9

Demand and Inventory Simulation using Time Series.

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Abstract

The importance of implementing an adequate demand and inventory management process improves coordination in supply chain models. The purpose of this research is to analyze and propose the application of a forecasting technique and the implementation of a continuous inventory review policy by designing a simulation for a company in the veterinary commercial sector. Currently, companies without this coordination obtains an inadequate inventory level generating losses in profits and a low demand level of service. This study presents as a result an optimization model based on the ARIMA technique and an inventory model simulated in Arena software.

Keywords
Inventory management, Time series, Optimization, Simulation.

1. Introduction

Nowadays, many companies are adversely affected by poor inventory management, which has a negative impact on the level of service offered to the customer and on the company's profits. According to Alharkan et al.(2020)it is stated that inventory management plays an important role in sustaining the balance between supply and demand, since it is one of the activities associated with the management of customers and suppliers. Also, according to Wang et al. (2020), the role of inventory management is to balance the stock level and customer demand since the uncertainty of the latter is difficult to predict. Therefore, due to such uncertainty, two unfavorable and recurring problems related to inventory demand arise: destocking and overstocking. For Vo et al. (2021), these problems require companies to pay attention to forecasting work because this is the most effective method to know the market demand. In fact, demand forecasting is a necessary and indispensable activity for any business.

On the other hand, demand forecasting is complemented by the recurrent application of tools for inventory management and control in the warehouse. One of the most commonly used methods are inventory policies, which according to Wang et al.(2020)According to the company, they manage the system's inventory efficiently and have two distinct policies, continuous review and periodic review.

Currently, there are many demand forecasting techniques and inventory control tools to decrease the problem of uncertainty between demand and supply. In this regard, Lei et al. (2019) states that many products are handled in the inventory of companies that on a large scale pose new challenges in forecasting demand. Likewise, this situation causes traditional forecasting methods not to adjust to the high complexity generated by large amounts of inventory, resulting in a lower predictive efficiency. However, as he mentions Benhamida et al. (2021)However, as he mentions, many companies are relying on their historical sales and demand records, and the availability of new tools and data processing methods to design and implement new inventory management systems.

For this reason, the application of time series tools for demand forecasting is presented as an important tool; as mentioned by Priore et al. (2019) by highlighting this type of techniques as a promising advance for the field of inventory management. Also Hussein et al. (2019)He also assures that previous studies have been using time series algorithms for the design and creation of predictive models for demand forecasting.

Pavlyshenko (2019) manifests regarding the development of new tools and processing methods, great progress has been achieved in time series modeling due to new programming languages and methods of data processing and analysis, being possible to obtain time series models such as ARIMA, SARIMA, SARIMAX, Holt Winters, etc. more effective and efficient.

In this study, time series models, such as the ARIMA and Holt Winters methods are used to obtain the demand forecast while the application of the Arena simulation technique will allow finding the appropriate inventory level and evaluating the correct inventory management. As stated by Al-Fandi et al. (2019) proper drug inventory management in healthcare systems prevents under and overstocking. Similarly, Franco et al. (2018) argues that it is more complicated to manage the supply chain of pharmaceutical companies because specific methods are not developed for this type of industries. Likewise, it is necessary for drugs and supplies to be always available and within reach. In reference to the following research question arises:

Are time series and simulation techniques suitable to improve the inventory management of a Peruvian veterinary pharmaceutical company?

The contribution of this research at an economic level is to reduce uncertainty in inventory management, thus reducing inventory costs and improving the level of service of the company under study. Also, at a practical level, the results of the research can be used by other companies in the sector that wish to apply a technique to forecast their demand and improve their inventory management.

1.1 Objectives

This article seeks to achieve the following objectives:

a). To analyze the results and the impact of the application of the time series technique in the optimization of the demand forecast of the pharmaceutical company.
b.) To analyze the results and the impact of the application of the Arena simulation technique in the optimization of the inventory reorder point control for an improvement in inventory management in the veterinary pharmaceutical company.

2. Literature Review

According to Conceição et al. (2021) the process of managing a company's inventories should be continuous and planned and with the objective of structuring the goods so that they are aligned with the company's needs and thus ensure proper administration. Likewise, supply and demand are correctly balanced to avoid overstocking. Based on this, the objective of inventory management is to have the products available in the right quantity and timely manner (Singh and Verma 2018).

To this end, there are various techniques, methods, strategies, and policies to organize and manage the inventory efficiently and effectively. Along these lines, there are two widely used resource management policies: periodic review and continuous review. According to Heng and Chiadamrong (2019) there are common policies for managing inventories with specific decision rules to determine with greater certainty the 'time to order', and the size of the order or 'quantity to order'. As for the continuous review policy(Q, r), Alharkan et al. (2020) mentions that demand and delivery time should be considered as initial and constant parameters or as random variables under a probability distribution behavior. In this type of policy, a minimum level or reorder point is considered, in which the inventory position should not be lower than this level since it will be time to make replenishment purchases to restore the inventory level. The following important concepts are defined within this inventory policy.

Safety stock, described by Anglou et al. (2021) is defined as the quantity needed to satisfy demand and the variability in delivery time and is expressed by the following formula:

$$Safety\ stock = FS.\sigma.\sqrt{\frac{LT}{PP}} \tag{1}$$

Where:

σLT: Demand deviation LT: Supply time
PP: Period number FS: Service Factor

Also, Heng and Chiadamrong (2019) defines the reorder point as the minimum level of warehouse stock that allows the company to replenish itself through a product purchase order. It is expressed by the following formula:

$$Reorder\ Point\ = D.L + SS \tag{2}$$

Where:
Ss: Safety stock
D: Demand L: Lead time of demand

In addition, for Wang et al. (2020) the economic lot or EOQ model describes the ideal and adequate relationship, under certain assumptions, between the order quantity and the different logistics costs, considering among them the cost of placing orders, the cost of holding inventory and the unit cost of the product.

$$Economic\ Lot - EOQ\ (\ Q^{\circ}) = \sqrt{\frac{2.D.S}{h.C}} \tag{3}$$

Where:
D: Annual demand S: Ordering cost per lot
h: Annual percentage maintenance cost C: Unit cost per product

However, due to the current computational technological advances, various demand forecasting techniques have been incorporated into inventory management. For Lolli et al. (2019), many forecasting techniques are based on machine learning, which is a computational discipline that enables the automation of complex decision-making processes but requires large amounts of information and data for its correct execution. In this line of development, the integration of these techniques with programming languages such as R makes it possible to enhance the application to a greater extent and obtain better results.

One of the functionalities of these Machine Learning techniques in favor of inventory management is the ease of making forecasts based on historical data, which facilitates demand forecasting and will allow proper inventory management. In other words, as stated by Benhamida et al. (2021) through the application of Machine Learning, new demand forecasting methods have been proposed and developed, driving several studies to implement techniques such as the time series method or some of its variants.

Seyedan and Mafakheri (2020) specify that time series are methods for extracting information from sequential numerical data of a certain complexity, considering that such data are recorded at intervals of constant time periodicity. In addition, this technique is considered a supervised method, since it predicts future behavior based on patterns of previous behavior, hence the need for historical data for its application. It should be noted that this technique has variants, one of which is known as smoothing methods.

A first smoothing method is the ARIMA model or Autoregressive Integrated Moving Average Model, which according to Vo et al. (2021) is considered an effective methodology for forecasting trends and fluctuations with seasonality. This method, by eliminating the non-stationary variation of the historical data record, is able to predict future values. Generally, ARIMA (p, d, q) projection models are differentiated by the non-negative integer parameters p, d and q, which delimit the smoothing method.

$$(1 - \phi^1 B - \phi^2 B^2 - \cdots - \phi_{\mathrm{p}} B^{\rho})(1 - B)^d\, X_t = \left(1 -\ \nu_1 B -\ \nu_2 B^2 - \cdots - \nu_q B^q\right) a_\tau \tag{4}$$

Where:
p: order of the autoregressive model q: order of mean movement
d: degree of differentiation

On the other hand, there is the Holt Winters smoothing method or Triple Exponential Smoothing Method, which according to Vo et al. (2021) is an ideal methodology for analyzing a series of seasonal and trend data. Similarly, this method predicts, and forecasts based on historical data using a level constant α, a trend constant b, and a multiplicative seasonal constant γ.

$$F_t = \alpha\,(At - 1) + (1 - \alpha)(Ft - 1) \tag{5}$$

Where:
αSmoothing factor

In recent years, research shows positive and optimal results of the use of time series technique in demand forecasting and for the simulation technique in optimizing the inventory level and profits of the company. According to Al-Fandi et al. (2019) and what was exposed in their study, reveals that modeling and simulation are suitable tools to determine the most effective inventory policy for a drug supply chain. Moreover, simulation is a technique widely used in several previous research to optimize the reorder point in a continuous review policy. This technique allows a similar replication of reality by defining variables and processes.

In the study conducted by Vo et al. (2021), a comparison of ARIMA and Holt Winters methods for demand forecasting was applied to simulate an optimization in an inventory model. The results of their study expose the solutions for the improvement of supply through the application of demand forecasting models in addition to a set of production policies applied to ensure an optimal inventory level. A predictive ARIMA model is proposed and chosen, whose forecasts are subsequently used in a simulation model in Arena under the EQP technique to determine the optimal production lot.

The positive results of the application of Machine Learning techniques are also reflected in the results of Pavlyshenko (2019), who makes a comparison of time series models based on Machine Learning techniques, such as ARIMA, RandomForest, Neural Network, whose results show a behavior like the real one and with low error deviation between the applied models.

On the other hand, according to Al-Fandi et al. (2019), after performing a simulation model in Arena, the results show statistically significant improvements in the cost indicators and the fill rate of each drug. With these results, it was possible to establish an inventory policy with optimal parameters for pharmaceutical products.

Next, the study conducted by Alsolami, (2020) proposes a simulation model to optimize the inventory level through a forecast to a historical demand of uncertain behavior. The result of the simulation concludes the need for the company to maintain a minimum safety stock to achieve inventory availability. Likewise, it reduces the negative effects of not satisfying the demand and avoids the subsequent economic loss to the organization.

Finally, the study conducted by Conceição et al. (2021) highlights the importance and the need to perform forecasts and correctly apply inventory policies in addition to other inventory control techniques such as the economic lot, since the actual implementation of such measures in the study allowed to achieve as a result a reduction of 48% in the value of inventory by stock without movement, which represents a reduction and savings of R US$ 386,614.74.

3. Methods

This research is structured under a quasi-experimental methodological design. This research will use three methods or techniques applied to the processed data of the company's activity during the last 18 months. Figure 1 shows the stages of research and the activities carried out in each project phase. In the first instance, in phase two of the research, the ABC categorization technique based on Pareto was used to select the 54 products to be used, which represent 50% of the total accumulated sales of the pharmaceutical organization. On the other hand, in phase 3, after obtaining the historical sales data of the 54 products, the second technique was applied, the time series method in ARIMA models using R programming language in Rstudio software and Holt Winters in Microsoft Excel VBA software to achieve the sales forecast for the next 4 months. Prior to the next phase, the best forecast was chosen by comparing MAE, MAPE, MSE error rates of both time series methods.

Finally, the simulation technique was carried out in phase 4 through the Arena Simulator program to generate an optimal model according to the real characteristics of the company, considering the adequate application of a continuous revision policy based on the reorder point and economic quantity of re-supply defined for each product.

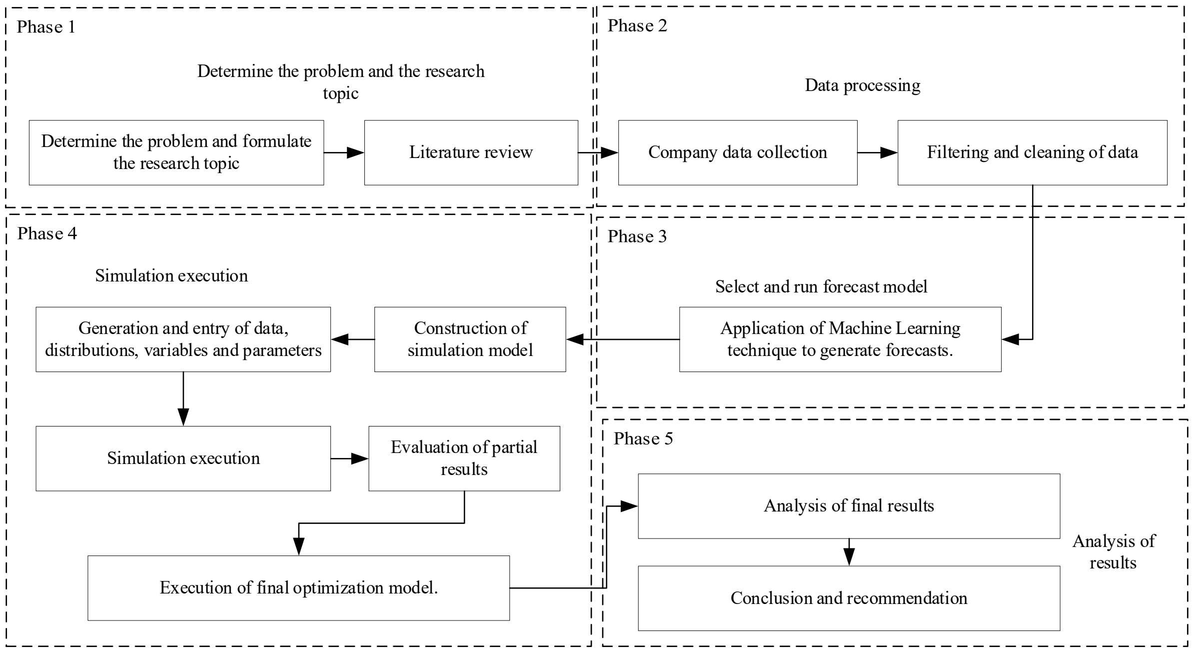

Figure 1. Stages of the investigation

4. Data Collection

The data was obtained from a peruvian company that implemented an improvement in its demand process and manages1555 stock keeping units (skus). However, it should be noted that for the information selection procedure, a sample of 54 products was selected from a population of 1555 products in inventory of the company under study, considering two main exclusion criteria. The first criterion eliminated those products with less than 18 months of information on historical demand, to filter out products with intermittent demand. The second criterion was based on excluding those products that do not belong to class A inventory stock, after performing an ABC classification to categorize based on the company's sales information.

5. Results and Discussion

5.1 Numerical Results

The findings found after the application of the methods, procedures and techniques that make up this research show the following results. After applying the time series methods to the historical record of demand, both ARIMA by means of a code in R programming language and Holt Winter through VBA language, it is observed that the ARIMA methodology presents a lower tendency to error and shows projections with greater precision than the Holt Winters method. For such comparison of model error, the MAPE and RMSE error indicators were applied.

As can be confirmed through the following table 1, the ARIMA time series show higher accuracy by having lower error, both the first product with 22.47% versus 23.04% and the subsequent ones with 22.76% to 30.95%, 15.76% to 28.16%, verifying the suitability of the ARIMA model versus Holt Winters, for the prediction of the demand of the pharmaceutical-veterinary company under study.

Table 1. Comparative table of the error of the Arima and Holt Winter model.

Products	**Arima**		**Holt Winters**	
	MAPE	**RMSE**	**MAPE**	**RMSE**
Apoquel 16 Mg X 20 Tab	22.47%	7	23.04%	8.39
Apoquel 16 Mg X Tab	22.76%	60.23	30.95%	89
Azodyl X 90 Capsules	15.76%	8.62	28.16%	13.8
Azodyl X Cap	11.00%	144.8	14.19%	215.22
Biocan Dhppi + L X 1 Ds	28.23%	103.31	28.23%	103.31
Biocan Dhppi + Lr X 1 Ds	25.57%	98.4	42.07%	171.79
Biocan Puppy Dp X Ds	28.89%	136.07	41.57%	178.9
Bravecto 10 - 20 Kg	17.07%	24.94	19.03%	28.37
Bravecto 20 - 40 Kg	20.82%	23.97	24.56%	28.32
Bravecto 4.5 - 10 Kg	17.07%	20.44	20.98%	23.94

Next, at the beginning of phase four of the research, we proceeded to define the parameters and values necessary to implement an adequate continuous review policy in the optimization proposal simulated in the study.

One of those parameters to be defined is the reorder point. This concept will allow to identify the situation in which the inventory requires replenishment to continue satisfying the demand and can be calculated using the formula (2). Another of those concepts is the economic lot quantity, which is the quantity of product to be replenished where logistics costs coincide at a lower level. By means of equation (2) and (3) respectively, the calculation is precise to obtain the data of table 2

Table 2. Determination of Reorder Point and Economic Lot Quantity

Products	**Average monthly demand**	**Reorder point**	**Economic Lot Quantity (EOQ)**	**Number of orders per year**	**Days for resupply**
	(Units)	**(Units)**	**(Units)**	**(times)**	
Apoquel 16 Mg X 20 Tab	59	39	18	26	14
Apoquel 16 Mg X Tab	414	239	55	80	5
Azodyl X 90 Capsules	56	31	22	31	12
Azodyl X Cap	1168	521	102	153	2
Biocan Dhppi + L X 1 Ds	299	137	54	80	5
Biocan Dhppi + Lr X 1 Ds	345	160	54	78	5
Biocan Puppy Dp X Ds	377	200	57	85	4
Bravecto 10 - 20 Kg	160	88	33	47	8
Bravecto 20 - 40 Kg	97	55	30	44	8
Bravecto 4.5 - 10 Kg	109	49	30	43	8

Once the parameters of the continuous review policy to be implemented in the company had been defined, the simulation scenarios were carried out. The first simulation scenario was carried out in order to emulate the company's current behavior. The second scenario was used to include the improvements made, both the demand forecast evaluated in Table 1 and the inventory policy and logistic parameters defined in Table 2. Likewise, the following model indicator was used as a comparison criterion between the two scenarios.

Monthly profit per product
This indicator measures the average profit generated quarterly.

$$Average\ Profit = inventory\ sold * Mg - Cost\ Log\ Total \quad (8)$$

Where:
Mg: Profit margin
Cost.Log.Total : Total logistic cost

It should be considered that the total logistics cost considers the different logistics costs such as storage cost, ordering cost, warehouse maintenance cost, among others.

5.2 Graphical Results

After running the simulation and analyzing the results obtained in the improvement scenario, the profit indicator was optimized. The average profit value of the improvement scenario amounts to USUS$ 3,490.4, while the average in the initial situation registers a value of USUS$ 2,179.1, thus showing an optimization of the profit value by 60.18% with respect to the company's current situation.

In this circumstance, there is an interquartile range of profits in the improvement scenario with a larger dimension, from 1,997 to 4,253 dollars, than the interquartile range of the current scenario, with values from 1,222 to 2,515 dollars. The above confirms a growth and optimization of the proposed improvement model. Figure 2 shows the distribution of the profit values in a cash flow chart in both scenarios.

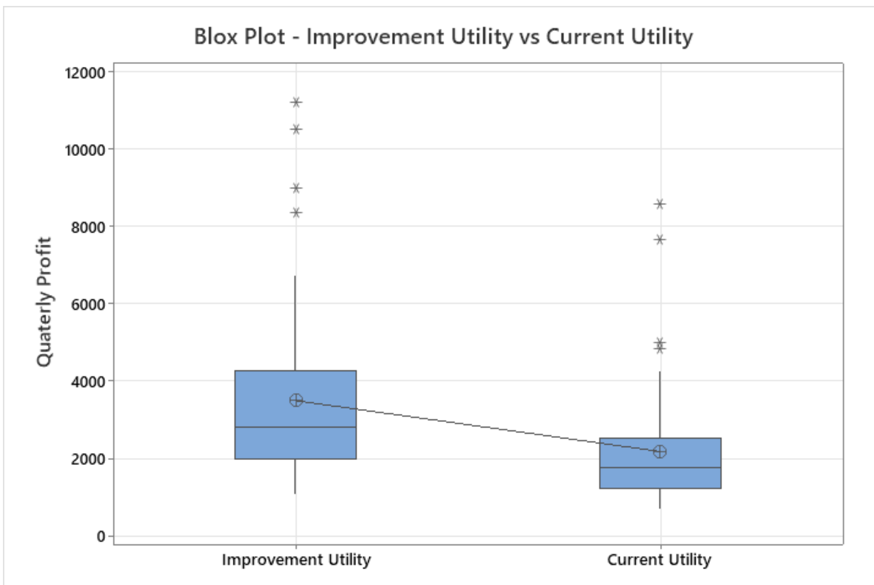

Figure 2. Utility Cash Flow Chart

Figure 3 also shows a comparison of the monetary values of the profit in both the initial scenario and the improvement scenario considering each product. In this way, the growth in the value of profits after the implementation of the optimization is reflected proportionally.

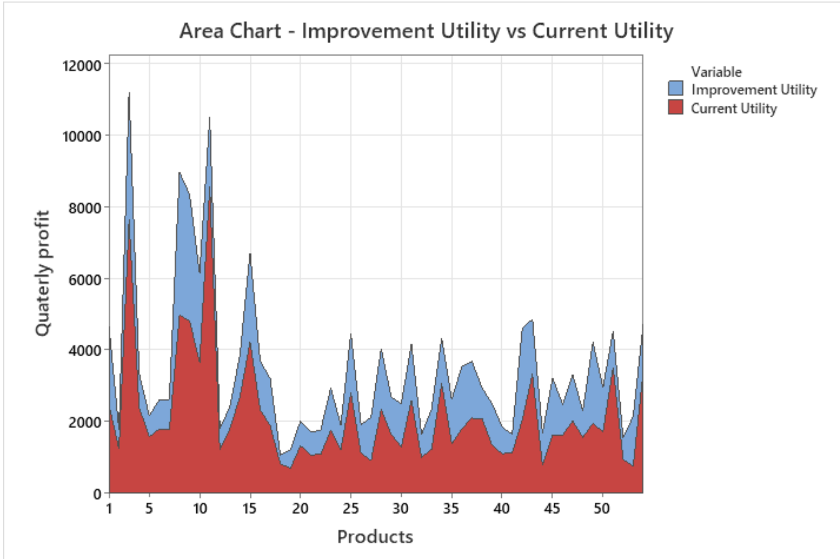

Figure 3. Graph of utility areas

5.3 Proposed Improvements

The proposals for improvement presented to the veterinary pharmaceutical company under study in its current situation are based on the results found in this article. The first improvement to be considered is the application of the time series forecasting method in its ARIMA variant developed in R programming language in this study. This is due to the purpose of reducing uncertainty in demand and avoiding problems of shortages and overstocking.

ikewise, as a second improvement to be considered is to establish a policy of continuous review together with the logistic parameters to find a balance between demand and inventory. The following are the concepts to be implemented in the inventory as a proposed improvement to the current situation of the company.

The difference found between the values presented in Table 2 and those currently used by the company, which have been determined incipiently and empirically, should be highlighted. For example, in the case of the reorder point found, these values presented are higher than those currently used by the company, doubling it for certain products. In addition, a similar situation occurs with the quantity to be replenished; the economic lot quantity calculated in the table triples the values used by the company. Likewise, the periodicity for restocking is higher for certain products, exceeding the range of 3 to 7 days managed by the company.

The third improvement to be considered is the application of a simulation model, developed in ARENA Simulation, with the parameters and requirements of the company. This last improvement is proposed to balance the first two improvements to find the demand and inventory balance. This model is then presented in the form of a logical schematic in Figure 5.

5.4 Validation

To validate the simulation model used, the similarity of the model's behavior with the real behavior was compared. Numerical evidence of this is the approximation of the monthly profit indicator obtained from the simulation, which has an average of US$ 117,671.01 at 95% confidence, within the range of 106,382.98 and 132,978.72 dollars managed by the company. It should be noted that after the confirmation of the model indicator, thirty replications were determined for the simulation of the model in the Arena Simulator software.

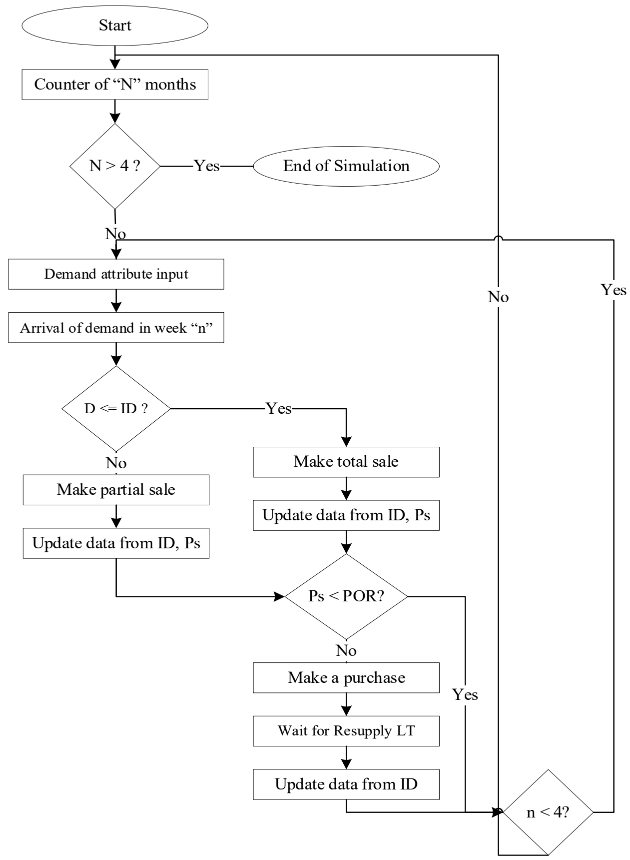

Figure 5. Schematic diagram of the Arena simulation model

Where:

N: Week number
n: Number of month
ID: Inventory on hand
Ps: Inventory item
POR: Reorder point
LT: Lead time

In addition, to verify whether the values obtained after implementing the proposed improvements, demand forecasting and inventory policy, represent an optimization of the model, both sets of model values are evaluated and statistically compared, the utility of the products in the real situation versus the utility in the improved situation. Table 3 shows the 10 products with the highest sales of class A inventory together with their profit in both scenarios. Comparing both scenarios show an increase in the profit improvement scenario of US$ 70,810.638, which represents an increase of 60.18% with respect to the current scenario. Thus, the current profit valued at 117,671.01 dollars can be optimized by means of the proposed improvements to a profit improvement of US$ 188,481.91.

Table 3. Comparative table of monthly profit by product

Products	**Utility (Dollars)**	
	Current	**Improvement**
Apoquel 16 Mg X 20 Tab	2,486.17	4,659.84
Apoquel 16 Mg X Tab	1,247.34	1,788.30
Azodyl X 90 Capsules	7,637.50	11,208.51
Azodyl X Cap	2,402.39	3,348.14
Biocan Dhppi Mas L X 1 Ds	1,585.90	2,174.20
Biocan Dhppi Mas Lr X 1 Ds	1,801.86	2,616.49
Biocan Puppy Dp X Ds	1,781.38	2,628.99

Bravecto 10 To 20 Kg	4,973.67	8,967.82
Bravecto 20 To 40 Kg	4,824.73	8,349.20
Bravecto 4.5 To 10 Kg	3,662.77	6,137.23

To test the above statements, a statistical analysis was performed in Minitab comparing both sets of utility values. A paired t-test was then applied, defining a 95% confidence interval. The characteristics of the statistical test used are summarized in Table 4. Likewise, the null hypothesis (H_o) was defined as the situation where there is no difference in utilities in both scenarios, so there is no improvement or optimization of the current situation. The alternative hypothesis (H_1) represents the scenario in which there is a significant difference between samples, and therefore, there is an optimization of profits in the improvement scenario.

Table 4. Paired difference estimation

Average (dollars)	State deviation (dollars)	Standard error of the mean (dollars)	95% CI for difference_µ
1,311.44	798.14	108.51	(1,093.35; 1,529.26)

As a result of the statistical test, the null hypothesis (H_o) was rejected when a p-value of less than 5% of the significance level was obtained and the alternative hypothesis was accepted. Thus, the proposed improvements represent an optimization scenario for the profits of the company under study. The significance values necessary to reject the null hypothesis in the statistical test are presented in Table 5.

Table 5. Paired t-test results

Paired t-test	
Null hypothesis	H_0: difference_µ = 0
Alternative hypothesis	H_1: difference_µ ≠ 0
T-value	12.07
p-value	0.001

After obtaining previous results, the findings show the feasibility of applying the ARIMA time series method by programming language as a variant of the time series technique, useful and effective for forecasting the demand of the company under study. Likewise, the present study exposes the possibility of applying a continuous inventory revision policy, confirmed based on the positive results of the utility indicator in the simulation. These results affirm the possibility of implementing an improvement in inventory management through a time series forecasting technique and the simulation technique.

In this sense, the results found on the demand with respect to the realization of forecasts with Time Series tools and simulation, are in accordance with what Vo et al. (2021) stated in their study, in which they point out the effectiveness and usefulness of the ARIMA forecasting technique over the Holt Winters technique, as well as the convenience of applying the simulation technique to determine an adequate productive lot. Although the study by Vo et al. (2021) is carried out in a productive company, this is not limiting for the results found in the marketing company of the present research, since the results expressed in the section on results show its viability.

On the other hand, the study Pavlyshenko, (2019) mentions and highlights the application of Time Series techniques to make forecasts on sales and demand. This research shows the possibility and feasibility of applying other Time Series techniques, such as regressions, to make forecasts obtaining lower results in error indicators compared to the ARIMA time series method. This background shows a greater possibility of applying other predictive techniques;

however, these require studies that evaluate their application to pharmaceutical demand models, which represents an area to be investigated in future studies.

In relation to the study of Conceição et al., (2021)who applied a 48% reduction improvement in the inventory value after the application of a continuous review policy and the implementation of traditional moving average forecasting, the present study differs in the application of the type of forecasting tool. The developed study differs by applying time series tools to avoid the difficulty of traditional forecasting techniques that lose predictive effect in situations of large quantities of products. However, if it agrees with the results of the study by Conceição et al., (2021) and its indicators on the usefulness and its relationship with a correct application of a revision policy.

Regarding the second part, the realization of a simulation to evaluate an improvement based on a continuous review policy, the results presented in the study by Al-Fandi et al. (2019), who after finding results, affirms that by means of simulation in Arena it is possible to achieve significant improvements in cost and fill rate in an inventory model. Likewise, the application of the simulation technique is present in the study of Alsolami (2020) who states that by means of a simulation he finds the forecast of an uncertain demand. Both studies show the versatility of the simulation technique in logistics models. Although the present study applies simulation as a technique to emulate an inventory model, the described studies do not apply any revision policy in their improvement proposals, so that certain parameters such as purchase quantity and supply range are not completely defined. The results of the present study show that a revision model complements the realization of the demand forecast.

6. Conclusion

After the completion of this study, it is concluded that it is feasible to propose an optimization scenario in inventory management through the ARIMA forecasting technique based on programming language and the simulation technique. The results obtained from this study show that it is feasible to propose an optimization scenario where the net profit achieves an increase of 60.18%, which represents US$ 117,671.01 additional to the current situation.

Likewise, it was possible to fulfill the main objective of the study to analyze and propose an efficient demand forecasting method and to propose an inventory policy suitable for the company to reduce uncertainty in both demand and inventory in search of a demand and inventory balance. For the above, it should be noted that it was necessary to apply a demand forecasting technique and a continuous review model based on a reorder point, adding, and proposing a defined economic lot quantity and a replenishment period. With respect to the practical implications of this study, the procedure developed in this study is presented as an improvement tool that encourages the correct practice of inventory management for other companies of the same characteristics, in terms of sector and size.

Finally, the article presented is proposed as a first step for future scientific research related to the topics developed. Also, as a proposal for future research is to study the seasonality of veterinary pharmaceuticals and its impact on the current logistics model.

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