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Improving Inventory Management in Peruvian Supermarkets through the Implementation of FEFO, SARIMA, and EOQ Tools to Reduce Non-Conforming Product Index

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Abstract

The scenario of this research is in the supermarket sector in Peru, where challenges were faced related to high rates of non-compliant products and losses due to product maturity. The contribution consisted in the implementation of tools such as FEFO, SARIMA and EOQ to improve inventory management and reduce losses. The proposed model integrated these techniques to optimize the supply chain and warehouse logistics, allowing a significant reduction in the index of products sold before the expiration date, achieving values below 3%. In addition, the predictive capacity of the model in the planning of product arrivals and departures was highlighted, as well as efficiency in inventory management by optimizing the economic order quantity. This integrated approach has demonstrated a significant reduction in products sold before the expiry date, resulting in more efficient and cost-effective inventory management.

Keywords
EOQ, SARIMA, FEFO, Lean Logistic, Lean Warehousing, Machine Learning.

1. Introducction
In recent years, the supermarket sector has had an accelerated growth in sales in 2023 compared to 2022, with an increase in sales of 17.3%, reaching 1,874 million soles. (Gestion, 2023). Currently, sales in supermarkets and mini markets show a positive trend in mass consumption products such as vegetables, dairy products, eggs and meat products. (INEI, 2023). In 2020, when the COVID 19 pandemic hit, many companies began to sell online, which led to more competition in the sector, so now retailers need to implement this system and find the perfect balance to meet all the purchases required by the customer. (Capece, 2021). However, this sector presents problems regarding nonconforming products, one of the main causes of this sector are the high percentages of shrinkage. A sample of 22 companies in the retail sector was taken and it was concluded that supermarkets have the highest percentage of shrinkage with 3.27%. (Saettone,2016). In a competitive market of the retail world, it is key to have a good efficient inventory management, because if you do not have a good control this can generate many logistics costs generating with it loss in the business with the aim of ensuring minimize costs and increase revenue. (Surahman & Gunadi, 2018).

For these reasons it is stated that the proper inventory management is a main challenge faced by supermarkets. (Surahman & Gunadi, 2018). Firstly, the case of the egg selling company was evidenced, where they implemented the FEFO methodology; achieving a reduction of more than 65% of spoiled products. (Carbajal et al.,2023). Secondly, the case of an airport in Panama was demonstrated, where the machine learning methodology was implemented with the SARIMA model; managing to forecast the
number of arrivals and departures for the next 7 months. (Trujillo, 2023).
In third place, the case of an SME hardware company was shown, where they did not have an EOQ system and it made them less competitive with large companies and by using the method they managed to reduce from 10% to 21%. (Caceres et al.,2023).
The literature review reveals that the use of methodologies such as machine learning, EOQ and FEFO has demonstrated significant improvements in inventory management. However, research at the retail level, especially in supermarkets and specific categories such as fruits, vegetables and groceries, is limited.

This dearth of studies has left a gap in understanding how to effectively address problems such as product expiration, inaccurate forecasting, and poor purchasing policies, which often result in non-conforming products. Therefore, our research focuses on applying, experimenting and validating these tools in a specific retail environment.

1.1 Objetives

The goal is to reduce the number of non-conforming products in supermarkets, thus minimizing losses caused by inefficient management. In doing so, we hope not only to contribute to existing knowledge, but also to offer practical solutions that will boost revenue and profitability in the supermarket retail sector.

2. Literature Review

2.1 The impact of implementing Lean Logistic and Lean warehousing in the food and/or similar sectors.

Lean Logistic focuses on optimizing both internal and external processes to ensure an uninterrupted flow of production materials and timely deliveries to customers. This is achieved by keeping quality and costs under control. In addition, it focuses on continuous improvement of all logistical aspects, with special attention on eliminating waste and activities that do not add value. (Wronka, 2017).

Toyota applied Lean principles to its entire supply chain, including its suppliers, resulting in reduced parts inventory and associated warehousing and distribution costs. This initiative also improved speed, flexibility and quality in production. In addition, the lean warehousing methodology focuses on optimizing warehousing processes to eliminate inefficiencies and waste, thereby increasing overall efficiency (Jones et al., 1997).

On the other hand, the lean warehousing methodology stands out, focuses specifically on warehousing processes. Its main objective is to eliminate inefficiencies and waste, such as activities that do not add value to the overall process (Gonzales et al., 2023). A transportation company chose to use Lean Warehouse tools, such as Kanban and the milk run system, to design an effective logistics solution. As a result, they were able to increase their revenue by 40,000 euros and improve productivity by 10%. (Burganova et al., 2021).

Previously evaluated case studies have shown that Lean Logistic and Lean Warehousing tools are effective in reducing waste. However, there is a paucity of research mentioning case studies applying other tools such as EOQ, FEFO and SARIMA in the context of supermarkets

2.2 The impacto of FEFO on nonconforming products in the food and/or similar sector

FEFO (First expired, first out) is an essential practice in any company dedicated to the purchase and sale to have a good inventory management and thus avoid the expiration of products. The FEFO methodology promotes the premise that products close to expiration are the first to go out. (Barreto et al.,2017).

FEFO (First Expired, First Out) is a fundamental practice in any buying and selling company to manage inventory effectively and avoid product expiration. This methodology establishes that products close to expiration should be the first to be sold or used. (Melgaço et al.,2021).

On the other hand, we have the FIFO (First-In-First-Out) methodology, which refers to what goes in first is what comes out first. (Sanjay Pandey & Raut, 2020). Moreover, according to a past research it was shown that implementing FEFO for fresh products could reduce from 12% to 4% compared to the FIFO system. (Ruiz Garcia & Lunadei, 2010). In addition, FEFO considers the shelf life of the product close to expiration, which makes it a superior model to FIFO (First In, First Out). (Herron et al., 2022). However, in other research they claim that implementing the FIFO method helped the company to reduce the number of expired products. (Sembiring, 2019).

An investigation was carried out in a company selling eggs where the FEFO method was implemented to minimize the spoilage of this product. The results were promising initially, they experienced a spoilage of 5.78%, but managed to reduce it significantly to 1.9%. (Carbajal et al.,2021). In addition, according to previous studies, the percentage of deterioration was validated by simulating the model in the Arena Simulator software. (Figueroa et al.,2023).

Therefore, the objective of this project is to implement the FEFO methodology in the company's fresh produce and grocery inventory management process, as mentioned above. This implementation has been shown to lead to a marked improvement in waste reduction. However, there is little research on the application of FEFO on products such as fruits, vegetables and groceries in supermarkets, despite the evidence of improvement mentioned above. Therefore, it is crucial to conduct research and disseminate the FEFO methodology in these types of products.

2.3 Application of machine learning for demand management in the retail sector and/or similar sectors

SARIMA stands for Seasonal Autoregressive Integrated Moving Average. It is a time series model designed to forecast future behavior based on different patterns, including both seasonal and non-seasonal trends. This model uses data from previous years as the basis for its predictions. (François, 2018).

Future forecast estimation using SARIMA is one of the machine learning models. Currently, the field of machine learning is an integral part of the development of artificial intelligence and spans several disciplines. Its application is broad in the prediction of key variables in the supply chain, such as production, prices and demand. Recent studies have shown how machine learning has improved price prediction in the automotive industry, taking into account consumer preferences for low-carbon vehicles. (Ma et al.,2023). Also other authors agree with this idea, because the application of machine learning has shown significant improvements over traditional methods, which improved from 60% to 86%. (Saeed Mian, 2023).

According to previous research, experiments were carried out with the ARIMA and SARIMA models, where it was observed that when ARIMA was implemented, an error of 8.72% was obtained, while with SARIMA the error was reduced to 6.69%. This difference in error percentages indicates that SARIMA is the more reliable model, since it presents a lower MAPE error score. (Singh, 2020). On the other hand, in additional research, a comparison of four models (ARIMA, SARIMA, LSTM and GRU) was carried out to predict bicycle demand. The results showed that the GRU model was the best choice, as it achieved a mean absolute error (MAE) of 30.36, considerably lower than the other models evaluated. (Subramanian et al.,2023). The GRU model captures complex nonlinear patterns in time series data. (Ridwan et al.,2024).

According to previous research, to implement the SARIMA model it is first necessary to collect historical demand data, covering at least the last 4 years. Then, the mathematical model is developed using the Python programming language. With this model, the future demand trend can be predicted with the least possible error. (Kato et al.,2023).

Tocumen Airport, having a constant flow of passenger arrivals and departures, requires accurate prediction of the amount of passenger flows for efficient management. Using SARIMA, it was possible to successfully forecast both passenger departures and arrivals for the next 7 months. (Trujillo, 2023).

According to the various case studies previously evaluated, it was evident that the SARIMA tool; it allows forecasting demand based on its seasonal periods. However, there is little research that applies SARIMA for supermarket forecasting focused on the categories of vegetables, fruits and groceries.

2.4 Purchasing policy and its impact on nonconforming products in the retail sector and similar (EOQ, purchasing policy)

The Economic Order Quantity (EOQ) method is an inventory management methodology that aims to determine the optimal quantity of orders or purchases, as well as the specific quantity that should be ordered from the supplier to minimize logistics costs. This involves considering several factors, such as the costs associated with ordering, storage costs and shortage costs. (Heaviside et al., 2023).

The application of the EOQ method is common in companies facing fluctuations in demand and challenges with their inventory. In situations of uncertainty, this model becomes a valuable tool as it takes a probability-based approach to order management. Through EOQ, it is possible to determine the optimal time to generate purchase orders and the precise quantity to request at each replenishment from the supplier. This helps to avoid both overstocking and stock shortages. Application of the EOQ method is common in companies that experience fluctuations in demand and face challenges with their inventory, which is why, in situations of uncertainty, they resort to such a model, adopting a probability-based approach to order management. Through this method, it is possible to determine the optimal time to generate the purchase order and the precise quantity to order for each replenishment requested from the supplier. This method helps to avoid overstocking and/or stock out. (Wirrdiana et al., 2023). According to Brigham and Houston (2016), when applying the EOQ method for effective inventory management, several assumptions must be considered. These include: a constant and uniform demand for goods, a predictable lead time from order to storage of goods, individuality of goods ordered without affecting other inventories, certainty in acquisition costs including purchase price, shipping and storage costs, and, finally, constant knowledge of the quantity, variety and availability of goods ordered.

According to Saegrandes companies that based their operation on the automation of their inventories, the research revealed that the implementation of the EOQ method in the management of small companies led to a remarkable increase in the efficiency of the distribution of daily purchase orders. With the incorporation of the automated component, this increase went from 10% to 21%. (Caceres et al.,2023). In a study conducted in a Nigerian supermarket, where information on 15 products, consisting of 10 non-seasonal and five seasonal items, was managed, the EOQ method was applied. As a result, a 43% savings in ownership and maintenance costs was achieved. In addition, by employing fuzzy EOQ, the savings were 35.65%. It is important to note that, in real-world situations, the savings with a fuzzy EOQ can be even greater than those obtained with a conventional EOQ. (Tsihrintzis et al.,2024).

3. Method

3.1 Model Basis

After an exhaustive literature review, as shown in Table 1, a model combining Lean Logistic and Lean Warehousing methodologies was developed. This model incorporates tools from both methodologies, such as machine learning, FEFO and a purchasing policy, with the objective of mitigating the problems identified in the case study. These tools are considered the most efficient to achieve the established objectives and generate significant improvements in the company.

Table 1. Comparison matrix of the causes developed in the case of study vs. the state of the art

Authors / Causes	**Demand Management**	**Purchasing Policy**	**Stock Management**
Barreto et al., (2017).			FEFO
François, (2018)	SARIMA		
Spagnol, (2017)			FEFO
Trujillo, (2023).	SARIMA		
Melgaço et al., (2021).			FEFO
Singh, (2020)	SARIMA		
Ruiz García & Lunadei, (2010)			FEFO
Setiawan et al., (2021).			FEFO
Cáceres et al., (2023).		EOQ	FEFO
Wirrdiana et al., (2023).	EOQ		
Brigham y Houston (2016)	EOQ		
Tsihrintzis et al., (2024).	EOQ		
Proposed Tools	**SARIMA**	**EOQ**	**FEFO**

3.2 Proposed Model

The basis of this model consists of working with and analyzing historical data collected over the last 5 years. It is designed to reduce the rate of nonconforming products in a supermarket online, focusing on the three categories with the greatest economic impact: fruits, vegetables and groceries. The model includes three components that are part of the Lean Logistic and Lean Warehouse tool. The current scenario will be compared with the future scenario of using this tool. The objective of this scientific study is to provide solutions to supermarkets facing similar problems, in order to reduce the indicator of nonconforming products. It is important to highlight the novelty of the research model, which implements such tools including forecasting (machine learning), purchasing policy and FEFO (Figure 1).

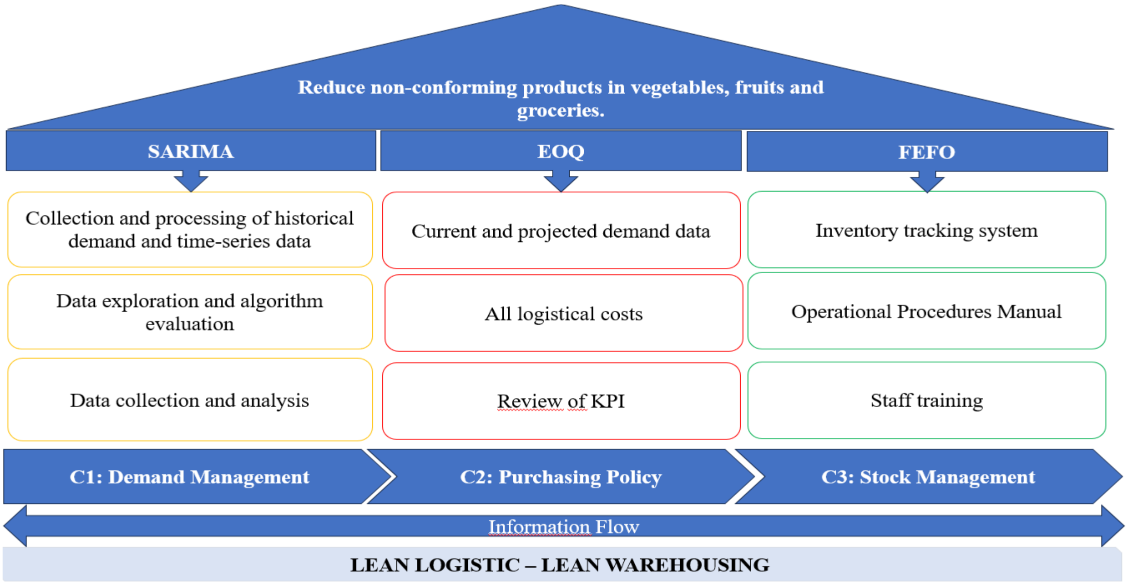

Figure 1. Proposel Model

3.2.1 Component 1: First, data collection for the case study was initiated to analyze and identify the main deficiencies in the processes, aiming to address the issue of inefficient forecasting leading to product deterioration and excessive purchases. Demand forecasting was employed as a tool, utilizing machine learning techniques. To implement this technique, it was necessary to gather data, particularly the sales history from the past 5 years, and select specific features to enhance forecast accuracy.

At this stage, data on sales from the last 5 years was collected, and an Augmented Dickey-Fuller (ADF) test was conducted to determine the seasonality of the data. With this understanding of seasonality, it was integrated into the SARIMA model. Subsequently, model estimation was performed, and finally, the SARIMA model was executed to obtain forecasted values to have the predictive demand for the next 10 months.

3.2.2 Component 2: In this stage of the study, an exhaustive data collection has been carried out regarding the costs inherent to the generation of purchase orders within the specific context of the project. This includes, fundamentally, the cost of product acquisition and the associated storage costs, aspects that directly impact the profitability and efficiency of the process.

Additionally, detailed information has been gathered regarding the delivery times of orders, complemented with sales projections for the next 10 months obtained through the SARIMA model, thus providing a solid foundation for analysis and decision-making.

Based on this data, an analytical approach has been applied to determine the Economic Order Quantity (EOQ), representing the optimal quantity to be purchased in each order, the formula of which can be visualized below. This analysis aims to minimize total inventory costs, leading to a more efficient resource management and a significant improvement in business profitability.
Moreover, this study allows for the derivation of other key indicators, such as Safety Stock and Average Inventory, crucial aspects to ensure an adequate inventory level and to guarantee operational continuity under optimal conditions.
In summary, this analytical approach provides a solid foundation for inventory management optimization, significantly contributing to the development and competitiveness of the organization in the market.

$$Q = \sqrt{\frac{2DS}{IC}}$$

3.2.3 Component 3: In this stage, it is crucial to implement a policy for the application of the FEFO (First Expired, First Out) practice with the purpose of ensuring that the oldest products are sold first, thereby reducing losses caused by expired products. In addition to establishing this policy, it is essential to train the staff in its implementation. Upon receiving products from suppliers, they should be stored on shelves organized by expiration date. This means that products closest to their expiration date should be placed in visible and easily accessible locations, while those with later expiration dates should be positioned towards the back. This ensures adherence to the FEFO policy, where products closest to expiration are sold first. This strategy will significantly contribute to mitigating the high rate of product deterioration before sale.

3.3 Implementation model

In Figure 2, the detailed process for implementing the proposed model is explained.

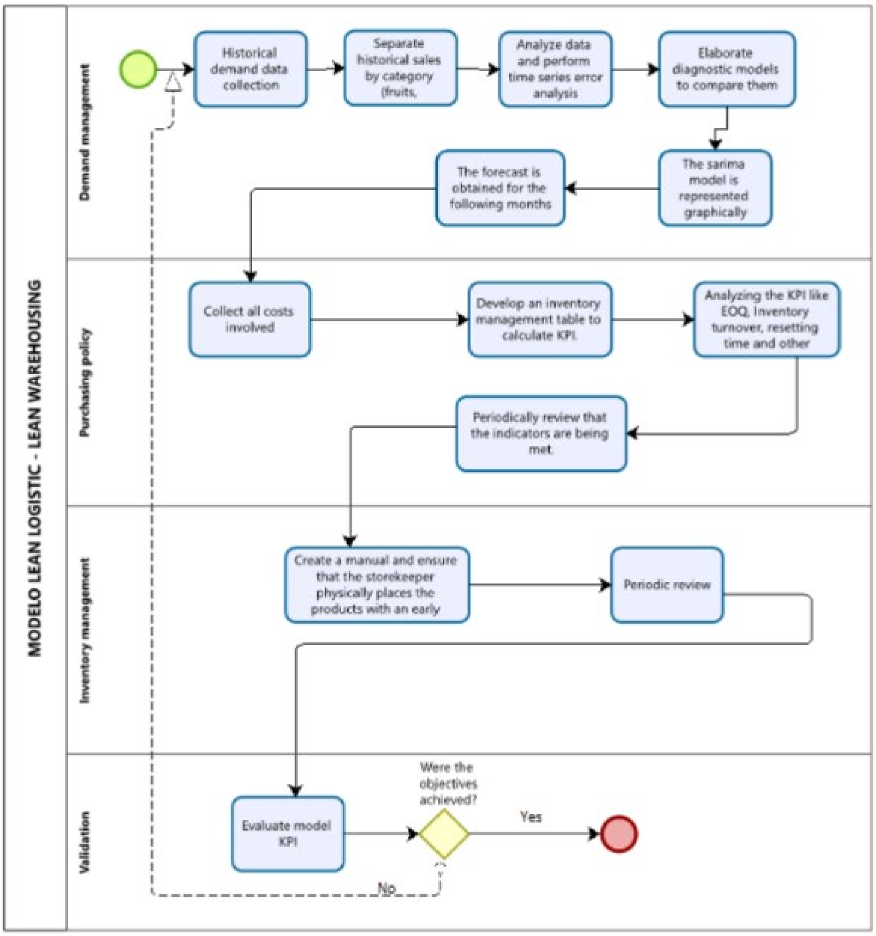

Figure 2. Proposed Model

3.4 Indicators of the model proposal

Table 2 details the 5 indicators, aligned with the components of the model and the literature, in order to measure them and validate the proposed model.

Table 2. KPI

KPI	Formula	Use

% Products sold before expiration date	$PSBED = \frac{Total\ products\ sold}{Expired\ products}$	Several studies indicate that the proposed model can reduce this indicator to a value of less than 3% (Carbajal et al., 2023).
Inventory turnover	$IT = \frac{Total\ sales}{Average\ Inventory}$	Several studies indicate that the proposed model can maintain the present indicator between 7-9 times during a period of 10 months (Gonzales et al.,2023).
Stock-out rate	$SOR = \frac{\#\ Breakage\ per\ unit\ of\ time}{Total\ period}$	Several studies indicate that the proposed model can maintain this indicator at a maximum of 5% (Neyra et al., 2023).

4. Results and Discussion

4.1 Numerical Results

When the processes of the supply area of a Peruvian supermarket were diagnosed, it was identified that it had a high rate of nonconforming products. Since this is a supermarket that handles various categories, the ABC method was used to select the 3 products that generate the most income, which are Groceries (34%), Fruits (11%) and Vegetables (13%), and from these 3 categories, the shrinkage due to expired products was analyzed and an average of 6% was obtained, while the average for the Chilean industry is 3.27%. (Capece, 2021).The conclusion is that there is a gap of 50%, which translates into a greater loss compared to the sector, as can be seen in Figure 3.

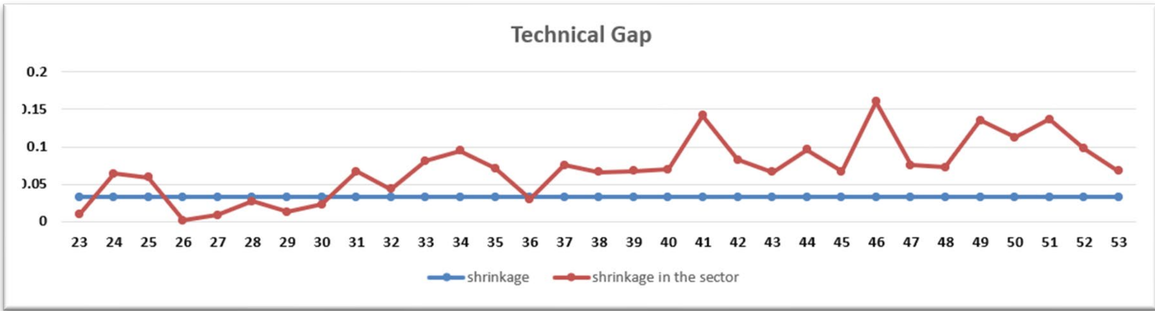

Figure 3. Technical Gap

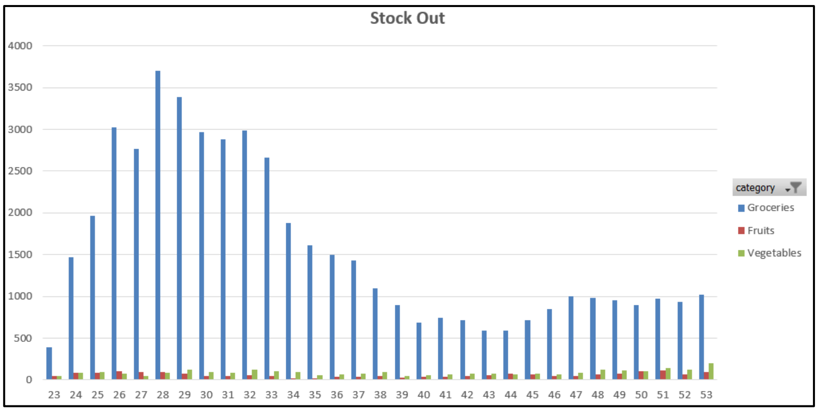

Figure 4. Stock out.

In addition, the year 2023 was taken as a sample and it was detected that there were periods when the products were out of stock. Figure 4 shows the number of times the categories were out of stock per week, i.e., there was a high percentage of stock out.

4.2 Proposed Improvements

4.2.1 Machine Learning

In order to attack the problem explained above, we will first employ the machine learning methodology using the SARIMA model to predict and analyze the demand and time series. The components are mixed with the calculation of the trend and seasonality of the time series, allowing predictions to be made that fit the proposed model, considering historical data and repeating patterns.

It is necessary to validate the seasonality of product sales, for which the time series of products to be analyzed uses the SARIMA model, as shown in (Table 3, Figure 5, Figure 6, Figure 7).

Table 3. Forecast demand by category

Month	Fruits	Vegetables	Groceries
2024-03	123,328	96,476	1,220,435
2024-04	106,738	89,856	1,198,471
2024-05	118,049	108,155	1,390,589
2024-06	96,203	101,714	1,512,253
2024-07	80,730	79,420	860,971
2024-08	94,763	95,970	963,569
2024-09	87,341	86,664	1,523,968
2024-10	84,506	78,461	1,025,122
2024-11	91,069	73,323	578,235

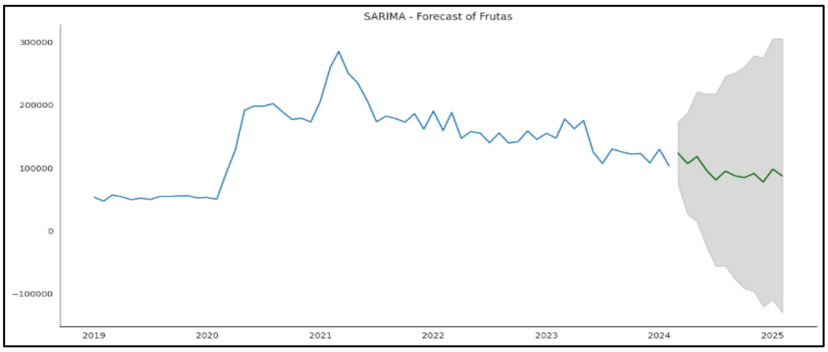

Figure 5. SARIMA – Forecast Fruits

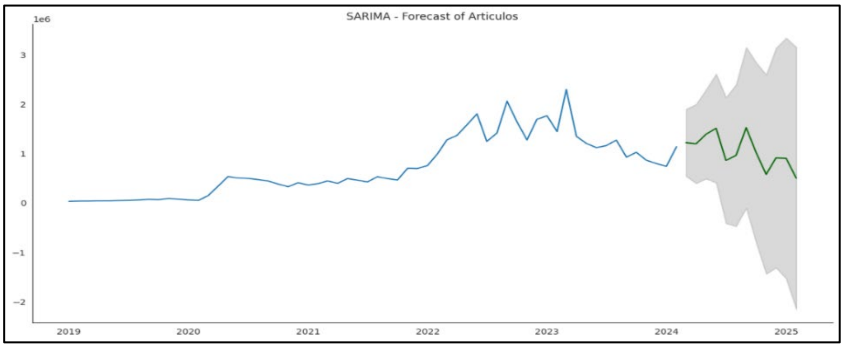

Figure 6. SARIMA – Forecast Vegetables

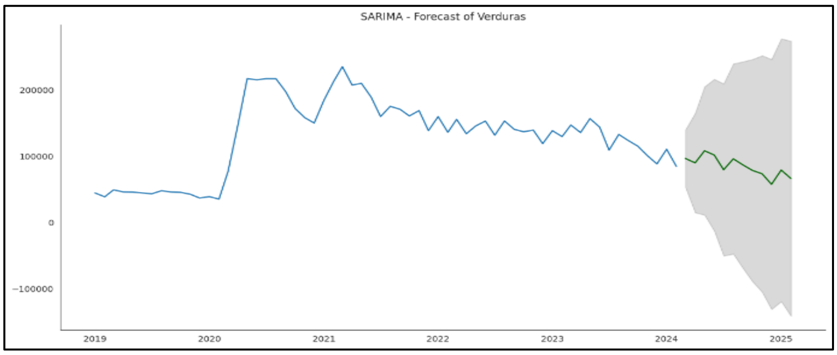

Figure 7. SARIMA – Forecast Groceries

Table 4 shows the MAE obtained for each product. According to Cabrera et al (2022), an MAE of less than 30% is acceptable for a company in the consumer goods sector in Peru. This indicates that the model is capable of accurately predicting patterns in the data over time.

Table 4. Errors

Error	Fruits	Vegetables	Groceries
MAPE	12.3422%	13.7068%	20.6503%
MAE	16495.3061	16230.7796	147168.0457
MSE	505327230.2370	477439177.5026	52017278755.9679
RMSE	22479.4847	21850.3816	228072.9681

4.2 EOQ (Purchasing Policy)

To mitigate errors in the forecast, a purchasing policy will be established, stock revision, which will help the supply area to have an estimated quantity to order at the exact time and in this way, there will always be products in stock, but without falling into overstock.

As shown in the figure, a template is created based on the EOQ method and with it we can have several indicators, as shown in the cells highlighted in orange, which will help to make decisions for a correct supply (Table 5).

Table 5. EOQ

SKU	Product	Current Stock	Total Demand	Standard Deviation	Z(95%) = 1.64	Cost of placing a purchase order (S)	Lead Time	Days Storage Cost (i%)	Price	EOQ (quantity to order)	T (resetting time)	SS (Safety Stock)	Average Inventory
65500	Florida Corn Oil - 1 Lt	75	55	1.76798669	2	40.20	3	80%	**23.4**	3.56	23.18	5.02	23.45

4.3 FEFO

For the implementation of this method, the people in charge of the warehouse were trained on the new methodology to be used, which covered its advantages and its purpose. Currently they were implementing the FIFO method; however, to attack the problem of expired products before sale, it is important to implement FEFO, because since they are working with food, the most important thing is to work with the shelf life. Continuing to use the current FIFO method would affect the indicator, since many suppliers bring products with different expiration dates.

5. Validation

5.1 Validation design and comparison with initial diagnostics

As for the validation of the FEFO methodology, a pilot project was carried out in the warehousing area. Figure 8 shows the visual manual for warehouse personnel. It refers to the arrival of the product, the reception and the storage operation, the order of the products on the shelves is visualized, so that the products that will go on sale will be the first to expire. For this reason, this method will help mitigate the problem of expired products before sale.

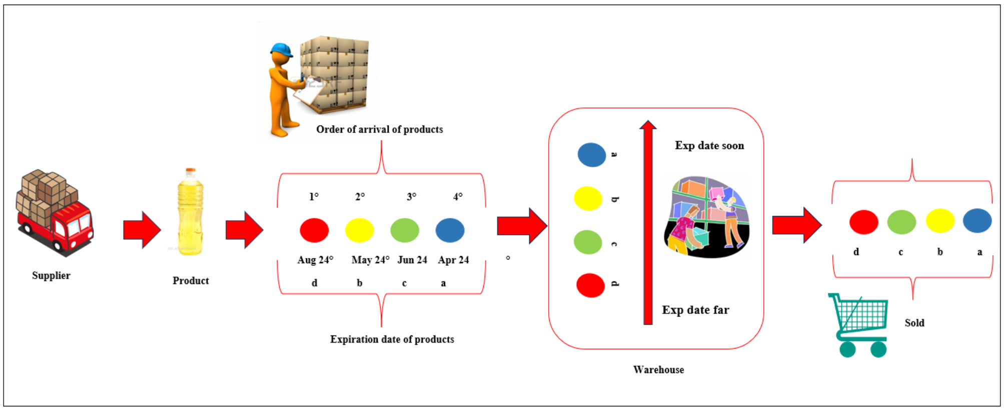

Figure 8. Visual Manual Fefo

5.2 Validation of improvement proposal simulation and the simulation model in the Arena software

After having detected that one of the current problems is that the products that are stored do not have an order, a new storage proposal was made which was the FEFO model, see figure 8, the other problem is not having a good forecast, for this reason the SARIMA and EOQ tools were implemented, this process will be added before performing the analysis for the supply of the product for the validation of the 3 proposed models will be used the Arena software.

As a sample, the last fourteen months of work of the operators in charge of the storage activities of the distribution center were taken; taking a confidence level of 95% and 5% for the margin of error for the analysis of the probabilistic distribution for each activity, taking as a factor for the start and end of a replica the 14h that lasts a working day (Table 6).

Table 6. Count of recurses

Resorurces	Quantity
Receiving operator	2
Order preparation operator	1
Quality operator	1
Supply Analyst	1

The system starts with the arrival of orders, as there are more than 1000 SKUs, only 3 products of each category will be sampled (trays of strawberries, trays of mushrooms and bag of rice), but in each arrival there is a probability of purchase of each product, it is worth mentioning that this information was obtained from the historical sales behavior of each of them. Likewise, the customer has the option of buying different options, i.e. he can buy a single product and pairs of products as shown in Table 7, for this purpose the purchase behavior of each customer buying products in pairs was analyzed and based on this, a probability of purchase was given to each one. Once the probabilities are defined, the stock verification process is carried out by one storekeeper and is released when the order is finished. In this verification, the warehouseman first verifies if the order is for a single product or in pairs and then proceeds to the stock check, if there is stock of the complete order or only a partial one. If there is only a partial order, only the partial order is attended and the unattended order is considered an unsold product, but an attended order. In addition to this, it counts how many orders were lost. The process is the same for each product, but another order cannot be processed without finishing the verification of the first one. The next process is to perform the pick-up and preparation of the order, here the orders are prepared as only one product or the pair of products is prepared, for this activity the staff that performs this process is another staff, the time it takes is 3 to 6 minutes and that is where the order arrival process ends; however for the improvement the FEFO method will be added in the order preparation process, that is to say that the products with short expiration date will be dispatched.

Table 7 Couples of producto

	Combinations per couple
1	Rice - Strawberry
2	Strawberry - Mushroom

3	Rice - Mushroom

On the other hand, replenishment is staffed and it takes 8 to 10 minutes to place a purchase order. The bottleneck is that the purchase order is generated when the product is out of stock, but with the improvement the EOQ method will be implemented so it will have a maximum limit to buy and a periodic review will be performed, also a reorder point will be considered as an alert to place an order before running out of stock. On the other hand, the supplier has a delivery time of 7 days. Once the order is shipped, the supplier replenishes within 7 days. There is a warehouseman who is in charge of receiving the products and another warehouseman who is in charge of stacking the products on the shelves; however, with the improvement of the process of storing the products on the shelves, this will be done using the FEFO model. Parallel to this is the operation of the quality area, where the resource is a staff that daily reviews the products that have passed their expiration date.
The data obtained was analyzed in the Arena software with the Input Analyzer tool, where each distribution for each process was evaluated and then chosen. Table 8 shows the results of the variable distributions obtained by Input Analyzer

Table 8: Distribution of Time by Process

Nº	Random Variable - Actual	Distribution	Units
1	Time between order arrivals	Expo (28)	minutes
2	Number of SKUs per order	Probability	percentage
3	Time to verify stock	UNIF (1,5)	minutes
4	Time to generate purchase order	UNIF (1,5)	minutes
5	Time to receive products from supplier	UNIF (40,60)	minutes
6	Time to store products in the warehouse	UNIF (25,30)	minutes
7	Time to pick up the order	UNIF(3,6)	minutes
8	Time to prepare the order	UNIF(3,6)	minutes

Figure 9 shows the complete simulation of the order arrival process, the checks that are made to the stock either by stock out or expiration date and the replenishment process. Figure 10 shows the same model with the addition of the 3 proposed tool, where the red mark is, is where the improvement was implemented.

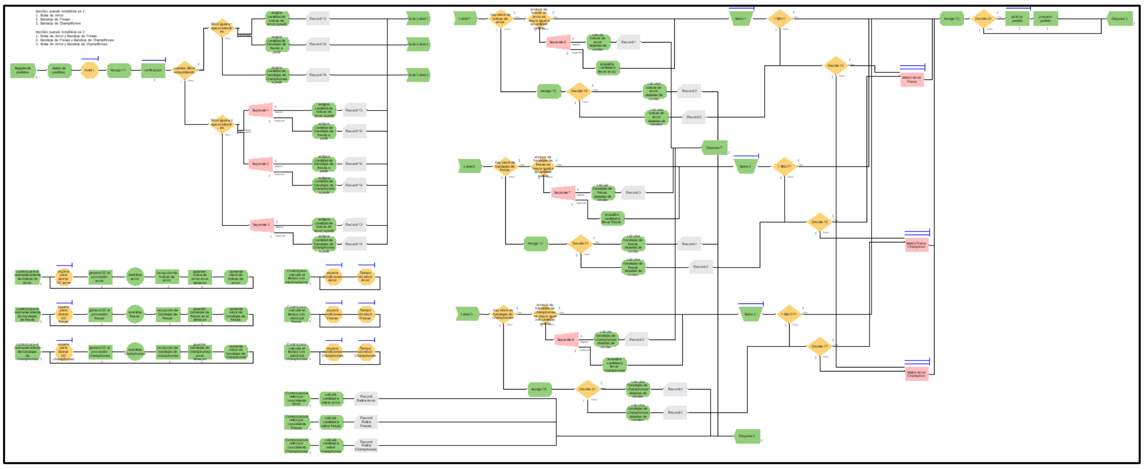

Figure 9. Actual Model

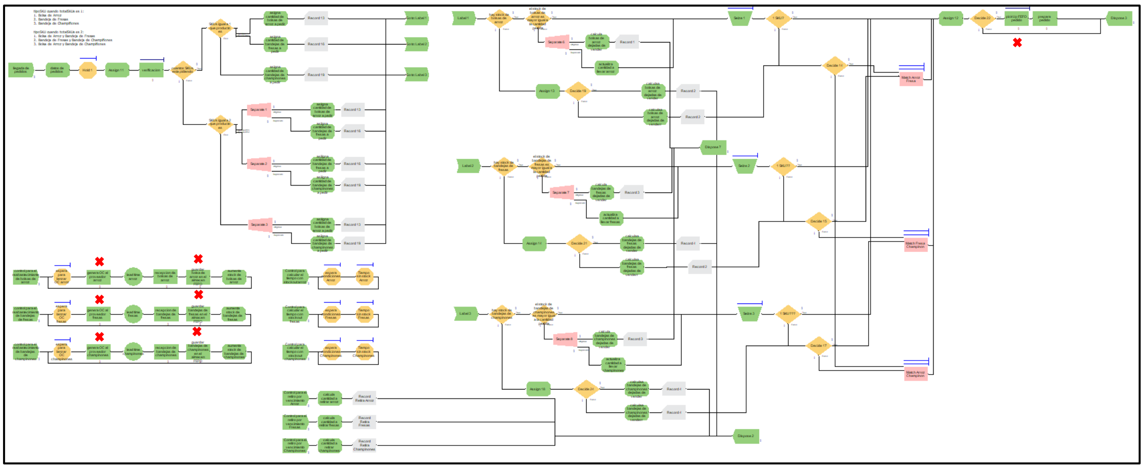

Figure 10. Proposal Model

For the calculation of the number of replicates needed by the simulation system for the 3 selected products, 129 replicates were taken as a preliminary sample to improve the accuracy of the model and the confidence intervals obtained and were introduced in the Arena software, giving a mean width of 60.53, very close to the desired 60.71 and with a CI [2808, 2929] units.

Table 9 shows with the indicators that there were improvements of the current model against the proposed one. The FEFO tool reduced the number of expired products by more than 15%, while the inventory turnover increased by approximately 4%, and the number of days without stock of stored products was reduced by 20%.

Table 9 Indicators

Producto	**Tools**	**Indicator**	**Before**	**After**	**Improvement**
Strawberry	FEFO	% Products sold before expiration date	22%	3%	products recalled by expiration date was reduced by 19%
	EOQ	Inventory turnover	1	5.27	Inventory turnover increse by 4%
	EOQ	Stock ou rate	23%	3%	Days out of stock reduced by 20%
Mushroom	FEFO	% Products sold before expiration date	23%	3%	Products recalled by expiration date was reduce in 20%
	EOQ	Inventory turnover	1	6.15	Inventory turnover increse by 5
	EOQ	Stock ou rate	23%	3%	Days out of stock reduced by 20%
Rice	FEFO	% Products sold before expiration date	24%	3%	Products recalled by expiration date was reduced by 21%
	EOQ	Inventory turnover	1	2	Inventory turnover increse by 1
	EOQ	Stock ou rate	23%	3	Days out of stock reduced by 20%

6. Conclusions

The findings of this research on improving inventory management in supermarkets through the implementation of tools such as FEFO, SARIMA and EOQ include a significant reduction of non-compliant products. The proposed model managed to significantly reduce the rate of non-compliant products in supermarkets, which represents a substantial improvement in operational efficiency and profitability. The combination of FEFO, SARIMA and EOQ proved effective in addressing issues such as product expiration, demand prediction errors and inadequate purchasing policies. The validation of the results through simulation using Arena software provided additional confirmation of the effectiveness of the tools implemented in inventory management. The integration of SARIMA and EOQ resulted in an increase in inventory turnover and a decrease in stock shortages, which contributed to more efficient management of products in supermarkets. The research not only demonstrated the effectiveness of the proposed model, but also contributed to knowledge in the field of inventory management in the retail sector, providing other supermarkets with a reference to address similar problems. These conclusions highlight the successful implementation of the proposed tools and their positive impact on inventory management in supermarkets, underlining the importance of innovative approaches to improve operational efficiency and reduce losses from non-compliant products.

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