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Original Article

Integrating Lean Warehousing and DDMRP to Improve Inventory Flow Efficiency in a Peruvian Commercial SME Warehouse

Rubi Geraldine Damian-Rojas[1], Maribel Lisset Pascual-Mendoza[2], Jose Antonio Taquía-Gutierrez[3], Juan Carlos Quiroz-Flores[4]

[1,2,3,4]*Carrera de Ingeniería Industrial, Universidad de Lima, Perú.*

[4]*Corresponding Author : jcquiroz@ulima.edu.pe*

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Abstract - *Like many other industries, the conveyor lift belt distribution market encounters many issues related to inventory, including issues such as inventory control, restocking, and warehouse organization. Most of the pertinent literature, including the ones on Lean Warehousing and DDMRP, focuses on them separately. Quite a number of scholars have tried to cross-integrate these two approaches, though in the context of Lean Warehousing and DDMRP pertaining to commercial Small and Medium Enterprises. This research gap on the integration of DDMRP and Lean Warehousing has been addressed by proposing a 5S DDMRP model whereby DDMRP streamlines inventory conditioning and reliability in addition to the optimization of inventory. The model developed from this research attempts to bridge the gap in the model's effectiveness in meeting demand and usefulness in aligning warehouse operations with demand-driven logic. Evidence from analyses of DDMRP implementation shows stockouts declined by 11.62%, inventory accuracy increased by 61.20%, and an overall 32% cost reduction. This research sheds light on the inventory flow of DDMRP in terms of reliability and efficiency. The 5S DDMRP model aims to assist Small and Medium Enterprises by providing a practical solution that does not involve overly sophisticated warehouse automation. On the other hand, practitioners and analysts are encouraged to focus on expanding the integration of automation, which has been proven to enhance investment adaptability alongside the investment needed to enhance it. This particular attribute will enhance the system's responsiveness and multi-capability to variable demand integration in real time.*

Keywords - *5S, DDMRP, Conveyor belts, Commercial sector, Stockout.*

1. Introduction

According to the experts, the commercial sector of the country has always been one of the more dynamic and significant pillars of the national economy, and the report produced by INEI in October 2024 establishes that this commercial sector has a yearly growth of around 3.82%, which is comparable to that of the previous time span. The major players of this sector and economy are the automotive and retail businesses, which, as a whole, aid in any economy by generating more employment opportunities. [1] The global conveyor belt market is one of these industries. It is currently valued at 5.7 billion US dollars as of 2024 and is expected to reach 8.2 billion by 2034, making its significant growth capitalized between the compound annual growth rate of 4.3 % between the years 2025 and 2034. The value is around 1.04 billion dollars in revenue, and North America is one of the world's leading economies, which is the reason that the North American economy is pegged at around 34% of the leaders in terms of revenue. This is due to the increase in conveyor technologies and innovations such as automotive, manufacturing, materials, and design. Mining, steel, cement, and food and beverages emphasized China's dominant position within the regional market, which is close to 50% of the global production capability. Infrastructure investment and expanding packaged food consumption will help sustain the expected demand growth. Germany, as the most advanced conveyor belt market in the region, alongside the industrial investment growth, holds a key position in the world's supply chain and manufacturing sectors, which powers industrial growth. [2] Previously, facultative investments, which provide alternative competitive belts, now provide principal substitutive materials, specifically, replaceable plastic and metal belts, which are lightweight and chemically and thermally resistant. Furthermore, the ease of controlling production costs is practically deemed speculative. Fluctuations in the prices of raw materials, such as synthetic rubbers and reinforcing fabrics, coupled with a lack of control in the global production chain, make speculative cost reduction unrealistic. Availability of the aggregate factors, actively planning and integrating delayed shipment within the input factors, and the world economic recession all affect the product's strategic planning, further controlling their availability. [3]

Changes in demand by customer type and sector, combined with a lack of real-time visibility into inventory, have exposed vulnerabilities in the supply chain. One report highlights that, although 67% of Peruvian companies have adopted ERP or e-commerce platforms, there is still a gap in inventory control accuracy and forecasting capabilities. [4] In this context, a commercial SME that sells conveyor belts by the meter has reported a stockout rate of 22.43%, almost three times higher than the industry standard of 7%. [5] The main problems identified include a disorganized warehouse layout, manual inventory tracking for products sold by length (in meters), and outdated or inconsistent records in the Kardex system.

The objective of this study is to reduce the company's stockout rates by implementing a combined improvement model based on Lean Warehousing and Demand Driven MRP (DDMRP). Currently, the company has an inventory turnover of 1.40 and a warehouse utilization of over 104%, indicating inefficiencies in both inventory control and warehouse management. This research focuses on optimizing the order picking processes for conveyor belts, a product that, after performing an ABC analysis, represents 69% of the company's total sales and plays a key role in its profitability. The identified technical gap of 15.43% in the stockout rate highlights the urgent need for structured inventory planning and better warehouse organization.

Previous studies have demonstrated the effectiveness of Lean tools such as 5S to organize warehouse spaces, improving inventory accuracy by up to 86.48%. [6] For its part, DDMRP, through continuous buffer evaluation, significantly improves system performance compared to periodic evaluation. This improvement is consistently maintained, although its magnitude varies according to the dispatch rule applied during execution, depending on whether a static or dynamic strategy is employed. [7] However, no known research has applied these methodologies in commercial SMEs that manage industrial products sold in variable units such as meters. The particularity of the company under study lies in managing the inventory of conveyor belts by meter rather than by whole units, which poses specific challenges that have not been addressed in the existing literature.

Despite the numerous advancements made in lean techniques in production systems, there is still limited consideration in the context of commercial warehouses, especially in developing countries. Most of the existing literature has focused on the manufacturing context, which has led to the oversimplification of operational challenges in inventory control, stockout minimization, and replenishment in a commercial context. This paucity of integrated models that blend lean and adaptive planning approaches emphasizes a need in the existing literature in terms of improving the efficiency of warehouses through demand-driven systems.

The focus of this research is motivated by the operational inefficiencies that stem from a Peruvian commercial SME warehouse, such as excessive stockout episodes, oversupply of products, and long restock intervals, all of which are detrimental to the service level. This ultimately threatens the reliability of the supply chain. This research aims to propose Lean Warehousing and DDMRP as a hybrid managerial approach to address this problem. This research is a novel contribution, as the lean tool of process optimization is combined with DDMRP's dynamic buffering to formulate a demand-responsive and sustainable inventory management system.

2. Literature Review

This section establishes the theoretical foundation supporting the development of the proposed hybrid Lean–DDMRP model. It reviews previous studies focused on optimizing inventory management and warehouse operations in commercial environments, with particular emphasis on approaches that integrate Lean principles with demand-driven methodologies. The review concludes by identifying the research gap that motivates this study: the limited empirical validation of integrated Lean–DDMRP applications in commercial SMEs managing nonperishable goods measured in metric units.

2.1. Lean Tools for Improving Inventory Management in Commercial Warehouses

Organizations operating in the commercial sector face constant challenges related to inventory control, such as stock breakage, clutter in warehouses, and excessive picking times. In response, Lean tools, especially the Lean Warehousing approach, have been adopted as a key strategy to improve operational efficiency. In this context, the 5S tool has been widely recognized for its positive impact on the organization of storage spaces, as it allows for improved inventory visibility and accuracy in inventory records. [8]

Several studies show that implementing 5S in warehouses reduces search times by up to 71.59%, improves record accuracy by 84.46% and increases picking efficiency by 12%, which translates into a significant increase in service level. [6, 9] Likewise, other research highlights that the initial diagnosis based on 5S audits allows establishing more robust inventory policies, achieving improvements of up to 64% concerning the initial state and increasing productivity through more functional and capacitated spaces.

However, some studies also demonstrate the application of 5S in different sectors, with the case of an interior design company without physical inventory, highlighting its usefulness in maintaining a clean, orderly, and organized work area in addition to reducing unproductive times. [10]

However, a relevant gap is identified between the literature and the case under study: most research focuses on perishable or high turnover inventories, while the analyzed company markets conveyor belts, whose units are stored in rolls, but are sold by meters, generating particular challenges in terms of the accuracy of registration and the organization's physical inventory.

2.2. Demand Variability and the DDMRP Methodology

Demand Driven Material Requirement Planning (DDMRP) has emerged as a modern alternative to address demand variability and reduce stockouts. Its adoption in South America has grown significantly, although recent studies warn about the critical importance of correct system parameterization. Other studies also highlight that an inadequate configuration of buffers and reorder points can generate cost overruns, inventory accumulation, or the inability to react to demand peaks. [11, 12]

And this was evidenced by a loss of up to 15 points in the On-Time Delivery (OTD) indicator as a consequence of errors in buffer configuration. [13] Although the literature agrees on the benefits of this methodology to reduce inventory levels, there is a lack of consensus on its application in environments with highly variable or customized demand. [12, 14]

Other research uses the Grey Wolf Optimizer algorithm (GWO) to adjust inventory levels [15]; however, there are also cases where variables such as customer satisfaction or qualified daily sales are considered to adapt the model to specific contexts. [16, 17]

Consequently, a relevant limitation is identified in the existing literature: most studies focus on products marketed in whole units. However, in companies selling conveyor belts with customized measurements, the variability of demand and the need for specific configurations require a more precise parameterization of DDMRP. This aspect has been scarcely addressed in previous research.

2.3. Joint Application of 5S and DDMRP for Stockout Reduction

Several studies have begun to explore the potential of integrating Lean tools such as 5S with DDMRP to improve inventory management, particularly in environments with high demand uncertainty. The joint implementation of these tools led to improved warehouse planning and reduced stock levels in a meat products company. [8] A model based on VSM and Pareto showed that such integration can reduce stockouts by 13.4% and increase inventory turnover, although the results were obtained in perishable products.

On the other hand, models integrating the DMAIC methodology were developed, achieving improvements of 35% in perfect orders and stockout reductions of up to 18.2%. [18, 19] Similarly, studies in the metal-mechanic sector report increases of 12.58% in OTD and improvements of up to 30.74% in delivery performance thanks to the combined application of 5S, DDMRP, and other Lean tools. [20]

These results reflect the synergistic potential of both methodologies to address complex inventory problems. However, previous studies have focused on industrial sectors with perishable or high-turnover inventories. In contrast, the present study focuses on a commercial enterprise that handles customized products with low replenishment, which represents an additional challenge to adapt both the physical organization of the warehouse and the inventory planning parameters.

3. Methodology

This research followed an applied and descriptive approach with a case study design, carried out in a Peruvian commercial SME dedicated to the distribution of conveyor belts and industrial supplies. The methodological framework aimed to design and validate an improvement model for inventory management through the integration of Lean Warehousing and Demand-Driven Material Requirements Planning (DDMRP).

The study was developed in three sequential stages. First, a literature review was conducted to identify the main models and approaches related to Lean and DDMRP applications in inventory management. From this analysis, a comparative matrix was constructed (Appendix 1) to highlight conceptual and methodological differences among existing studies and define the distinctive features of the proposed model.

Second, a diagnostic assessment was performed in the case study company through document analysis, direct observation, and interviews with key personnel, identifying the main causes of inefficiencies in stock control and warehouse utilization. Finally, an improvement proposal was designed by integrating the 5S methodology for warehouse organization with DDMRP for dynamic, demand-driven replenishment.

This methodological structure ensured both scientific rigor and practical applicability, providing the foundation for validating the hybrid Lean–DDMRP model in the context of commercial SMEs.

3.1. Proposed Model

The model outlined in Figure 1 attempts to partially fill the gap with Lean and inventory planning techniques applicable to the commercial industry. This gap is an area of concern in the published research. While in the Balanced Scorecard system, tools such as 5S and DDMRP have been used in the manufacturing and mass consumption industries, their use on nonperishable industrial items, such as conveyor belts, is a methodological shift.

Those in control of the 5S methodology will yield orderliness, unclutteredness, and speed of working in the warehouse; space resources; and elimination of sterilization of hazardous materials and materials to work in a safe and affordable house, thus improving warehouse organization. This basic warehouse will enhance the locating of stocks, thus improving inventory control.

On the other hand, DDMRP will bring inventory control to the master planning so that he has an easier and more controllable planning structure in which stock levels can be brought into balance. This overcomes the old system of using sense and replace, which typically led to stock overstocking and stockouts. With lesser stock, the system avoids keeping excess inventory of old stock, which is unnecessary and will keep the working capital more readily available.

The model, as discussed, has three main subsections: warehouse planning and layout design, DDMRP inventory control, and DDMRP moderation of Lean workflow tools.

3.2. Model Components

3.2.1. Component 1: Warehouse Conditioning

To begin with, a study of the current situation in the warehouse was performed with the goal of outlining the challenges and their fundamental aspects. After that, the 5S phases of warehousing seiri. s/he: the set of actions where s/he discriminates and classifies necessary items and the unnecessary ones. s/he: the rational arrangement of elements and items to facilitate ready, effective use of the arrangement. s/he: the practice of order, cleanliness, and the elimination of waste, and s/he: the assignment and articulation of exercise-related governing order and cleanliness to undertake procedures, along with seiketsu of the adopted firm disciplines Shitsuke in order to attest their reliability, and s/he: the improvement of these actions in the long term.

This rearrangement initializes the basic principle upon which the rationalization of the use of space in the warehouse can be built. Finally, adherence is confirmed with self-assessments that are part of the cycle.

3.2.2. Component 2: 5S Validation

Starting with an audit to assess the level of implementation of 5S, the Lean tool for the validation phase is about starting with an audit to check the level of implementation of 5S. This phase includes the optimization of the review frequency and warehouse capacity.

The focus remains on keeping the environment tidy, clean, and functional, which helps with the implementation of the DDMRP model that follows. The effectiveness of the Kardex system is also assessed as having great importance in the attainment of productivity in controlling the levels of the inventory. It enables the system to perform stock control in real-time with optimal tracking of the processes, which integrates the operations with the demand-driven planning control principles.

3.2.3. Component 3: DDMRP Development

In this stage, information is gathered and examined, and includes inventory counts, demand patterns, and restock lead times. From this, more detailed target and threshold inventory levels are set, and buffer limits are configured to stock levels to meet real demand.

Employees are instructed on the DDMRP methodology, visual dashboards are built, and inventory level automation is set up. The goal is to maximize the available stock in the warehouse, unlike the case of the bulk sale of the inventory, where it is sold in meters and onsite. The analysis methodology on DDMRP provided in the reference book on DDMRP is the basis for component 3. [21]

Figure 2 presents a flowchart that summarizes the procedure followed for implementing the model. It is organized according to the previously described components and clearly outlines the sequence of activities carried out in each section.

Model Indicators

Stock Out (SO): Represents the percentage of products not supplied versus demand. Studies suggest that implementing 5S and DDMRP improves stockout to 7% [5].

$$SO = \frac{Cantidad\ No\ atendida}{Cantidad\ Total\ requerida} * 100\% \quad (1)$$

Reduction of Inventory Level (RNI): Measures the amount of products that are reduced in the process. Studies propose an estimated value of 10.87% [8].

$$RNI = \frac{Cant.Inv.Real - Cant.Inv.Propuesto}{Cant.Inv.Real\ o\ actual} * 100\% \quad (2)$$

Warehouse Utilization (WU): Evaluates the effective use of space in relation to the total available. According to studies, it is expected to improve warehouse utilization to 60.14% [22].

$$UA = \frac{Área\ útil}{Área\ total} * 100\% \quad (3)$$

Inventory Turnover (ROT): Measures how many times inventory is renewed in a period. According to studies, an inventory turnover of 4.79 is expected to be achieved [8].

$$ROT = \frac{Costo\ de\ ventas}{Inventario\ promedio} \quad (4)$$

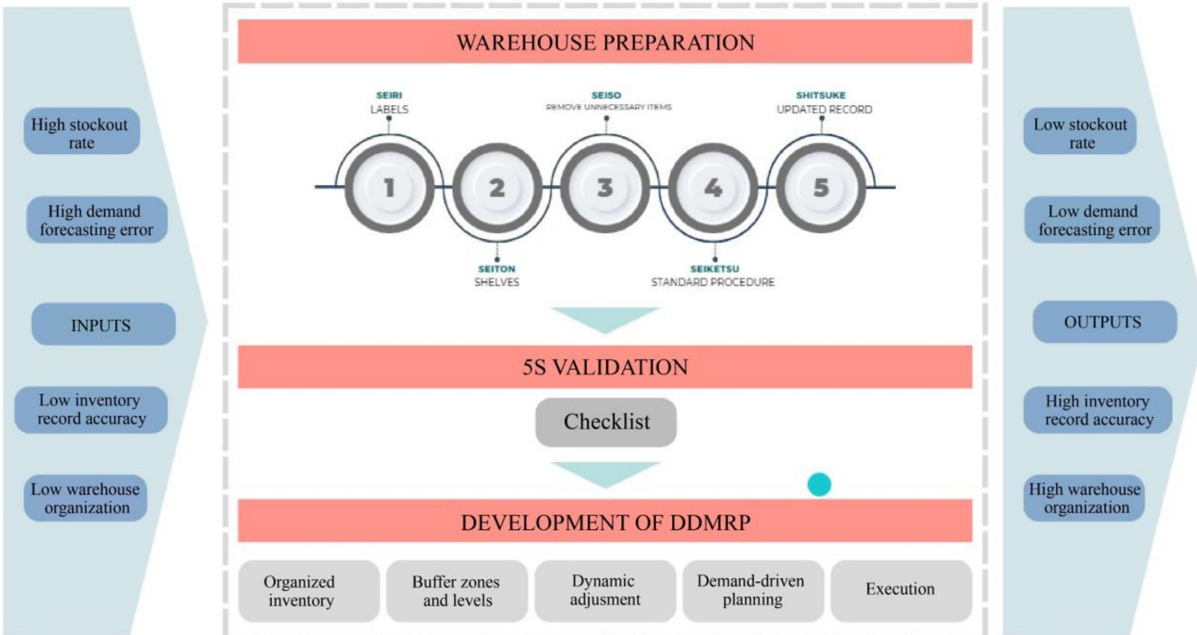

Fig. 1 Proposed model

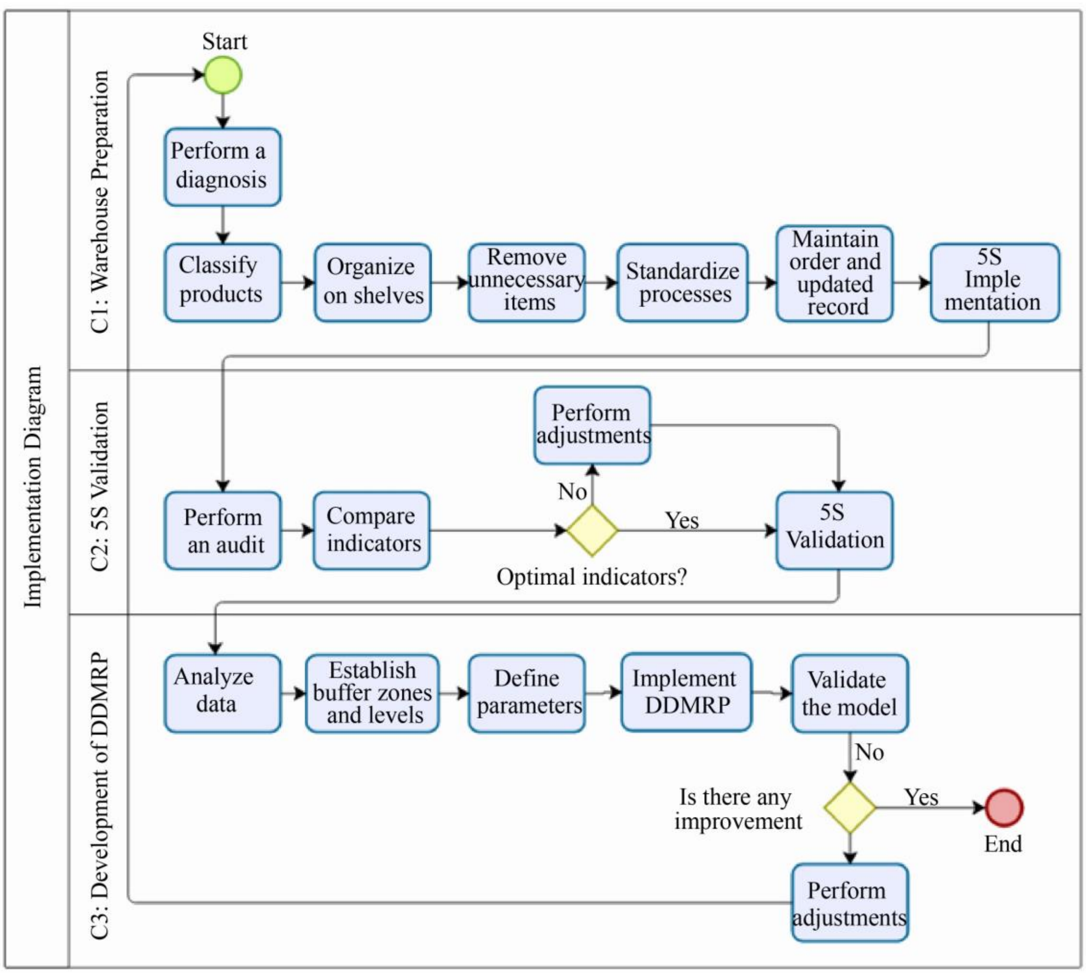

Fig. 2 Model components

4. Results

4.1. Scenario Description

This section is dedicated to the validation of the implementation of the proposed methodology described in the previous sections. A detailed report of the development process of each of the selected tools is presented, emphasizing their integration within the model. The evaluation includes the application of the 5S methodology and a simulation of DDMRP using a code in Google Colab. Finally, the results obtained are presented and analyzed, considering their relevance and impact.

4.2. Initial Diagnosis

The company under study is a trading company whose main problem is stock breakage, with a gap of 15.43%, which has generated economic losses during the period analyzed for a value of S/.16,272.37, mainly due to unfulfilled orders that directly affect sales and operating costs. The reasoning behind the increased stockout level encompasses a deficiency in inventory management brought about by inadequate purchasing, which ultimately resulted in the loss of 36 orders on average in the evaluated time frame. Also, there was a low level of systematic order in the warehouse due to the over 44% congestion of the warehouse space. Lastly, the low inventory replenishment was attributed to inaccuracies in the product entry, in particular, a segment of 43.92 meters of conveyor belts, which was improperly documented.

Figure 3 presents the problem tree along with the proposed linkage tools designed to address each of the root causes identified in the initial diagnostic assessment.

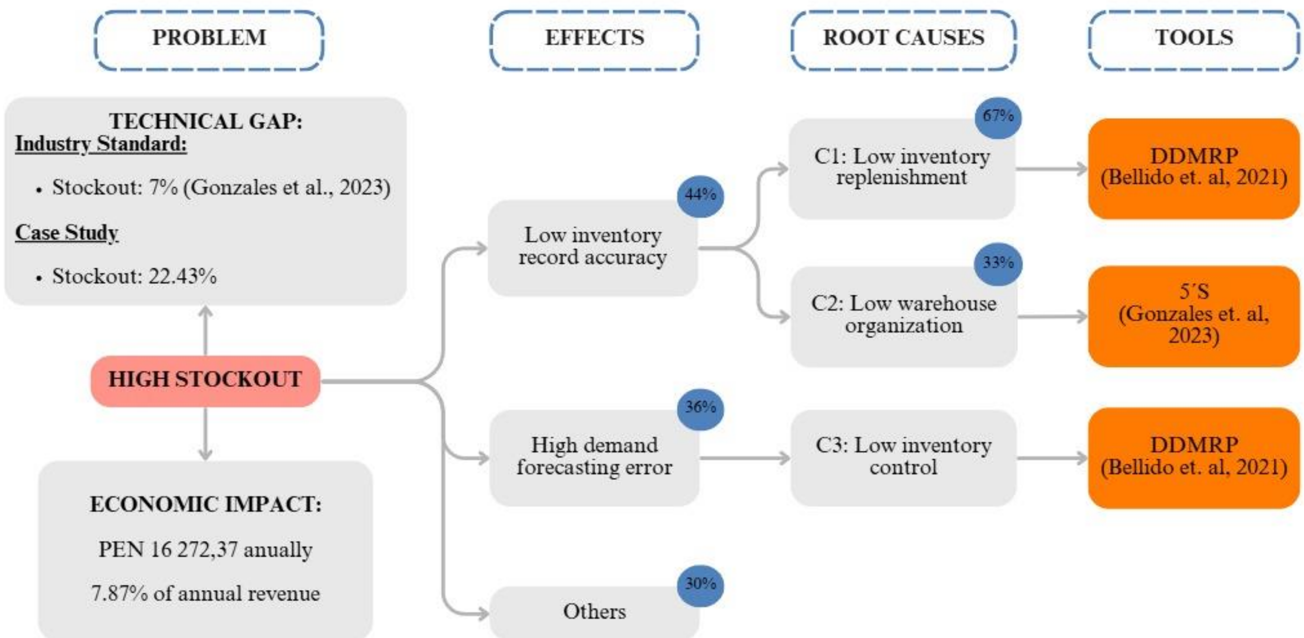

Fig. 3 Tree problems

4.3. Design and Validation Results

The proposal covers the entire process within the warehouse, from reception and storage to packaging. The company's product portfolio consists of conveyor belts, rubber balls, buckets, and bolts, so a Pareto analysis was performed to determine the most critical product family, which turned out to be the family of conveyor belts. Through the application of Lean Warehousing and DDMRP, we seek to reduce stock breakage, minimize unused meters of conveyor belts, and optimize the use of space in the warehouse, significantly improving inventory management.

4.3.1. 5S Implementation

To implement the 5S methodology in the warehouse, a pilot plan was designed considering the most representative products of a total of 22 types of conveyor belts obtained from the ABC classification.

The main objective of this plan is to demonstrate how the application of 5S principles can positively impact different critical aspects of the picking process. In this sense, an adequate organization of products, the elimination of unnecessary elements, and the standardization of procedures will optimize inventory replenishment and minimize errors in the recording and control of stock, in conjunction with a Kardex, thus improving the accuracy and continuity of the warehouse workflow.

Following the implementation of the pilot plan, an initial evaluation was conducted to assess the level of implementation of each 5S element within the company. The results showed that there is not adequate development of the methodology, since the five stages present deficiencies in their application. The results are presented in Figure 4.

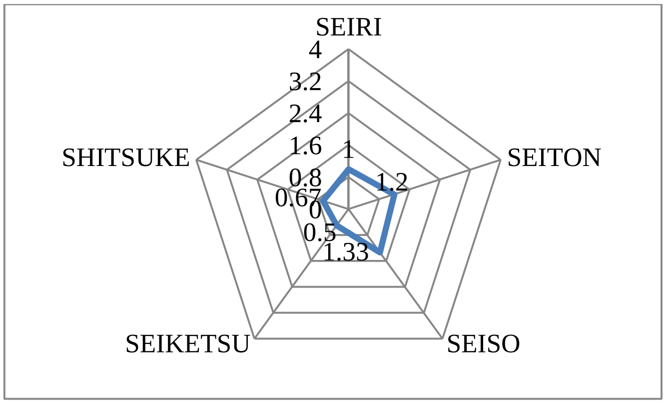

Fig. 4 Initial evaluation results

Application of the First S-Classify (Seiri)

Organizational priority in the warehouse is the segregation of needed materials from unneeded materials for a smoother workflow within the customer order fulfillment dynamic. For this purpose, red card methods of identification and compliant removal of expendable items and tools aid in rapid retrieval. For the first month, no follow-up systems beyond the use of the cards themselves formed the basis of problem identification. Starting the second month, the reports formed in the preceding month became the basis for the systematic monthly reports documenting the nonconformities detected. This, the first stage, visual inventory management, a reduction in the needed inventory, and improvement of the organization, simultaneously increased shelving space in the warehouse. This, in turn, increased the level of attentive awareness throughout the staff and the organization, and there is a need to retain, use, and manage more of the space available more effectively.

Application of the Second S - Organize (Seiton)

After classification, the warehouse space was reorganized by family groupings and order of use. Each group was allocated to designated shelving units that were sized, typologically, and visibly labeled for rapid identification. At first, there was only the use of labels to classify types of bands and a register that reconciled physical inventory with what was available in the other systems. Later on, a compliance report was added to record the status of the starting and finishing activities of procedures and activities carried out. These changes eliminated space duplication, improved the flow of materials from reception through to dispatch, and optimized the routes to reduce congestion. In a revised organizational system, shelves were color-coded, discrepancies between system and physical stock were reconciled, misclassifications due to labels were eliminated, and discrepancies across systems were eliminated through adjustment layer coding of the inventory, which was deeply understood. Finally, a revised set of organizational procedures was put in place alongside bi-weekly performance measures, which enabled order to be maintained in a self-sustaining manner.

Application of the Third S - Clean (Seiso)

The warehouse cleaning was viewed as a prerequisite for the proper implementation of the other Ss. For the first phase, it was necessary to remove dust, stains, and, most importantly, humidity from the stored products so as to conserve and deliver them in the best possible conditions. This was a task assigned to the operators as per the monthly timetable. In the beginning, though, there was just the timetable, devoid of any control mechanisms. To improve accountability, a monthly report recording the tasks fulfilled and the efforts attested was introduced. In the end, the conveyor belts were maintained in proper working order, deterioration from dirt was prevented, and the likelihood of recording errors due to indecipherable labels was significantly reduced.

Application of the Fourth S - Standardize (Seiketsu)

At this step, formalized procedures were followed for documenting inventories in the Kardex, along with achieving a policy of order and cleanliness, which the operators had to follow systematically. Also included was training of the personnel in charge to guarantee the correct exercise and sustainability of the defined processes. At the outset, a baseline procedure with a policy for sustaining order was present. However, over time, an evaluation report for trained personnel was added, thus enabling the assessment of conformity and the enhancement of individual standards. Consequently, the mechanisms for product storage and recording were systematized, thus removing the reliance on subjective personal criteria, guaranteeing uninterrupted operational continuity. This was crucial in ensuring the uninterrupted availability of the products, thus eliminating stockouts to enable a smooth and effective operational flow.

Application of the Fifth S - Maintain (Shitsuke)

The previous phases and the associated improvements from them were the focus of the final stage. A 5S evaluation form, completed monthly, enabled the fostering of discipline, order, and commitment, and supportable observation of the S Set on the controlled criteria. Every S helped consolidate individual S report criteria, thus it monitored discipline, order, and commitment. Over time, numerous corrective measures continuously enhanced practices that enabled the detection of deviations and improvement. Enhanced organization, a greater portion of daily activities, as well as hygienic practices, helped create a cleaner, safer workplace. A systematic 5S approach was developed from the final evaluation, which recorded uninterrupted improvements in planning activities, thus helping to improve the basic activities of the warehouse operations system.

4.3.2. 5S Validation

The final audit was carried out after the implementation of 5S for 4 months, obtaining the expected optimum value as shown in Figure 5. The results obtained during this time for the warehouse organization were that the warehouse capacity was reduced from 104% to 73.74%, while the inventory recording accuracy increased from 29.22% to 90.42%.

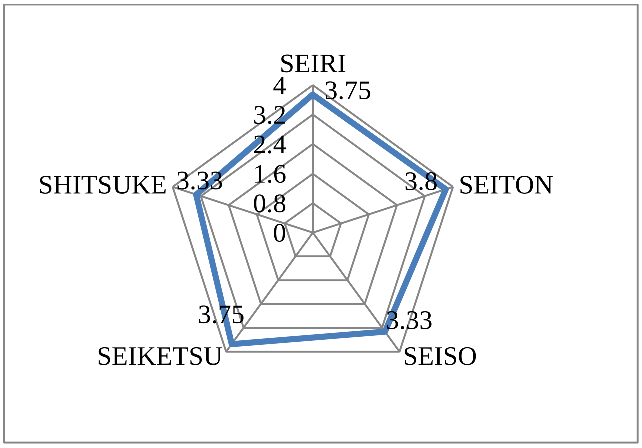

Fig. 5 Final evaluation results

4.3.3. Model Simulation in Python Code

In this section, the technical aspects of the DDMRP simulation applied to optimize inventory management will be detailed with an in-depth analysis using a script developed in Google Colab, which allows evaluating purchase planning, replenishment times, inventory levels, and demand forecasting. The validation techniques used to assess the model's performance and ensure its ability to adapt to new scenarios will also be discussed. Figure 6 shows the libraries that were imported for the development of the model:

```
#Importing necessary libraries
import pandas as pd
import numpy as np
import matplotlib.pyplot as plt
import statsmodels.api as sm
from statsmodels.tsa.arima.model import ARIMA
from tabulate import tabulate
import datetime
```

Fig. 6 Importing libraries

Dates and sales data corresponding to the last three years were loaded to provide the model with the necessary information to generate accurate predictions. For this purpose, the corresponding code is presented in Figure 7.

```
# Create DataFrame
months = pd.date_range(start="2022-01-01", periods=36, freq='MS')
df = pd.DataFrame({
    'date': months,
    'demand': monthly_demand
})
df.set_index('date', inplace=True)
```

Fig. 7 Create dataframe

The code shown in Figure 8 converts monthly demand data into a weekly DataFrame, dividing each monthly value into four equal parts.

```
# Create DataFrame for weeks
week_list = []

for date, demand in df['demand'].items():
    weekly_demand = demand / 4  # divide into 4 equal parts
    for week in range(1, 5):
        week_list.append({
            'month_date': date,
            'week': week,
            'weekly_demand': weekly_demand
        })

weekly_df = pd.DataFrame(week_list)

# Show result
print(weekly_df.head(180))
```

Fig. 8 Create a dataframe for weeks

Figure 9 illustrates the historical evolution of sales, using a graphical representation in which dates are placed on the X-axis and sales values on the Y-axis.

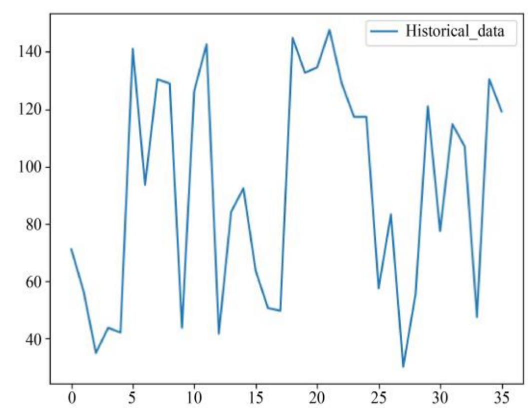

Fig. 9 Historical sales evolution

Figure 10 shows the projection of the three months with the ARIMA model and the historical data.

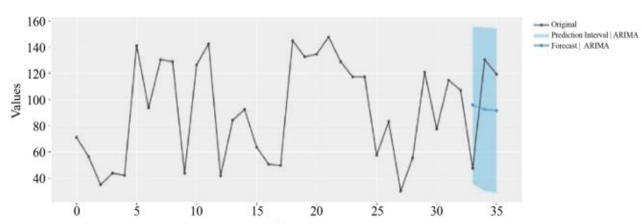

Fig. 10 Actual vs.` out of sample' forecast | Historical data

Then, Figure 11 shows the details of the calculation of the buffer levels for each zone. In DDMRP, the buffer is divided into three zones:

```
# --- CALCULATE BUFFERS ---
DLT = daily_average_demand * lead_time_days
DPR = daily_average_demand * purchase_frequency_days
total_sigma = np.sqrt(lead_time_days * daily_std_deviation**2
                      + purchase_frequency_days * daily_std_deviation**2)
safety_buffer = service_level * total_sigma
safety_buffer_array = np.full_like(daily_average_demand, safety_buffer)

total_buffer = DLT + DPR + safety_buffer_array
red_zone = DLT + (safety_buffer_array * 0.5)
yellow_zone = DPR * 0.5
green_zone = total_buffer - red_zone - yellow_zone
```

Fig. 11 Buffer calculation

Finally, the DDMRP buffer zones along with the corresponding inventory levels are illustrated in Figure 12.

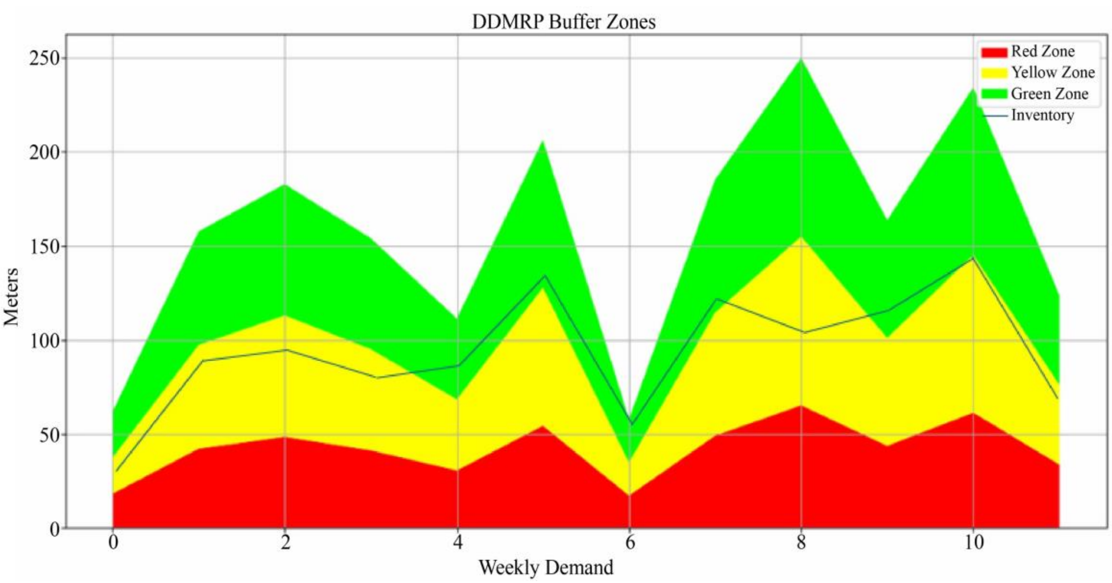

Fig. 12 DDMRP plot

Table 1 shows the values assigned to the DDMRP buffer zones: the Red is based on variability and protects against disruptions, the Yellow covers demand during lead time, and the Green sets the upper limit with no need for replenishment.

Table 1. Results of calculate buffers

Zones	Value (meters)
Red Zone	0-68
Yellow Zone	68-155
Green Zone	155-250

4.3.4. DDMRP Validation

The validation of the DDMRP simulation, where 62 observations were considered, using the Argumented Dickey-Fuller test, where the p-value was greater than 0.05 (p-value > 0.05); therefore, the alternative hypothesis is accepted. This validation implies that the series is stationary.

Table 2 shows the results of the ADF test applied to verify the stationarity of the analyzed time series.

Table 2. Results of the Augmented Dickey-Fuller (ADF) test

Property	Value
Test Statistic	-3.371711
p-value	0.011962
Number of Observations Used	62.000000
Critical Value 1%	-3.66992
Critical Value 5%	-2.964071
Critical Value 10%	-2.621171

H_0: (p-value >0.05) indicates that the series is White noise, and H_0 cannot be rejected. Thus, the series is not stationary.

H_1: (p-value < 0.05) The series is a Random Walk, rejecting Ho; thus, the series is stationary.

As shown in Figure 13 for the model used in Python, the ARIMA model is used to make the prediction.

```
model = sm.tsa.arima.ARIMA(df, order=(1, 0, 0))
fitted_model = model.fit()
forecast = fitted_model.forecast(3)
average_demand = df['demand'].mean()
```

Fig. 13 ARIMA prediction

The company started marketing conveyor belts with an initial inventory of 95 meters. To adequately respond to demand, a buffer zone system was implemented that issues purchase alerts, allowing a more efficient and timely supply plan to be executed, considering that orders are dynamic.

4.3.5. Results

Table 3 presents the indicators of the initial and final situations. After the application of the 5S and DDMRP tools, a noticeable improvement in stockout, inventory level reduction, warehouse capacity, and inventory turnover was observed. The proposed model effectively addresses the stockout problem, resulting in a 51.81% reduction. Unfulfilled orders improved significantly from 18 orders to 2 orders, resulting in an 89.51% improvement. In addition, inventory level reduction decreased by 52.55% and inventory turnover increased by 87.86%.

On the other hand, the warehouse capacity shows a reduction in space, decreasing by 28.88% and going from using 43.46 m^2 to 30.97 m^2 of warehouse area. Figure 14 shows the initial situation of the warehouse.

Fig. 14 Initial situation of the warehouse

The warehouse went from being an overcrowded and disorganized space to a properly conditioned environment, with signs that facilitate product identification and shelves or pallets with spaces assigned according to each type of conveyor belt. Operating procedures were established to maintain an orderly work area, which allows for more accurate inventory control and recording with the practical improvement of the Kardex. In addition, inventory planning based on actual demand was implemented to reduce excesses and shortages, optimize the use of space, and ensure the timely availability of critical materials.

Figure 15 shows the final situation of the warehouse after the implementation of the 5S tool.

Fig. 15 Final situation of the warehouse

The results collected both in the implementation period and in the simulation were validated in the Minitab software, applying the student statistical test, where for each indicator, the null hypothesis is rejected by the p-value, and the alternative hypothesis showing an improvement in the stockout by applying the model was accepted.

Table 3. Results of the application of the model

Indicator	Initial Situation	Final Situation	Literature
Stock out	22.43%	10.81%	7.00%
Inventory level reduction	39.58%	18.78%	10.87%
Warehouse utilization	104%	73.74%	60.14%
Inventory turnover	1.40	2.63	4.79

5. Discussion

The combination of DDMRP and the 5S tool proved to be exceedingly effective in enhancing inventory management of a conveyor belt selling commercial SME in the SME sector of industrial sales. The validation of this proposal showed a positive impact on the stockout rate, which increased in product availability by 11.62% (from 22.43% to 10.81%). This impact shows the positive effects of the strategic buffers developed through DDMRP, which dynamically, in real-time, adjusted to demand and enabled prompt and accurate replenishment decisions.

Also, the 5S technique improved the organization of the warehouse, which improved the visibility of the products and improved the accuracy of the Kardex system. This was shown in the increased productivity with the warehouse occupancy, which decreased from 104% to 73.74%, increasing the spatial safety and order.

In the operational domain, there was a decline in inventory levels from 39.58% to 18.78%, whereas inventory turnover rose from 1.40 to 2.63, which reflects a move toward more efficient and responsive inventory control. Improvements in obsolete and slow-moving items increased liquidity and decreased storage costs. The results align with earlier studies, underscoring the efficacy of DDMRP in correlating actual consumption with replenishment and in the efficiency gained from order and standardization. Nonetheless, the methodology in a commercial setting, which accepts products sold in linear meters, is a new contribution, considering the integration of high variability and customization typical of such operations.

Ultimately, the results sustain the assertion that the amalgamation of DDMRP with 5S, apart from improving DDMRP logistics metrics, operationalises sustainability by waste reduction, improved material flow, and data-driven decision making.

5.1. Limitations

This study's main shortcomings concern the constraints of finances, technology, and human resources, which, as reported, is a common phenomenon in SMEs. Such constraints made it impossible to take proper steps to invest in training, digital infrastructures, and dedicated software critical to the effective application of DDMRP and Lean Warehousing. Not having 'Advanced Information Systems' made capturing and controlling active demand, as well as associated inventory, challenging, which in turn reduced the 'responsiveness' of the planning system. Also, the extent to which these defined improvements can be implemented in order to be completely tangible may influence the way management perceives the project's impact on the overall short-term performance of the organization. Last but not least, the integration and synchronization of the planning, Lean, and DDMRP (drum, buffer, rope) methodologies even in small-scale operations is a challenge in itself, mainly in the form of conceiving 'balance' between system sophistication and operational oversimplification, in addition to effective and real-time active coordination with the suppliers to avoid any supply outages.

5.2. Recommendations

To evaluate the adaptability and effectiveness of DDMRP and its inventory management counterparts like MRP and Kanban, the performance of the two systems and their corresponding conditions must be described. There is insufficient data that characterizes DDMRP in the context of Small and Medium Enterprises (SMEs) demand, product families, and supply sufficiency variability. Further, DDMRP demand scenarios (such as seasonal, intermittent, or high-value and low-volume) must be defined to assess the relevance of DDMRP to inventory systems in the commercial belt conveyor sector. Performing such evaluations enables researchers to determine the boundaries and scale within which DDMRP is applicable in complex commercial systems. Ultimately, this strengthens the practical relevance of DDMRP systems to inventory management.

5.3. Future Work

Exploration of hybrid models that pair DDMRP inventory control with demand forecasting or machine learning for stock optimization and mitigation of demand variability should be the focus of relevant future research. Such DDMRP and ML demand model algorithms would allow configurable predictive and responsive inventory control systems for mid-range tech companies. Furthermore, as a suggestion, try to assess the impact of DDMRP on constrained SME resources to formulate operational and financial fit DDMRP methodologies. Such research would show how Lightweight Lean DDMRP models would enhance customer service and lower inventory holding costs, supporting the long-term sustainable development of supply chains for developing countries.

6. Conclusion

The principles of Lean Warehousing, combined with the 5S methodology and Demand-Driven Material Requirements Planning (DDMRP), demonstrated effectiveness in reducing stockouts and improving inventory management in a commercial SME within the conveyor belt industry. The primary diagnosis indicated a 15.43% inventory performance gap below the industry benchmarks, which resulted chiefly from inefficiencies in the order processing and controls. The model resulted in order fulfillment improving by 51.81%. The stockout rate improves from 22.43% to 10.81% and inventory turnover improves from 1.40 to 2.63. Thus, inventory was reduced from 39.58% to 18.78%, and warehouse stock was reduced from 104% to 73.74%, which improved operational safety and efficiency through more orderly and organized operations.

These outcomes indicate the effectiveness of the combined use of Lean principles and demand-driven methodology in achieving substantial and lasting improvements in the performance of logistics. This research illustrates the transformation of disorderly and reactive inventory systems to flexible and rational management from the combined use of 5S and DDMRP.

This research addresses an unexplored area of literature by putting an integrated Lean–DDMRP framework to practice within a commercial SME context, which remains underinvestigated. Moreover, it offers proof that these methods are not merely confined to manufacturing situations, but extend to operational spheres concerned with the sale of metricated, nonperishable goods of a standardized nature.

Subsequent works ought to emphasize the combination of digital technologies, predictive analytics, and staff development strategies to improve the Lean–DDMRP systems' scalable, automated, and resilient sophistication, which in turn will improve agile adaptability within shifting supply networks.

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Appendix 1

Appendix 1. Comparative analysis of the proposed lean–DDMRP model and related studies in the literature

Criterion	Inventory Management Model for Reducing Stockout Rate by Applying Lean Warehousing and DDMRP Tools in SMEs in the Commercial Sector.	Implementation of the Lean 5S methodology in a logistics enterprise	Increasing the service level in an industrial supplier company using the Winters Forecasting Method, Lean Warehouse, and BPM	Implementing the Lean Warehousing model to increase on-time and in-full delivery of an SME commercial company: A research in Peru	Inventory management optimization model based on 5S and DDMRP methodologies in commercial SMEs	Proposed Hybrid Model Based on Lean Warehousing and DDMRP for Stockout Reduction in Commercial SMEs
Authors	Gonzales-León et al., (2023)	Wojtynek et al., (2018)	Palomino-Cárdenas et al., (2022)	Vasquez-Quispe et al. (2023)	Bellido-Mantilla et al., (2021)	Damián-Rojas et al., (2025)
Purpose	Reduce stockout by applying Lean Warehousing and DDMRP	Apply 5S and Lean rules to improve efficiency and productivity	Increase service level using Winters Forecasting, Lean Warehousing, and BPM	Improve to solve problems in order picking and inventory control.	Optimize inventory management	Reduce stockouts by applying 5S and DDMRP.
Application	VSM design, simulation, proposed model	By auditing and training personnel who will depend on the company's information.	Simulation and validation based on a review of articles.	Lean Warehousing methodology model combined with analysis tools.	Simulation and proposed model	Company diagnosis, VSM, proposed model, simulation, and comparison of results.
Objective	Reduce losses due to product expiration.	Improve the manufacturing process, reducing material losses to increase efficiency.	Design a model to reduce stock breakage. Stock out.	Improve the quality of the logistics area and the level of service.	Maximize profitability, the level of satisfaction with the use of technology and minimizing costs.	Reduce stockouts through demand-driven replenishment. Minimize inventory levels while maintaining product availability. Improve warehouse utilization and operational order.

						Increase inventory turnover to enhance flow efficiency.
Result	64.8% increase in inventory turnover.	Both performance, complaints, and level of interference decreased in workers, which increases productivity.	Decrease in stock out to 6.93%.	Inventory recording accuracy increased 27.93%, time reduction of 32.73% and an increase of 23.46% OTIF.	Inventory turnover of 3.80, the optimum being 4.79%.	Stockout decreased from 22.43% to 10.81%. Inventory level was reduced from 39.58% to 18.78%. Warehouse utilization dropped from 104% to 73.74%. Inventory turnover increased from 1.40 to 2.63.
Difference	Lack of implementation of metric units in NONperishable products.	No mention of 5S strategies to introduce workers to an inventory system.	No implementation of DDMRP for variable demand forecasting.	The Kardex system does not allow recording meter outputs of existing units.	Lack of implementation in NONperishable products.	Implementation in conveyor belts is marketed by meters or inches.
Methodology/sTools	Lean warehousing, DDMRP	5S and Lean	Winters forecasting, Lean Warehouse, and BPM	5S, Standardized Work, Kardex, Multicriteria ABC, and Poka Yoke	5S and DDMRP	5S and DDMRP
Sector	Commercial sector (food)	Commercial sector (food)	Commercial sector (hardware)	Commercial sector (footwear)	Commercial sector (food)	Commercial sector (industrial equipment)
Distinctive Contribution	Focuses on the food commercial sector; does not address nonperishable products sold in metric units.	Improves productivity but lacks integration with demand-driven inventory planning.	Uses simulation and forecasting but excludes dynamic buffer control.	Applies Lean tools but is not integrated with demand-based replenishment.	Lacks adaptability to nonperishable metric-unit inventories and does not consider warehouse space optimization.	Proposes a Lean–DDMRP hybrid model for commercial SMEs, aligning replenishment with real demand and reducing stockouts and space saturation while improving turnover in non-manufacturing contexts.