Improvement proposal to increase the service level in a pharmaceutical company using Lean Warehousing and CNN

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Abstract*– Lean Warehousing is a philosophy oriented toward reducing waste and operational errors in warehouse processes; however, its integration with Convolutional Neural Networks (CNN) to strengthen verification activities in pharmaceutical logistics operations remains under-researched. The objective of this research was to increase the Service Level of a Peruvian pharmaceutical distribution company. To achieve this, an applied improvement proposal was developed and simulated using Arena Software (version 16.2), integrating packaging policies, Standar Work and Poka Yoke as Lean Warehousing tools, accompanied by a CNN-based model for the automated detection of products and quantities to enhance warehouse operational performance. The main findings demonstrated an increase in the service level from 89.9% to 95.45%, exceeding the 95% industry benchmark and closing the identified technical gap. The research contribution is focused on the integration of continuous improvement tools and Artificial Intelligence through a replicable model that optimizes order preparation and verification in logistical operations.

Keywords*—Pharmaceutical sector; Standar Work; Poka Yoke; quality assurance; CNN.

I. Introduction

The role that the pharmaceutical sector plays in the Peruvian economy is crucial. A significant number of the companies of this sector are classified as Small and Medium-Sized Enterprises (SMEs) due to their organizational size, representing 99.2% of the total registered companies [1], while the sales of pharmaceutical products represent 15.7% of domestic internal sales [2]. However, commercial SMEs which constitute approximately 44.2% of the total SMEs [3] face severe operational challenges linked to warehouse inefficiencies and human errors. Process improvement studios identified the most relevant problems such as stockouts, and inadequate inventory management caused by inefficient supply chain management, lack of process standardization, and poor warehouse organization [4].

Understanding the main issues identified in the pharmaceutical distribution company under investigation is crucial. Deficiencies in operational processes were identified, focused on the undercompliance of the exact composition of the orders, delivery of products with shorter expiration dates than those agreed upon, and orders arriving at their destination with damaged packaging. These incidents are intended to be resolved through the implementation of a strategy combining Lean Warehousing tools and Artificial Intelligence. The objective is to improve the precision of the content of orders, reduce costs associated with returns, and optimize the logistical process. Against this backdrop, the following question arises: How does the integration of Lean Warehousing tools and a model based on Convolutional Neural Networks (CNN) allow the increase in the service level and a reduction in human errors in a pharmaceutical distribution company?

The Standard Work tool represents a fundamental pillar in this research, being one of the more efficient ways to reduce variability in the processes of picking, checking, and packing [5]. Since the current operation exhibits unstable cycle times and non-uniform methods, the standardization is focused on error prevention and the correct execution of each process. Academics highlight that standardized work ensures quality by defining the optimal way to execute repetitive tasks, eliminating non-value-added activities, providing a solid foundation for operator training [6].

Within this approach, packaging policies emerge as a component to include in Standard Work. In the pharmaceutical sector, packaging transcends its logistical role during the packaging stage, acting as the first line of defense of the pharmaceutical product. Research indicates that the technical design and selection of protective materials ensure medication integrity against physical and environmental risks during transport [7]. In the company, the absence of packaging criteria is one of the roots of the returns attributed to deficient quality, which directly impacts on the company's profitability.

Furthermore, the Poka Yoke tool, that belongs to the Lean approach, is characterized by its capacity to prevent errors at the source [8]. The lack of visual and preventive control mechanisms in the warehouse manifests as an increase in drug returns due to short expiration dates. Experts mention that by implementing customized labels and visual signals, companies reduce the incidence of selection errors drastically, achieving the immediate identification of deviations prior to order consolidation [9].

Finally, as indicated by recent research, integration of Convolutional Neural Networks (CNN) makes it possible to overcome the precision and sensitivity (recall) limits of traditional manual verification methods [10]. While human eyes are susceptible to visual similarities of pharmaceutical packaging, models based on YOLOv5 act as a technological

Poka Yoke to identify and count products with high precision. Literature suggests that Lean Warehousing philosophy is oriented towards waste elimination and the standardization of operational tasks. [11] For that reason, the synergy between Lean tools and Neural Networks is oriented to optimize the service level, transforming manual warehouses into high-fidelity distribution centers.

II. DIAGNOSIS

The current case study was developed in a pharmaceutical distribution company, where adherence to quality standards and delivery lead times are critical factors in ensuring customer satisfaction. The diagnosis revealed three principal issues that affect operation performance: returns associated with order quality, incomplete orders, and deliveries exceeding established timeframes. These situations cause complaints, operational reprocesses, and additional costs stemming from product returns, redistribution, and reprogramed deliveries, ultimately exerting a negative impact on the service level provided by the organization.

With the objective of evaluating the company's performance, the service level (SL) indicator was calculated considering three dimensions: complete orders (In Full), on-time deliveries (On Time), and order quality (Quality). Unlike other studies, this indicator incorporated the quality dimension due to the specific requirements of the pharmaceutical sector concerning product integrity and expiration dates. As a result, a Service level of 89.90% was obtained from the analysis of one year of historical data from the company, below the distribution sector standard established between 95% and 98%, evidencing a technical gap of 5.10% [12]. Furthermore, the associated economic impact amounts to USD 171 094, equivalent to 3.63% of the gross profit.

Data analysis enabled the identification of primary incidents affecting the service level. The returns linked to quality represent the biggest proportion, accounting for 49.19% of the total, mainly originated by damaged packaging and products close to their expiration dates. In second place, there are incomplete orders, representing 42.42%, caused by the omission of products or incorrect quantities during order preparation. Furthermore, deliveries made outside their established timeframe correspond to 8.39%. Because of that, due to its low incidence, this issue was not considered within the scope of the current improvement proposal.

Based on the identified root causes, improvement tools were selected to address each specific issue. Diverse authors point out that applying Standard Work and Poka Yoke contributes to standardizing warehouse operations, reducing errors, and improving service level [13] [14] [15]. Furthermore, the relevance of establishing pharmaceutical packaging criteria is emphasized to ensure product integrity during distribution [16]. Additionally, computer vision-based models allow the automatization of product identification with high precision [17] [18]. Figure 1 illustrates the strategic alignment between the identified causes and the tools selected for the improvement proposal.

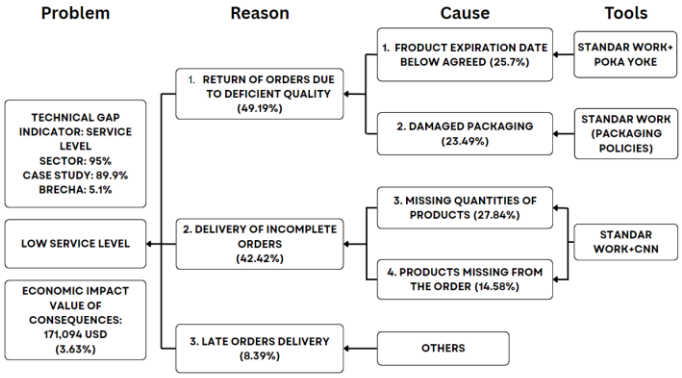


Fig. 1 Link between the identified root causes and the proposed improvement tools

III. METHODOLOGY

The current investigation corresponds to an applied improvement case, simulated using Arena Software (Version 16.2). Three methodological stages were considered for the design of the solution proposal: analysis of the current situation of proposal development, and validation. The first stage was oriented towards the company's diagnosis. Later, the improvement model was developed, focusing on optimizing warehouse operations. Finally, the results obtained were evaluated through scenario comparison.

The initial state analysis was intended to identify the main root causes affecting the service level. To achieve this, recollection and analysis regarding the order fulfillment process were executed. Based on these findings, Key Performance Indicators (KPI) were evaluated, and a problem tree was developed. Moreover, a literature review was carried out to identify engineering tools previously implemented in similar cases.

Based on the results obtained during the diagnosis stage, an improvement model was developed comprising two complementary components. The first component was oriented to product integrity assurance through packaging policies. The second component was focused on warehouse operation optimization through the integration of Standard Work, Poka Yoke, and a model based on Convolutional Neural Networks (CNN). Figure 2 contains the conceptual model, detailing the components integrating the solution proposal in the current study case.

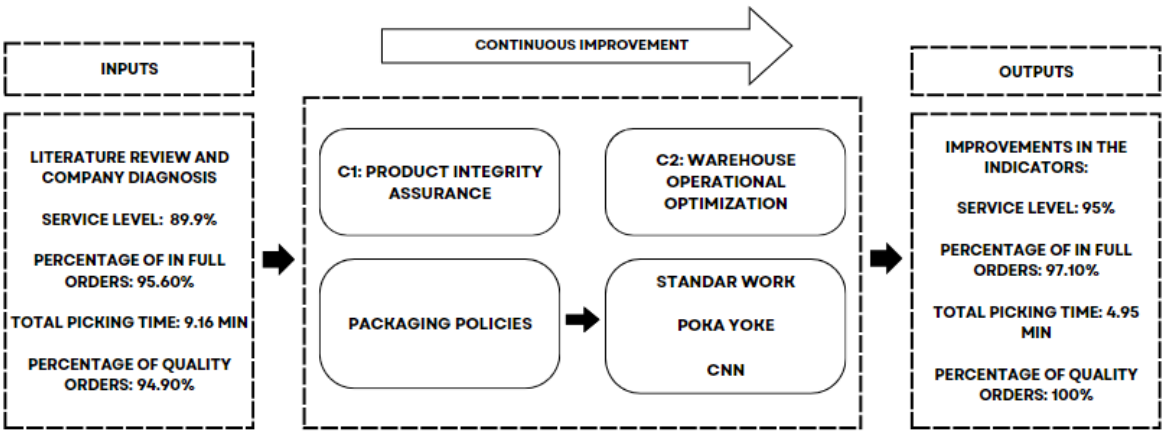


Fig. 2 Conceptual model

A. Component 1: Product integrity assurance

The first component consisted of the design and implementation of policies aimed at standardizing the use of secondary materials during the order packing process, to ensure the adequate conservation and presentation of the products. To this end, materials used during the packing process were evaluated and packaging alternatives were selected, based on technical criteria, considering the physical characteristics of the products, their protection requirements, and their storage and transport conditions. Subsequently, the packaging policy was elaborated and operators in charge of its application were trained.

B. Component 2: Warehouse operation optimization

As the first tool of the second component, Standard Work was implemented to define the optimal sequence of picking, checking and packing, with the purpose of reducing the variability and ensuring the correct execution of operations. For its development, critical activities associated with incomplete orders and deficient quality were identified, establishing a standardized work sequence.

Additionally, Key Performance Indicators (KPI) were determined, and cycle times of each process were registered to analyze their behavior and identify improvement opportunities. Subsequently, the Takt Time was calculated, and the Eliminate, Combine, Rearrange, simplify (ECRS) matrix was applied to analyze and redesign non-value-added activities. Based on this, the standardized procedure was documented through Process Analysis Diagrams (DAP) and work formats.

The second tool of this component was visual Poka Yoke, implemented to prevent errors during the picking process. During its development, the main incidents of the process were identified, including the selection of products with similar packaging and products inside the consolidated order with expiration dates inconsistent with customer requirements Based on this, customized visual labels were designed for each product, enabling rapid and standardized identification based on information from the picking proformas. In this way, the tool was integrated into Standard Work to enhance overall process efficiency.

To complement the second component of the conceptual model, a tool based on Convolutional Neural Networks (CNN) was implemented to automate the identification of pharmaceutical products during the checking process using a detection model based on YOLOv5 architecture. For the model's development, pharmaceutical products that comprise the dataset were initially selected, considering differentiable variables such as packaging size, color, shape, and design. The selected pharmaceutical products were Vaporub, Mensille, Dolol, and Repriman, together with an empty category to represent orders that did not contain all the selected products.

Furthermore, a photographic environment was designed to obtain a set of images representative of warehouse checking operations. A total of 150 images were obtained, including different combinations and quantities of the selected products, as well as variations in their positions and orientations, to represent conditions similar to those encountered during the checking process. These variations were considered to increase the diversity of the dataset and support the model's ability to detect products under different checking conditions.

Later, the images were reviewed, labeled using bounding boxes, and categorized into training, validation, and test subsets. Finally, the YOLOv5 model was configured and trained, involving hyperparameter tuning and performance evaluation based on precision, recall, and mean Average Precision (mAP). This process aimed to verify the model's capacity to accurately detect products and their quantities within each order.

The technical feasibility of this system is grounded in the use of accessible and commercial hardware, avoiding high implementation barrier costs. The acquisition pipeline comprises an Intel RealSense D435 camera for image capture, a processing computer with a dedicated GPU for model training and real-time inference, and a controlled photographic station. To ensure high-fidelity feature extraction by the YOLOv5 architecture, the environment was designed with uniform LED

lighting to eliminate reflections on the packaging, alongside a contrasting black background. The setup was designed to favor the quality and consistency of the captured images and facilitate the extraction of relevant visual features by the model.

As part of the process, warehouse personnel were trained in the application of the developed tools, and pilot tests were conducted. The first pilot test was conducted inside the company to validate Packaging Policies, Standard Work, and Poka Yoke under real operational conditions. The second was performed at a laboratory level to evaluate the performance of the CNN-based model. Figure 3 presents photographs of the implementation activities carried out during both pilot tests.

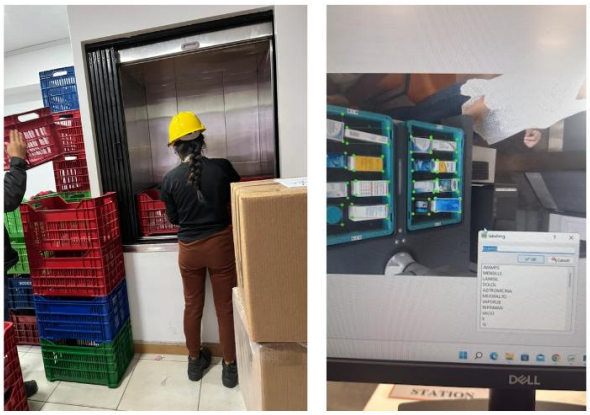


Fig. 3 Implementation of the proposed improvement model

The final stage involved the validation of the proposal through a comparison between the initial and the proposed scenarios. To this end, performance indicators obtained from the registered times of the picking, checking, and packing operations were analyzed to evaluate the implementation's impact on warehouse operations and the overall service level.

IV. Results

To validate the effectiveness of the proposal, a simulation process was carried out using Arena Software (Version 16.2). Initially, the main indicators that evidence the improvements resulting from the improvement proposal were determined. Subsequently, the sequence and the entities of the process were modeled, cycle times were collected, and the corresponding statistical distributions were assigned to the activity modules. Furthermore, scenario variables and specific attributes of the orders were configured. Finally, ten replications were performed to ensure statistical reliability and a 95% confidence level. This procedure was developed for both the As-Is and To-Be scenarios to compare results based on the defined indicators. Figure 4 shows the model developed using Arena Software.

The results from the Arena simulator analysis, considering the critical variables of the pharmaceutical logistical process, are presented in Table I. This comparison allows the evaluation of the effectiveness that the integration of Lean tools and the Convolutional Neural Network in the closure of the technical gap concerning the Service Level.

TABLE I
COMPARATIVE TABLE OF INDICATORS (AS IS VS TO BE)

Variable	Current Process (As Is)	Proposal Process (To Be)
Service Level	88.83 %	95.45 %
Complete Orders (In Full)	95.60 %	97.12 %
Adequate quality orders (Quality)	94.90 %	98.50 %
Picking time	9.16 min	9.09 min
Total cycle time per order	26.00 min	25.27 min
Correct orders	241 orders	255 orders

A detailed comparison is observed between the initial and the final situation regarding the indicators considered. The analysis reflects significant differences between the scenarios. The service level of 88.83% obtained for the current scenario in the simulation is close to the 89.90% obtained from one year of historical company data, with the difference attributed to the representation of the real process through the simulation model.

The 95% confidence intervals for the service level, corresponding to the current scenario [82.427, 93.765] and the proposed scenario [92.843, 97.431], do not overlap, indicating a statistically significant improvement. In the proposed process, an increase in the service level is observed, reaching the value of 95.45%, thereby exceeding the sector benchmark established at 95% and closing the identified technical gap. This improvement is mainly caused by the standardization of the warehouse's processes and the reduction in operational errors.

The enhancement in order quality (from 94.90% to 98.50%) is directly attributed to the implementation of Packaging Policies and Visual Poka Yoke checkpoints. These tools mitigated physical damage during transit, while color-coded expiration labels along with ERP system parameterization prevented the dispatch of short-dated pharmaceutical products and ensured compliance with agreed-upon expiration dates.

Regarding order completeness, the increase in the indicator (from 95.60% to 97.12%) is the result of the joint effect of Standard Work throughout the process and the YOLOv5-based CNN as a complementary technological tool. Standard Work implementation mitigated picking sequence errors, while in the manual process operators occasionally confused products with similar packaging. The CNN system provided automated verification during checking, identifying and counting the products before the packaging and dispatch stages, achieving a precision of 98.40%, a recall of 83.10%, and an mAP@0.5 of 82.40% which resulted in an F1-Score of 90.10%. The final order completeness indicator is the result of a weighted integration of the field pilot result (98.88%) and the CNN F1-Score (90.10%).

The reduction in the time of the process from 26 to 25.27 minutes reflects the effectiveness of the Standard Work and the packaging policies in the optimization of operational flow. Although the difference may appear minimal, the reduction in variability was significant. This was achieved through the

standardization of the activities, the elimination of bottlenecks and the alignment of the order output interval with the operation's takt time.

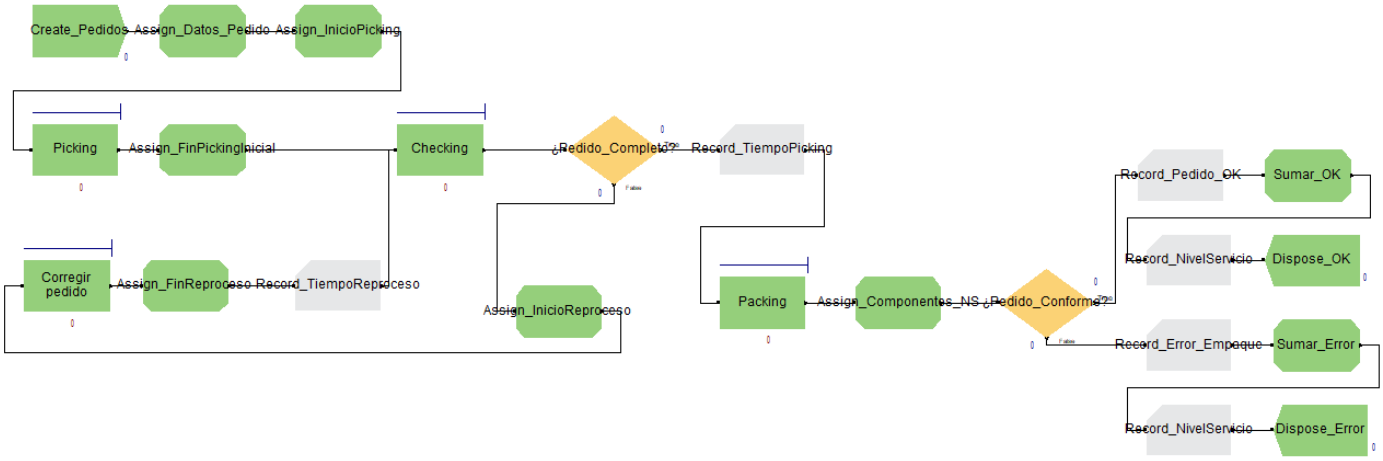


Fig. 4 Simulation model (Arena 16.2)

V. Discussion

The integration of Standard Work and the packaging policies enabled the standardization of order fulfillment operations through the definition of procedures for picking, checking and packing activities, complemented by guidelines for the use of secondary materials. This approach converges with studies that implement Standard Work to reduce the variability in the processes [19] [20]. Similarly, coincides with research that evidence that an adequate packaging design contributes to reducing the damage during distribution. [16] [7]. However, unlike these studies, the current proposal integrates both tools within a single improvement framework, enabling the simultaneous standardization of operations and the assurance of product integrity from preparation to dispatch.

Poka Yoke and Convolutional Neural Network (CNN) model-based implementation facilitated the control of picking and checking processes through error verification and prevention mechanisms. These results are consistent with studies demonstrating that Poka Yoke reduces incidents during picking operations and that computer vision models enhance the automated identification of pharmaceutical products [8] [10]. Nevertheless, the current research diverges from proposals based on traditional Lean tools by incorporating the CNN model as a complementary technological support to strengthen control during order preparation [21].

The current proposed model jointly addresses the main root causes affecting order preparation, by integrating Lean Warehousing tools complemented with a model based on Convolutional Neural Networks (CNN). This integral approach coincides with research that proposes the combination of diverse tools to enhance logistical performance and highlight the need to implement integral models for the pharmaceutical sector [9] [22]. However, the current research diverges from these proposals by complementing Lean Warehousing with a technological solution based on Artificial Intelligence to reinforce order control through automated verification.

The service level reached after the proposal implementation was 95.45%, a result that falls within the sector's reference range established between 95% and 98% [12]. This result coincides with studies that evidenced logistical performance improvements through warehouse processes optimization [13] [14]. Likewise, the reduction in waste and returns has also been linked to increases in the service level [23]. Jointly, these findings evidence that enhancing the service level depends on the optimization of order preparation processes and the control of operational errors that directly affect order fulfillment.

VI. Conclusions

The implementation of this research successfully addressed the identified technical gap of 5.10% in the service level of the pharmaceutical distribution company. The initial analysis revealed a service level of 89.9%, which was below the sector's benchmark of 95%. Moreover, the proposal mitigated economic impact due to returns and operational inefficiencies. Through the proposal execution, the Service Level increased to 95.45%, effectively exceeding the standard and minimizing the financial losses associated with low performance.

To achieve these results, a synergy of specific engineering tools was deployed, focusing on the root causes of errors in picking, checking, and packing. The implementation of packaging policies ensured product integrity against physical risks, significantly increasing the Quality indicator from 94.9% to 98.5%. Furthermore, Standar Work was established to determine the adequate sequence and execution of activities and resulting in a reduction of cycle time variability; while Poka

Yoke prevented errors at the source. These traditional Lean Warehousing tools were complemented by a Convolutional Neural Network (CNN) model based on YOLOv5, which automated product identification and counted with a precision of 98.4%, enabling the In Full indicator to rise from 95.6% to 97.12%.

The proposed integrated model represents a holistic framework that combines Lean Warehousing and continuous improvement approach with Artificial Intelligence, transforming manual operations into high-fidelity processes. The effectiveness of this model was verified through a hybrid validation approach, utilizing pilot tests and discrete-event simulation in Arena Software (Version 16.2) with a 95% confidence level. This methodology proved to be replicable for similar organizations and transferable to other logistical environments facing challenges in order fulfillment and product integrity.

Regarding recommendations, it is suggested that future research employ methodologies that integrate Lean tools and Artificial Intelligence (AI) technologies within logistical processes. In this sense, it would be vital to evaluate the application of Convolutional Neural Networks (CNN) under real operational conditions and over more prolonged periods to analyze their behavior. Finally, further investigations should explore the incorporation of emerging AI tools as a complement to traditional Lean framework to drive continuous improvement and enhance logistical performance.

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