1,235, each representing a storage space. The cards were designed to withstand wear and tear, ensuring durability. Training materials, including specifications for pallet handling based on food safety regulations, were provided to key personnel to maintain compliance and operational consistency.

Implementation Phases and Continuous Monitoring

Initial Adaptation Phase

The initial adaptation phase focused on modifying the work environment to accommodate the new system. This included setting up the process planner's desk near visual panels for efficient oversight. The adaptation ensured that personnel could interact with the system easily, enhancing productivity. The space for the panels and workstation was designed based on anthropometric data, ensuring that all users could operate the system comfortably and efficiently.

Training and Information Dissemination

The training phase involved three key personnel: the process planner, warehouse coordinator, and traceability coordinator. The training included detailed sessions on the new system's functionality, supported by informative sheets explaining processes like pallet flow and storage policies. Proper dissemination of these materials ensured that all staff understood the new procedures and could implement them effectively.

Future VSM

After implementing all the previously described lean logistics methodologies, it was observed, through Figure 4 showing the future VSM, how the existing issues in the company were reduced, particularly the waiting time for fruit entering the cooling area and the unproductive time generated in the packaging area (Figure 9).

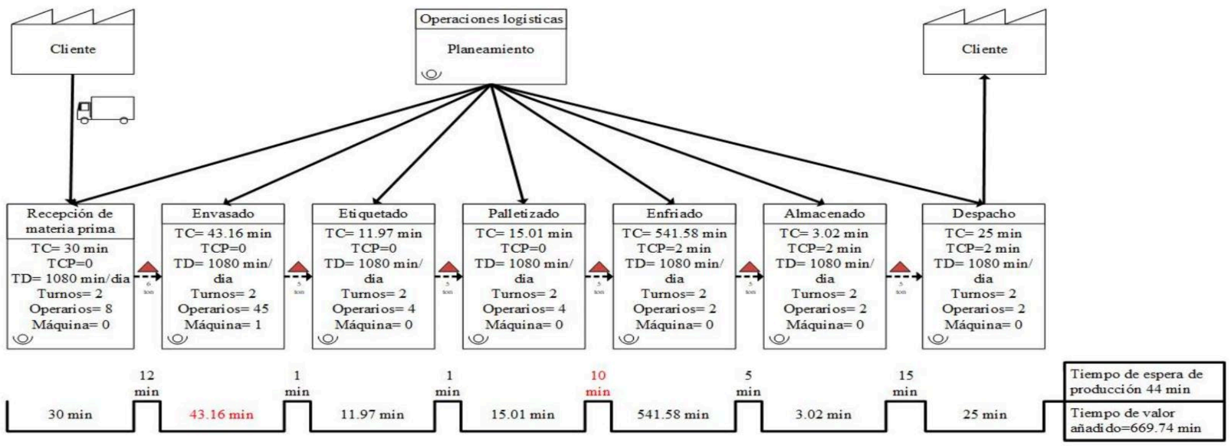

Figure 9. Future VSM of the production process in the fruit maquiladora

The detailed implementation of lean methodologies within the maquiladora's processes demonstrated the effectiveness of structured, data-driven approaches in enhancing operational efficiency. The quantitative gains observed in storage capacity, process times, and overall system organization validate the importance of integrating lean tools such as VSM, CONWIP, and 5S in optimizing production environments. The improvements also highlight the potential for these methods to adapt dynamically to client requirements, ensuring competitiveness in international markets.

5. Results

Table 1 presented the results of the validation of the operations management model based on Lean Logistics tools for an SME providing maquila services for export fruit. A significant reduction was observed in service lead time (-55.57%), supply time (-72.00%), and waiting time for the cooling process (-95.24%), significantly enhancing operational efficiency. Additionally, a 41.04% decrease in the capacity used to store production balances indicated an optimization in inventory management and available space utilization.

Table 1. Results of validation of the proposed model

Indicator	Unit	As-Is	To-Be	Results	Variation (%)
Service Lead time	minute	1626.6	750	722.67	-55.57%
Supply time	minute	15	7	4.2	-72.00%
Capacity used to store production balances	%	25%	15%	15%	-41.04%
Waiting time to start cooling process (bottleneck)	minute	210	105	10	-95.24%

6. Conclusions

The main findings of the study indicate that implementing Lean Logistics tools, specifically VSM, CONWIP, and 5S, significantly optimized the operational processes within the fruit maquiladora SME. The application of these tools resulted in a 55.57% reduction in service lead time and a 95.24% decrease in waiting time for the cooling process. Furthermore, the reorganization and redesign of the storage areas enhanced storage capacity by 41.04%, contributing to better inventory management and space utilization. The integration of these lean methodologies improved not only the flow of materials but also the efficiency of each operational stage, validating the model's effectiveness.

The importance of this research lies in its practical application to a crucial sector of the Peruvian economy. The agro-export industry, particularly SMEs involved in fruit maquiladora services, is fundamental for local and national development. By enhancing efficiency, these enterprises can remain competitive in international markets, meet the increasing demands for high-quality products, and ultimately contribute to job creation and economic growth. The study's findings emphasize the relevance of adopting continuous improvement models that are adaptable to the operational needs of such businesses, aligning them with global industry standards.

The contributions of this research extend beyond the immediate outcomes of reduced lead times and increased efficiency. This study offers a comprehensive approach that integrates various Lean tools, showcasing a scalable model for similar SMEs facing process inefficiencies in the agro-export sector. The adaptability of this model suggests that it could be applied to other areas within the supply chain, promoting further optimization across different stages of production and distribution. Additionally, the methodology contributes to the broader field of industrial engineering by providing empirical evidence of Lean's effectiveness in the agro-industrial context.

In conclusion, the findings support the value of Lean methodologies in enhancing operational efficiency and competitiveness for SMEs in the agro-export sector. However, further investigation is suggested to expand the application of this model to different types of products and processes. Future studies could explore integrating technology-based solutions, such as automation and advanced data analytics, to further enhance process optimization. Additionally, evaluating the long-term sustainability of such improvements would provide insights into maintaining efficiency gains over time. These suggestions could build upon the existing framework and offer innovative directions for expanding the use of Lean Logistics in various industries.

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