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Lean Warehousing philosophy to increase the level of service in a Peruvian small automotive enterprise

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***Abstract*– The automotive industry in Peru is experiencing sustained growth, presenting a significant opportunity to implement Lean philosophy principles alongside advanced inventory management practices to improve operational efficiency. A critical challenge faced by organizations is the low order service level, which is primarily caused by inaccurate demand forecasting, poor time management, stock-outs, and inefficient warehouse distribution. This study focuses on high-demand products, such as shock absorbers, terminals, springs, and trapezoids, which currently have an average service level of 81.10%. This issue is particularly important as low service levels often lead to delivery failures, resulting in lost sales and reduced profitability. The objective of this research is to propose strategies based on Lean Warehousing, including Business Process Management (BPM), Economic Order Quantity (EOQ), and Demand Forecasting. In addition, the study will apply the Kaizen approach to improve the service level by at least 10%, targeting the root causes of the identified problems to drive more efficient and profitable operations.**

***Keywords*-- Service Level, Lean Warehousing, Automotive Sector, EOQ, Demand Forecast.**

I. Introduction

The automotive sector, a major generator of employment worldwide and a driver of technological progress and international economic ties, plays a crucial role in the growth of GDP and employment in Peru, thanks to considerable increases in production and commercial activity. However, low service levels – manifested in delays and product shortages – continue to represent significant challenges for the industry, negatively impacting customer satisfaction, business profitability and operational efficiency.

This study analyses cases of auto parts suppliers that face common operational problems, such as poor inventory control, excessive shelf storage, and inefficient utilization of warehouse areas, which cause delays in order management times. To address these challenges and improve service quality, while reducing operational costs, the implementation of Lean Warehousing techniques is proposed, including Just-in-Time (JIT) and Business Process Management (BPM) principles.

Based on a structured analysis of the problem—summarized in a problem tree that identifies root causes and associated tools—the research develops a comprehensive model for improvement. Techniques such as demand forecasting (Winters' Method), inventory record improvement (ERI), and warehouse management strategies (ABC analysis and EOQ models) are integrated.

The successful results observed in the case studies demonstrate significant improvements in service levels, cost reductions, and improved resource management. This research seeks to optimize the fulfillment of orders for high-demand auto parts through the application of demand forecasting techniques, Lean principles and continuous improvement methodologies. The article presents a detailed review of the current state of knowledge, the proposed model and its validation through a case study in the automotive sector.

II. State of the Art

A. Error in the demand forecast

This study explores demand forecasts using the Winters method for time series analysis of specific products. The results showed that the most effective hybrid models for ATE, Campo de Marte, San Borja, and Santa Anita stations were identified, based on superior out-of-sample forecast results, with lower error values for RMSE, RMSPE, MAE, and MAPE, indicating better accuracy than other models [1].

In a different context, an advanced predictive model for the pharmaceutical sector combined algorithms like the hybrid ARHOW (ARIMA-HW) technique, improving forecast accuracy. This model was validated by industry experts with 95% satisfaction and a MAPE of 9.37% [2].

B. Stock Out

A research project on vaccine shortages in underdeveloped countries identified high storage and maintenance costs as the cause. Implementing the Economic Lot (EOQ) model in a pilot test led to a 52.17% reduction in storage costs and a 42.12% decrease in maintenance costs compared to previous semesters [3].

C. Incorrect distribution in the warehouse

Industrial studies implement Six Sigma, DMAIC and ABC multicriteria to decrease incorrect distribution in the warehouse. The results indicated that it decreased by 53.17%, which indicates that warehouse space is effectively utilized [4]. The objective of this research is to improve stock rotation in the warehouse using 5S, ABC and Poka-yoke methodologies. The results show an increase from 0.83 to 2.4 in raw material turnover [5].

D. Error in safety inventory

One study established a safety inventory strategy to mitigate the effects of unpredictable demand, leading to total inventory savings of PEN 19,251,527.75 [6]. Another study applied mathematical algorithms to the safety inventory policy, resulting in a 56% increase in profits for the company involved [7].

III. CONTRIBUTION

A. Basis

The proposed model applies Lean Warehousing tools, focusing on process planning, control, and inventory management. The Winters Method is used for demand forecasting, optimizing inventory levels by 43.17% and reducing costs by 76.41% compared to the previous quarter [8]. Business Process Management (BPM) improves process efficiency by 36.56%, while the DMAIC model targets an 80% reduction in non-value-added times.

The Economic Order Quantity (EOQ) model reduces storage costs, cutting inventory expenses by 35.64%, freeing up capital, improving efficiency by 45.66%, and increasing profitability by 20%, enhancing customer satisfaction [9]. Multi-criteria ABC analysis optimizes warehouse layout, reducing storage costs by 15%, improving critical product availability by 20%, and increasing supply chain flexibility [10].

B. Proposed model

The model contains three components as can be seen in Fig. 1. The first component focuses on understanding the current situation through structured data collection and analysis using tools like Pareto, Ishikawa, ABC analysis, Average Control, and ANOVA.

The second component centers on process planning and inventory control. In terms of forecasting, we apply the Winters Method, which allows us to model both trends and seasonality in demand—something particularly useful for industries with fluctuating product cycles. We complement this with Business Process Management (BPM) to visualize and optimize key workflows. On the inventory side, we incorporate tools such as Economic Order Quantity (EOQ), a multi-criteria ABC analysis—which considers not only usage value but also lead time and criticality—and the Efficient Replenishment Index (ERI), which supports better stock decisions. These methods are applied specifically to the highest-demand products, maximizing their impact on operational efficiency and service level.

The third component involves the continuous monitoring and evaluation of performance indicators. Here, we focus on two key metrics: Forecast Accuracy (FA) and Accuracy of Recorded Inventories (ARI). These indicators help us assess whether our planning efforts are aligned with real-world behavior and whether our inventory records reflect actual stock. Improving these metrics translates into better service levels, fewer stockouts, and a more reliable supply chain. In summary, this model integrates proven tools and methods into a structured framework that supports decision-making in complex inventory environments. By combining analysis, planning, and control in a practical and targeted way, it offers

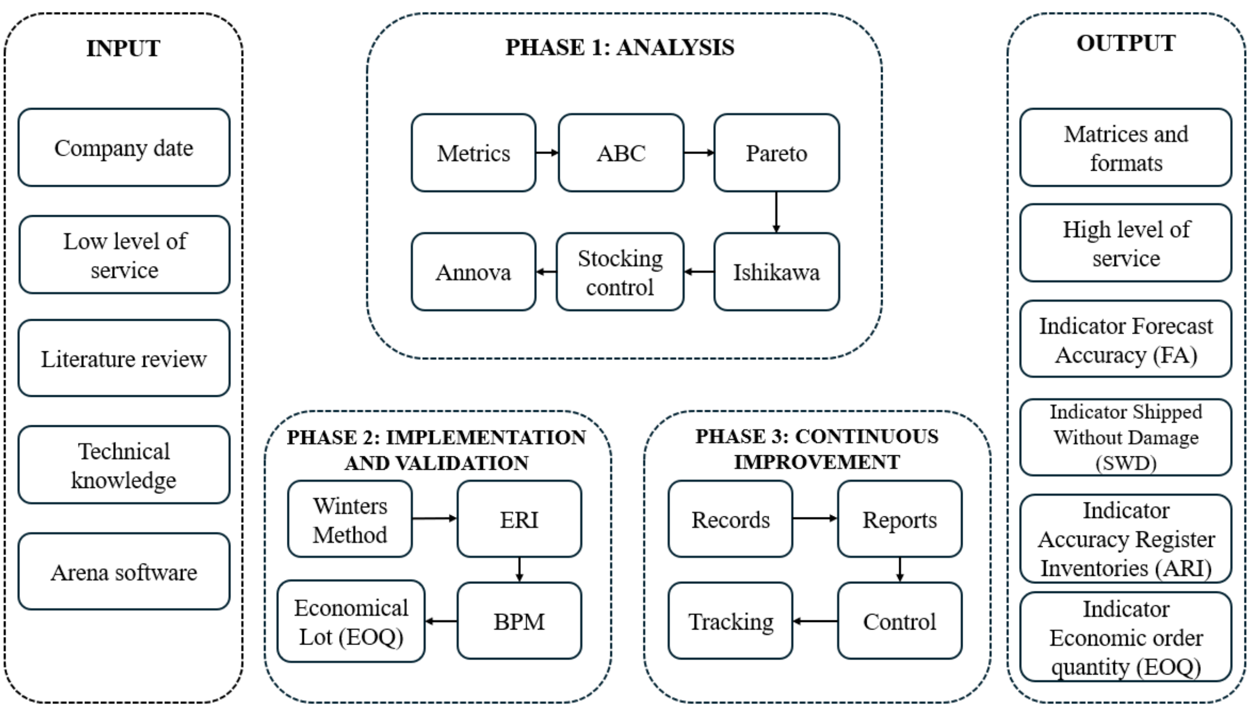

Fig. 1 Proposed model

a path toward more efficient, accurate, and responsive inventory and demand management.

C. *Model details*

The proposed study consists of three main components that address various aspects of inventory and supply chain management. The first component, Analysis, focuses on understanding the current state of operations and demand. The Simple ABC technique is used to prioritize the most demanded products from 2022 onwards. ANNOVA is employed to evaluate the relationship between variables, such as causes and problems, while Pareto and Ishikawa Diagrams are used to identify both qualitative and quantitative causes contributing to low service levels.

The second component, Implementation and Validation, seeks to validate and optimize inventory and demand forecasting processes. The Demand Forecasting Method (Winters) is applied to estimate product demand over a 16-month period, using statistical methods and time series forecasting models, with a strong reliance on historical sales data [11]. Several factors must be considered when developing the forecasting model, such as the forecasting period, model accuracy, budget availability, and trained personnel [12]. The Accuracy of Inventories (ARI) approach is used to assess the reliability of inventory records by comparing them to actual physical stock, with data from 2022 being analyzed [13]. The primary goal of ARI is to provide a reliable measure of the effectiveness of inventory control [14]. The ABC Multi-Criteria approach is implemented to refine the prioritization of inventory items, improving resource allocation and supply chain management for the most demanded products from 2022 [15]. Furthermore, Business Process Management (BPM) is employed to optimize processes, focusing on improving efficiency, agility, and alignment with strategic goals [16]. The Economic Order Quantity (EOQ) model is applied to determine the most efficient order quantity to minimize inventory costs, specifically for the most demanded products from 2022.

Continuous Improvement, the third component, places a strong emphasis on process improvement throughout time. Continuous improvement initiatives are organized using Deming's PDCA (Plan-Do-Check-Act) cycle, which is utilized once a month to assess and improve operating procedures. Key performance indicators (KPIs) are updated daily via a dashboard in Power BI to monitor and visualize performance, guaranteeing real-time insights and facilitating prompt decision-making. All these elements work together to provide a thorough strategy for managing and enhancing inventory systems, emphasizing demand forecasting and prioritization, process optimization, and continuous improvement.

D. *Proposed Process*

This section outlines the process in three phases: identifying high-demand products and analyzing service issues, implementing selected tools for innovation, and analyzing and validating results, followed by a thorough follow-up to ensure effectiveness.

The first phase (Fig. 2), Analysis, begins by collecting recent data, classifying products by demand using ABC analysis, and identifying issues through Ishikawa and Pareto analysis. Abnormal data are filtered during ANOVA, and the link to low service levels is confirmed.

The second phase, Implementation and Validation (Fig. 3), starts after analyzing the data with a tree diagram. It involves forecasting demand, calculating inventory accuracy, automating warehouse processes, and receiving products using the Economic Lot method. Results are compared with company data to validate the effectiveness of these strategies.

The third phase, Continuous Improvement (Fig. 4), follows the implementation of the tools. Results are evaluated for improvement opportunities and compared with company data. Continuous monitoring is carried out through a Power BI dashboard and the Deming cycle to ensure sustainable improvements. This ongoing process ensures the effectiveness and long-term success of the implemented strategies.

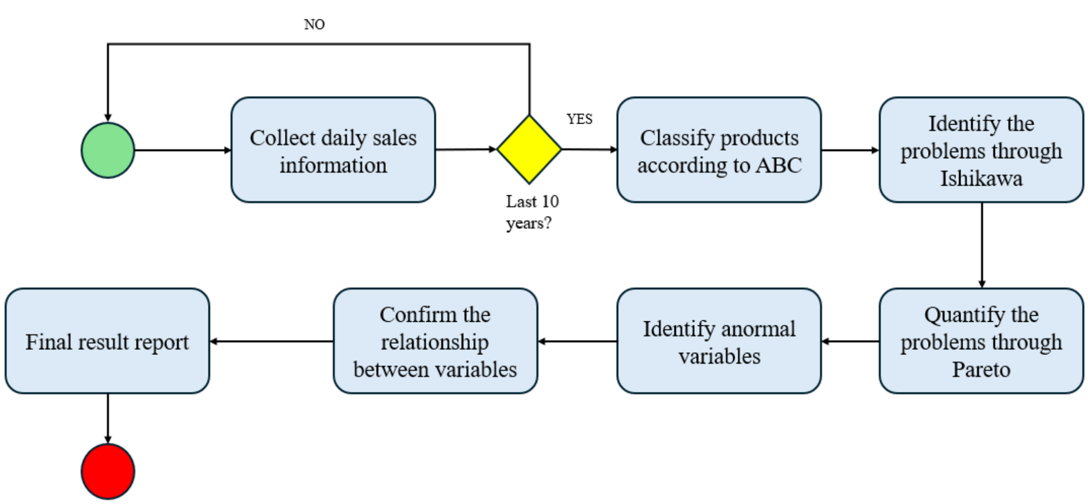

Fig. 2 Analysis process

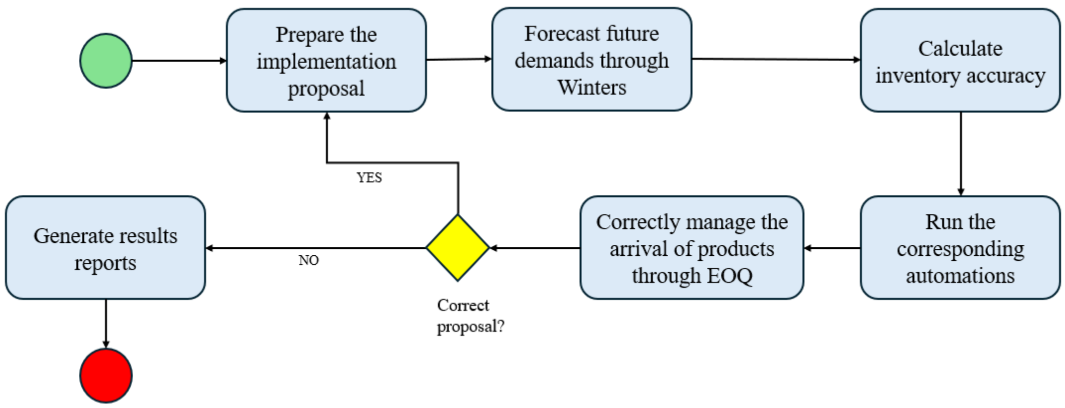

Fig. 3 Implementation and validation process

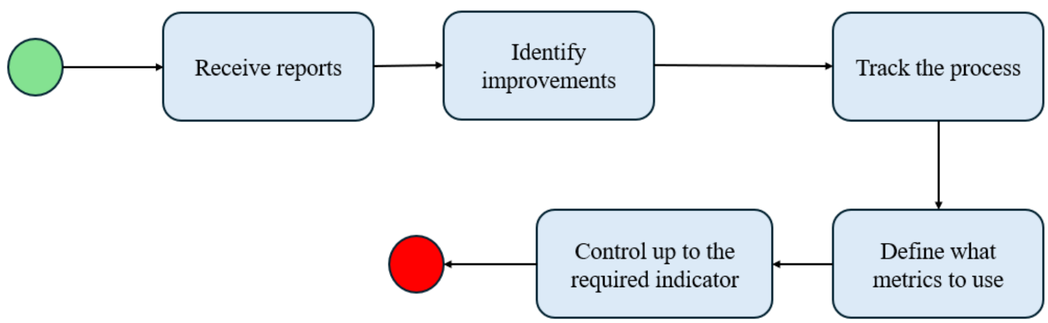

Fig. 4 Continuous improvement

IV. VALIDATION

A. *Initial diagnosis of the scenario*

The initial assessment reveals improper use of forecasting tools and a lack of error indicators, leading to a 12.40% average monthly variation between forecasted and actual demand (Table 1).

TABLE I
FORECAST PERCENTAGE CHANGE

Product	Manual forecast	Demand quantity	Variation (%)
Shock absorber	1551	1328	16.79%
Terminal	2000	1806	10.74%
Patella	2653	2263	17.23%
Trapeze	2014	1944	3.60%
Horn	1923	1700	13.62%

Disparities between ERP and physical inventory records, along with non-standardized stock count procedures, have led to an average inventory inaccuracy rate of 34.40% (Table 2).

TABLE II
PERCENTAGE VARIATION OF MOVEMENTS

Product	Physical inventory	ERP Inventory	Variation (%)
Shock absorber	110	123	11.8%
Terminal	101	130	28.7%
Patella	56	76	35.7%
Trapeze	48	70	45.8%
Horn	10	15	50.0%

The plant layout evaluation revealed that warehouse areas exceed available square meter capacity, resulting in a recorded square meter variation index (Table 3).

TABLE III
PERCENTAGE VARIATION OF AREAS

Area	Current area (m2)	Required area (m2)	Variation (%)
A	36	68.2	89.44%
B	21	12	42.86%
C	6	6.4	6.67%
D	128	279	117.97%
E	104	90	13.46%
F	15	16.09	7.27%
G	9	6.22	30.89%
H	12	9.15	23.75%

B. Pilot Design

A pilot test and simulation will validate the solution, enhancing its real-world applicability. The pilot must define the area, personnel, duration, and in-volved processes. The focus will be on improving inventory management and demand planning, with the sample including the five highest-demand products—shock absorber, trapeze, terminal, ball joint, and horn—due to their low service levels (Table 4). Techniques will be selected based on the tools implemented.

TABLE IV
VALIDATION TECHNIQUES ACCORDING TO TOOL

Tool	Paper	Technique
Demand forecasting method	O. Vicil (2020) [14]	Pilot
Inaccuracy and inventory management	E. Ramos, et al. (2022) [8]	Pilot
Business Project Management part 1	R. Cabrera et al. (2021) [1]	Pilot
Business Project Management part 2	L. Cusihuaman, et al. (2023) [18]	Simulation
Economical purchase lot	N. Jurado, et al. (2021) [19]	Pilot

C. Forecasting Accuracy Results

The Demand Forecasting Method is implemented during the pilot phase to assess the seasonality and trends of each product, enabling the selection of the most suitable forecasting method. All products exhibit a positive trend with annual seasonality. Three methods are then analyzed: classical decomposition, Winters smoothing, and multiple regression. The method with the lowest Mean Absolute Percentage Error (MAPE) is chosen for its accuracy (Table 5).

TABLE V
MAPE CALCULATION ACCORDING TO FORECAST

Product	Classical decomposition	Winters Dimming	Multiple Regression
Shock absorber	19.26%	3.20%	17.09%
Terminal	58.92%	5.34%	10.86%
Patella	20.02%	13.03%	13.31%
Trapeze	11.94%	8.37%	17.09%
Horn	24.63%	16.59%	16.67%

D. Inventory Optimization

Inventory Management techniques, including economic lot and inventory accuracy, are applied during the pilot phase to products such as shock absorbers, terminals, ball joints, trapezoids, and horns. By implementing these codes in the ERP system, new data is generated. The plant distribution is then carried out using ABC Multi-Criteria analysis, and the resulting data for the area is obtained (Table 6).

TABLE VI
CALCULATIONS OF ID REPETITIONS

ID	Product	Times	Accumulated	Relative
10026	Shock absorber	80	36%	80
132	Terminal	68	67%	148
10201	Patella	35	82%	183
1162	Trapeze	28	95%	211
6362	Horn	11	100%	222

The plant distribution is carried out according to ABC multicriterial. when deploying the distribution strategy, the following data is obtained for the designated area, including key parameters such as space utilization, resource allocation, and efficiency metrics to optimize operations and streamline workflow (Table 7).

TABLE VII
CALCULATION OF AREAS

Areas	Post-deployment area	Current variation
Customer service	62.3	9.5%
Picking	15.1	20.5%
Quality control	6	6.7%
Storage 1	128	118%
Storage 2	104	13.5%
Returned products	15	7.3%
Maintenance and Cleaning	9	30.9%
SSHH	12	23.8%

Calculations for safety stock are made using the economic purchase lot method, which helps maintain the right balance between inventory availability and cost efficiency. This method considers factors such as demand variability, lead time, and order frequency to determine the ideal stock level that prevents shortages without excessive holding costs (Table 8).

TABLE VIII
SAFETY INVENTORY CALCULATION

Product	Current Safety Inventory	EOQ Safety Inventory	Variation (%)
Shock absorber	231	204	13.24%
Terminal	390	343	13.70%
Patella	524	478	9.62%
Trapeze	190	178	6.74%
Horn	190	167	13.77%

Once the safety stock is established, the optimal purchase lot is calculated to ensure cost-effective procurement. this step considers factors like bulk purchasing benefits, storage capacity, and supplier conditions to determine the most efficient order quantity by optimizing the purchase lot, businesses can minimize costs while maintaining a steady supply of materials (Table 9).

TABLE IX
CALCULATION OF ECONOMIC PURCHASE LOT

Product	EOQ economic lot	Purchase order EOQ	Total cost EOQ (PEN)	Current Total cost (PEN)	Saving (PEN)
Shock absorber	97	9	1,696.17	2,375.00	678.83
Terminal	177	13	865.31	980.40	115.09
Patella	145	12	1,522.42	1,975.49	453.07
Trapeze	111	9	963.75	1,639.87	676.12
Horn	167	9	582.10	1,315.48	733.38

E. Inventory Accuracy Assessment

Inventory accuracy is assessed to ensure that recorded stock levels match the actual physical inventory. This process helps identify discrepancies, reduce errors, and improve stock reliability. maintaining accurate inventory records is essential for operational efficiency and financial reporting (Table 10).

TABLE X
CALCULATION OF ECONOMIC PURCHASE LOT

Month	Physical inventory	Software inventory	ERI per month	ERI per year	ERI 2023
January	806	790	98%	99.10%	92.80%
February	791	787	99%		
March	1055	1034	98%		
April	889	881	99%		
May	706	700	99%		
June	696	692	99%		
July	689	680	99%		
August	1110	1096	99%		
September	1038	1030	99%		
October	952	947	99%		
November	890	889	100%		
December	822	822	100%		

F. Warehouse Simulation and Picking Times

The Simulation of Picking Times According to BPM is conducted due to the variety of data. The customer service process, specifically picking, is replicated. After establishing the procedure, a model system is designed to define inputs, outputs, and activity flows. The process is simulated to adjust the time in the picking process. A total of 31 observations were obtained during 8 working hours (M-F), with 80% of the clients being regular customers and the remainder being competitors in the sector.

The picking process takes approximately 50.99 minutes, or 10.62% of the total process time. Key indicators will be recalculated to assess the overall performance and any increase in the technical gap. The Service Level will be calculated using the Fill Rate formula (1) (Table 11).

$$\frac{Total\ order\ complete}{Total\ orders\ attendet} = Fill\ Rate = 97\% \tag{1}$$

TABLE XI
RESULTS OF UNFULFILLED ORDERS FOR 2023

Month 2023	Purchase order	Purchase order satisfied	Unfulfilled orders
January	806	779	27
February	791	765	26
March	1055	1034	21
April	889	870	19
May	706	675	31
June	696	679	17
July	689	647	42
August	1110	1067	43
September	1038	1008	30
October	952	927	25
November	890	875	15
December	822	802	20

By using lean warehousing tools in a small Peruvian company, it increased the service level percentage by 15.90%, thus exceeding the average service level in similar sectors of 95%.

G. Economic Evaluation

The Economic Impact Assessment considers savings from avoided penalties and income generated from product sales. A cash flow evaluation is performed to assess the project's economic viability. The economic analysis shows a positive Net Present Value (NPV) of PEN 185,706.30, indicating a return on the initial investment. The Internal Rate of Return (IRR) of 20% exceeds the required rate of return (COK) of 13%, confirming the financial viability of the project. Additionally, the Future Net Present Value (NFPV) is NPE 148,883.30, suggesting strong long-term performance, while the Profit on Cash Flow (B/CF) of PEN 5.04 demonstrates the project's capacity to generate cash (Table 12).

TABLE XII
ECONOMIC EVALUATION CRITERIA

Financial indicators	Ratios
COK	13%
VAN	PEN 185,706.30
VPNF	PEN 148,883.30
TIRF	20%
B/CF	PEN 5.04

VI. DISCUSSION

A. *Scenario vs Results*

In this section, the results obtained during the validation phase will be compared with the initial proposed scenarios, providing a comprehensive assessment of the effectiveness of the proposed model. The Proposed Model (%) implementation during the Pilot and Simulation phases resulted in notable improvements. Demand forecast error decreased by 9.56%, surpassing the 7.50% target; repeated identifiers were reduced by 14%, exceeding the 10% goal; and picking accuracy improved by 9.38%, surpassing the 7% target.

The Analysis of the Results shows that the proposed model effectively applied the Winters method to forecast demand, reducing forecast error variation from 12.29% to 2.73%. The companies facing inventory control issues due to inaccurate forecasts can achieve deviations around 3% using the Winters method, with similar improvements observed here. In the second part, the implementation of ABC matrices and reduction in repeated identifiers resulted in a decrease in repetition variation from 30.8% to 16.8%. The reports that organizations integrating ABC and repeated identifiers typically experience deviations of around 15%, with similar improvements observed here, though linear programming may influence the results. Finally, the use of BPM through Simio reduced picking time from 20% to 10.62%. Also notes that companies can reduce picking times to under 10% by using

ABC matrices with inventory management, although variations exist due to the use of different software (Lingo).

B. Additional Analysis Criteria

Economic Profitability shows a substantial increase in the reduction of annual economic losses, indicating a positive effect on the financial profitability of the project. Long-Term Sustainability is reflected in the persistence of improvements related to availability and unplanned downtime, suggesting the long-term sustainability of the proposed model. Operational Efficiency is demonstrated through the integration of improvements in inventory management and monthly picking time, showcasing efficient optimization of resources and processes.

C. Future Jobs

Continuous Optimization of the Proposed Model suggests making ongoing adjustments to the model, considering new variables and evaluating its performance in specific scenarios. The Long-Term Sustainability Study proposes exploring the long-term sustainability of the improvements applied, considering potential modifications in technology and innovative strategies to maintain operational effectiveness. Additionally, Monitoring of External Factors recommends deploying a monitoring system to analyze how external elements, such as variations in market demand, may affect the efficiency of the model over time.

VII. Conclusion

The auto parts market in Peru is growing due to rising vehicle demand and economic progress, though challenges like competition, technological advancements, and customer service remain. Excess inventory is a major cause of economic losses and improving service levels by reducing delivery delays and optimizing safety inventory control is a key focus.

The Pilot and Simulation phase showed promising results, surpassing goals: a 9.56% reduction in forecast error, a 14% decrease in repeat tags, an increase in inventory accuracy from 92.8% to 99.1%, and a 9.38% improvement in picking accuracy. However, the target of reducing stock-outs to 5% was not fully met, achieving a 3.85% decrease instead.

Economically, the project shows strong viability, with positive indicators like Net Present Value (NPV) and Internal Rate of Return (IRR), signaling promising re-turns. Long-term revenue potential is also favorable, as shown by the Net Future Present Value (NFPV) and Cash Flow Benefit (B/CF).

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