Proceedings of the 21st International Conference on Modelling and Applied Simulation (MAS), 006
19th International Multidisciplinary Modeling & Simulation Multiconference

2724-0037 © 2022 The Authors.
doi: 10.46354/i3m.2022.mas.006

Simulation inventory policies of vaccines at the Veterinary "El Trébol"

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Abstract
Inventories are essential for any company, in the case of commercial companies, inventories are the support of their main activity: the purchase and sale of products. Poor inventory management, as well as a null or poor inventory policy, can lead to loss of money, loss of customers, or even bankruptcy, raising the question of whether there is a way to obtain an ideal inventory policy for microenterprises and to determine the economic impact of such a policy. This article proposes the use of discrete event simulation to analyze the impact of changes in different scenarios for inventory policies in the Veterinary "El Trébol", and thus determine an adequate policy for the revision of vaccines, to have the lowest average price as possible.

Keywords: Simulation, Inventory policy, Veterinary, Average price, EOQ model

1. Introduction

In Mexico, microenterprises represent 97.25% of companies (ENAPROCE, 2018), so it is extremely important to seek their preservation and growth. One of the key factors for its growth is good inventory management, as this involves ordering material, storing, keeping records with the help of software, to keep costs low, meet customer demand and thus maximize their profits.

> *"Good inventory management results in good product quality and more efficient operations. However, mismanagement can have an impact on unhappy customers and financial problems that can drive the company into bankruptcy."* (Torres and Garcia, 2018)

Not having someone who knows enough about inventories triggers to decide empirically or even not handle them properly, which leaves open the possibility of improvement, therefore the effort was focused on a micro-enterprise and the implementation of a solution in the aspect of inventory.

The veterinary clinic and pet shop "El Trébol" has been operating for more than 20 years and it's located in avenue Las Torres Mz 560-Lot 14, Plateros, 56356 Chimalhuacán, Mex. It offers different services, however, for this article the focus of attention are the vaccines: Puppy 6, Puppy 4, Bordetella, Sextuple with rabies, Rabies, Leukemia, and Triple feline.

In the Metropolitan Area, according to data from INEGI (DENUE, 2021), veterinary clinics are divided into the private and public sectors, in addition, some of them are specialized in livestock while some others in pets, as it is shown in Figure 1. The service veterinarian for pets of the private sector has an occupation of 98%, which corresponds to the State of Mexico a 51% of this percentage, where the clinic is located.

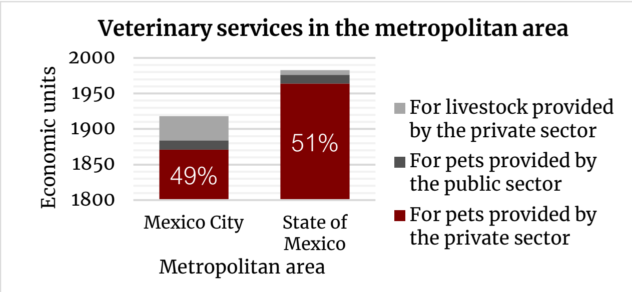

Figure 1. Public and private veterinary services in the metropolitan area, with data from INEGI, DENUE 2021.

Clients located in Chimalhuacán are more likely to not return to the clinic if they do not have the requested vaccinations or medications, such behavior has been seen over the years of working in that area by the owner of the Veterinary Clinic. Therefore, it is important to always have vaccines to avoid the loss of potential customers. In this way it is important to review inventory policies to know when and how much to order.

The management of the inventory is carried out manually, the manager keeps a control of the sales made in the day through a notebook, but the registration of the stock of the products that leave is not made, In the same way there are erroneous data and lack of information collected daily.

The design and simulation of the vaccine inventory system will be shown for the selection of the inventory policy that adapts to the needs of the "El Trébol" Veterinary clinic; the process followed to determine the inventory policy will be addressed through simulation using @Risk to help to validate which inventory policy is enough to avoid stockouts and reduce the costs. Similarly, it will be of potential help for a future expansion that is currently proposed.

2. State of the art

Discrete Event Simulation helps explain how inventories behave and their importance; inventories support activities, such as maintenance, repairments or planning (Stevenson,2015), customer service (pull and push systems) and support the variations in the supply chain (Durán, 2012). The use of simulation allows veterinaries to develop and validate different alternatives to be reproduced and to quantify their benefit with affordable resources (Microsoft Excel® and @RISK). Durán assures that inventory is one of the most important investments for a company, in relation to the rest of their assets, as they are critical for sales, optimizing profits, keep a minimum stock available for sale, meeting customers' demand, among others (Durán, 2012). It is essential to always consider that they involve a cost.

Experience have demonstrated the effectiveness of Discrete Event Simulation (DES); it has been the mainstay of simulation community for over 40 years, in specific for subjects such as Operational Research (Siebers, et al., 2010). It is known that DES models are process oriented and their input distributions are often based on collect/measured (objective) data, which makes it a great option for inventories simulation. Two examples can be found below: Zhang, et al. propose a DES case for perishable inventory management, where they maximize profits and determine an optimum inventory scheme, working with inventory models and estimating profit curves. Bhosekar, et al. showed its use for coordinating management and material handling in hospitals, by building sceneries where the best option assumes full coordination with Just-In-Time approach. It is important not to consider only the simulation, but external tools and approaches in order to have a complete analysis.

Economic Order Quantity is the fundamental model for inventory control, and it answers the questions *"how much to order?"* and *"when to order?"*. Simulation has been present in the creation of scenarios of the EOQ model to create optimized systems and analyze risks and important variations without compromise the real system and its elements. Gallego, Gallego and García provide a simulation case study for an optimize system to reduce procurement risks and stock-outs making use of Excel, since "it includes additional programmable functionalities with standard tools and allows the storage and interconnection of databases for their calculation and processing" (Gallego, Gallego and García, 2021). For this reason, most of the cases of simulation orientated to EOQ model use Excel and get successful results.
Inquilla and Rodríguez (Inquilla and Rodríguez, 2019) used the @RISK software in combination with Monte Carlo Simulation, and present how the model was able to respond to the real dynamics of the project, including the distribution of the data and considerable variations. This software allowed them to visualize probabilities and costs within 1000 iterations, therefore, @RISK is a Microsoft Excel add-in that has multiple applications in industries, to analyze risk and uncertainty. In this case, it was used to estimate the minimum and maximum inventory, in order to optimize inventory management by identifying the required vaccines. This leads to lower costs, improved quality of service, and retention of customers.

Chowdhury et al. indicates that SMEs often have limited resources and knowledge to collect and use data and, as a result, are unable to effectively leverage advanced support tools such as DSS or enterprise resource planning (Chowdhury, Lau, and Pittayachawan, 2019) and they are more vulnerable than the LE in terms of competitive advantages (Industry 4.0) and it leads us to an issue of digital transformation and this is the case of the "Trébol" veterinarian, so we agree that data and information are essential for decision making (Teerasoponpong and Sopadang, 2021). No articles were found where @RISK was used in a scope or size of organization similar to the veterinary "El Trébol", therefore the relevance of writing this paper, taking Inquilla and Rodríguez as a reference from the simulation, were successful. Using computational modeling techniques, since the built systems combine the descriptive richness of verbal and mathematical models; "... this allows to analyze and model the behavior of any complex, systemic environment, facilitates the presentation of future scenarios, and optimizes resources and time for those who use it" (Izquierdo, Galán, Santos, et al., 2008).

3. Materials and Methods

Nowadays, simulation is a fundamental tool for engineering projects; simulation helps us to model and to understand how a system work in a visual way, it provides information and most importantly, it helps organizations to make decisions. The concept system was defined by Wymore (1967) as a basis for unifying various forms of discrete and continuous model specification. Most processes of an organization could be described by a sequence of discrete events, that occurs at a particular instant in time and alter the state of a system. This is called discrete-event simulation.

For this article, three stages of simulation were taken on count (Harrel, Ghosh and Bowden, 2004), based on Chapter 5 "Getting Started" of "Simulation Using ProModel" by Harrel, Ghosh and Bowden. This approach helps modelers to set a base for the experiment, also to ensure that the necessary resources (trained personnel, budget, and time) are in place to conduct the study. It is also important to consider a methodology for the development and implementation of the simulation.

1. Planning: Preliminary activities
    a. Specialized software selection the development of modeling and simulation
    b. Methodology or technic of simulation selection
    c. Personnel and responsible of modeling identification

2. Implementation: This is the longest stage in terms of time, required budget and efforts. Successful simulation projects are well planned and coordinated, and the following steps are recommended to conduct a simulation:

    a. Define objective, scope, and requirements
    b. Collect and analyze system data
    c. Built the model
    d. Validate and verify the model
    e. Conduct experiment

3. Closing:

    a. Present the findings
    b. Make recommendations

3.1. Process

There were two fundamental processes to understand the system: Customer service process (Figure 2) and vaccine ordering process (Figure 3).

- **Entrance to the consulting room**: A check of the patient immunization record is carried out to know which vaccine is required

- **Vaccination**: The pet is vaccinated

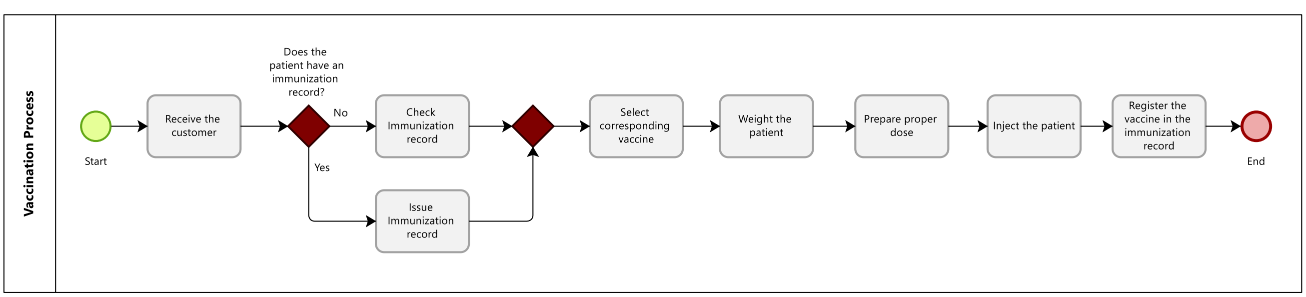

Figure 2. Vaccination customer service process mapping

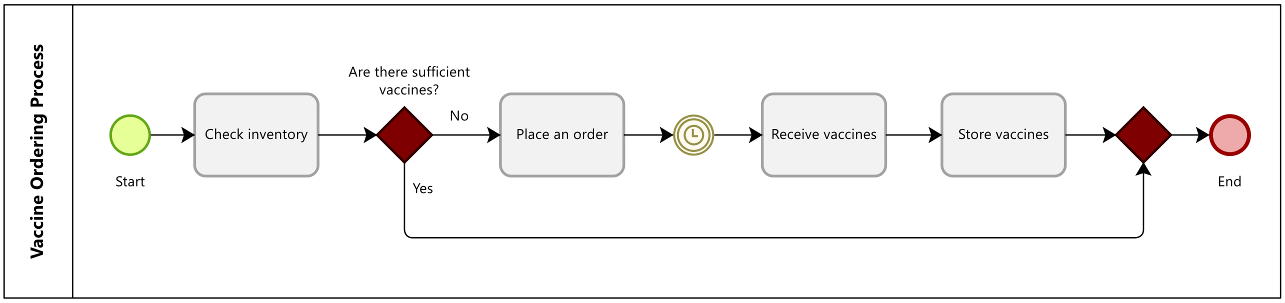

Figure 3. Vaccine Ordering Process

- **Exit of the consulting room**: The vaccine is recorded in the immunization record and in the clinic's sales record.

It is important to consider that by the zone the veterinary is located there are several veterinaries nearby, and if the client do not find the product or the vaccine they are looking for, they leave and buy to another veterinary. On the other hand, if they find the product, they tend to become a loyal customer. That is the reason it fundamental that the Vaccine Ordering Process gets improved and controlled.

3.2. Economic Order Quantity (EOQ) Model

Assumptions

- The inventory follows the EOQ model without shortages.
- Data were obtained from historical records from March 6 to October 23 of 2021. This data was entered into a computerized system.
- A weekly demand is being considered for 33 weeks, from Sunday to Saturday.
- Available vaccines are:
  - Puppy 6
  - Puppy 4
  - Bordetella
  - Sextuple with rabies
  - Rabies
  - Feline leukemia
  - Triple feline

Input variables

- Vaccine's demand
- Vaccine's cost

Decision variables

The decision variable for this model is the number of units to order or quantity to order (Q), which is a positive integer.

The cost parameters are known with certainty:

- c = unit cost ($/unit)
- i = annual cost of maintaining inventory (% per year)
- h= ic = annual cost of holding inventory ($/unit per year)
- A= ordering cost ($/order)
- D= weekly demand
- $K(Q)$= average annual cost according to batch size

$$K(Q) = cD + \frac{AD}{Q} + \frac{hQ}{2}$$

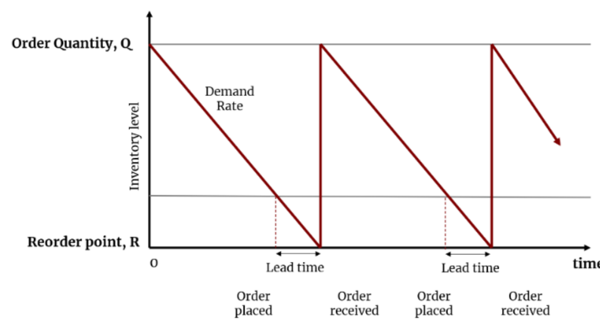

Figure 4. EOQ Model geometry

Indicators of performance:

- Reorder point
- Average price
- Holding cost
- Ordering cost
- Shortage cost

3.3. Data collection

Data related to vaccines and inventory were obtained through the information provided by the owner of the veterinary and the written record of all sales including other products and services offered by the veterinary. This register contains information on sales from 6 March 2021 to 23 October 2021.

A filtering of the information focused on the quantity sold for each vaccine offered was performed, obtaining the information shown in Table 1. Likewise, the prices and costs of the vaccines shown in Table 2 were obtained.

Table 1 . Vaccines sold from March 6, 2021, to October 23, 2021, at the "El Trébol" veterinary clinic

Vaccine	Number of vaccines sold
Bordetella	20
Feline leukemia	3
Sextuple with rabies	13
Triple feline	18
Puppy 4	33
Puppy 6	74
Rabies	30
Total	191

Table 2. Costs and prices of veterinary vaccines "El Trébol"

Vaccine	Cost	Price
Bordetella	$ 5.76	$ 12.00
Feline leukemia	$ 5.76	$ 14.40
Sextuple with rabies	$ 5.76	$ 14.40
Triple feline	$ 5.76	$ 14.40
Puppy 4	$ 5.76	$ 15.36
Puppy 6	$ 5.76	$ 15.36
Rabies	$ 5.76	$ 14.40

The veterinary did not have information about the weekly cost of placing an order, as well as the maintenance of the inventory, so the information was collected for the calculation of these. For the cost of placing the order the following information was collected:

- Weekly salary: $72
- Time to make a request: 10 minutes
- Hours of veterinary service per week: 65 hours

The calculation was made by multiplying the salary by the 10 minutes it takes to place an order, all this between the 65 hours multiplied by the factor of conversion of hours to minutes:

$$Weekly\ cost\ of\ placing\ an\ orden = \frac{(\$72.00)(10)}{65 * 60} = \$0.18$$

As for the holding cost, the energy consumption of the mini refrigerator used to conserve vaccines is involved. First, an investigation was made of the price of the energy consumption tariff of the Federal Electricity Commission (C.F.E.) where the intermediate consumption tariffs were used, since the veterinary is in such consumption and the average tariffs were calculated during the period of registration of the vaccines (Table 3).

Table 3. Prices of C.F.E. intermediate consumption tariffs during March 2021 until October 2021.

Month	Intermediate consumption [$/kWh]
March	0.0499
April	0.0501
May	0.0502
June	0.0504
July	0.0505
August	0.0506
September	0.0508
October	0.0509
Average	0.0504

Subsequently the support of a calculator was needed for the energy consumption of a refrigerator provided by "Refrigeradores.top" (Figure 5), where the data of the number of hours of use of the refrigerator, use of energy of the mini refrigerator, which is 120 watts and finally the average rates obtained previously.

Figure 5. Calculator for your refrigerator's energy consumption by Refrigeradores.top

Once having the cost per day, it is multiplied by 7 to get the weekly cost of maintaining the inventory.

$$Weekly\ cost\ of\ holding = \$0.1452\ (cost\ per\ day)\ x\ 7\ days\ of\ week = \$1.0160$$

3.4. Simulation and scenarios

The simulation model is based on the influence diagram shown in Figure 6. It shows that factors were considered to obtain the average inventory price. The simulation was performed for a period of 52 weeks, in other words, one year. The vaccines that were considered for the simulation are: Puppy 6, Puppy 4, Bordetella, Sextuple with rabies, Rabies and Triple feline.

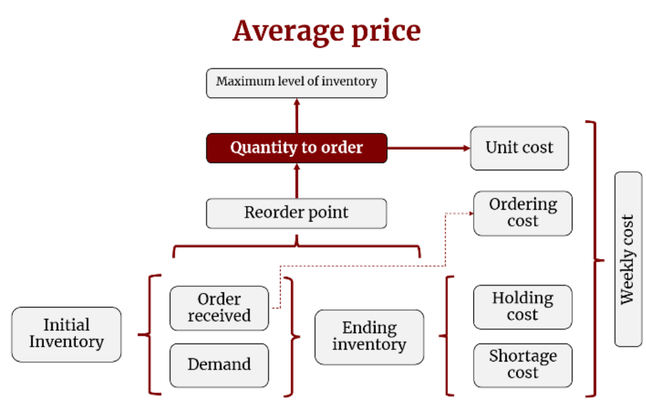

Figure 6. Average price influence diagram

The factors determining the inventory policy were first established:

- Missing costs
- Holding costs
- Fixed cost of ordering

- Cost per unit purchased
- Order up to
- Reorder point

Then the programming is done in Excel for the 52 weeks where it is considered:

- Initial inventory
- Quantity to order
- Next order received
- Demand
- Final inventory
- Cost

The average cost of the 52 weeks is obtained and with the help of the @Risk program and 1000 iterations were made, to obtain the minimum, maximum and mean of the average price. This was done for each vaccine and for various scenarios.

The scenarios for the determination of the inventory policy consisted in the variation of the reorder point for each vaccine from a reorder point of 1 vaccine to a reorder point of *n-1*, where *n* is the maximum inventory determined for each vaccine (Table 4).

Table 4. Maximum level of inventory for each one of the vaccines of the veterinary "El Trébol"

Vaccine	Maximum level of inventory
Bordetella	5
Sextuple with rabies	5
Triple feline	5
Puppy 4	10
Puppy 6	10
Rabies	5

4. Results and Discussion

With the help of the programs Minitab and Stat-Fit, it was determined that neither of the seven vaccines had a particular distribution, being the reason of the use of a triangular distribution to aid in the simulation. The data used in the triangular distribution for the simulation of each vaccine is showed in Table 5, except for the feline leukemia vaccine given that there are only three registered vaccinations in the period of eight months making possible the analysis of the inventory policy without the use of simulation.

Table 5. Amount of data collected, the minimum, maximum and mean of each vaccination record of the veterinary clinic "El Trébol" from March 6,2021 to October 23, 2021.

Vaccine	Amount of data collected	Minimum	Maximum	Mean
Bordetella	20	1	3	1.5384
Feline leukemia	3	-	-	-
Sextuple with rabies	13	1	3	1.3000
Triple feline	18	1	2	1.0588
Puppy 4	33	1	4	1.7368
Puppy 6	74	1	6	2.5517
Rabies	30	1	3	1.5000

By varying the reorder point for vaccines: Bordetella, sextuple with rabies, triple feline, puppy 4, puppy 6 and rabies; the mean of the average cost for each inventory policy was obtained, in Table 6 it can be observed that the lower the reorder point the higher average costs are presented.

From the results obtained, the mean of the average price is reduced by 49% in the case of the triple feline vaccine up to 87% with the Puppy 6 vaccine. Finally, inventory policies that reduce the average cost can be seen in Table 7.

Table 6. Mean of the average cost per vaccine and reorder point of the inventory policy of vaccines of the veterinary clinic "El Trébol" from March 6,2021 to October 23, 2021

Vaccine	Reorder point						
	1	2	3	4	5	7	9
Bordetella	$ 22.83	$ 17.72	$ 14.39	$ 5.88	-	-	-
Sextuple with rabies	$ 22.23	$ 17.05	$ 13.38	$ 6.48	-	-	-
Triple feline	$ 14.00	$ 10.50	$ 9.24	$ 7.21	-	-	-
Rabies	$ 24.38	$ 18.66	$ 14.68	$ 6.39	-	-	-
Puppy 4	$ 27.38	-	$ 20.20	-	$ 17.18	$ 17.29	$ 7.21
Puppy 6	$ 43.99	-	$ 33.70	-	$ 26.07	$ 17.03	$ 5.59

Table 7. Final inventory policy of vaccines of the veterinary clinic "El Trébol" from March 6,2021 to October 23, 2021

Vaccine	Reorder point	Maximum level of inventory
Bordetella	4	5
Sextuple with rabies	4	5
Triple feline	4	5
Puppy 4	9	10
Puppy 6	9	10
Rabies	4	5

5. Conclusions

By simulating inventory policies in @Risk and implementing a simulation model of discrete events "Monte Carlo", that a better understanding of the operation of the inventory was given by the model. It is necessary to have a fixed policy that allows the veterinary clinic "El Trébol" to reduce costs, while keeping the vaccine inventory stocked. This is due to, according to data analysis, there is a reduced demand for them. In the case of the Feline Leukemia vaccine, sales were too low, so it is only necessary to have one vaccine in stock and order another every time that vaccine is sold.

The costs of ordering ($ 0.18 dollars) and maintaining ($ 1.01 dollars) were obtained as results, with these data knowledge of the exact cost, the way it can affect the average price of the inventory policy and the finance, or the veterinary were understood.

As future work, it is recommended to make a digital transition, to have rapid access and manipulation of data and improve its management. It can be deduced that data and information are essential for decision making.

According to the scope of the simulation, the digitization of data would be focused on the vaccine inventory, due to its multiple advantages, such as not losing information on each of the sales, and the potential expansion of the analysis for other items that are currently commercialized, such as accessories for pets, pet food, medicines, among others.

In addition, it is considered that an analysis of the seasonality of the demand could be carried out, since there are seasonal threats, increasing vaccination, for example, rabies and vaccines for puppies. Finally, improving the management of the current inventory, and the competitive advantage over the rest of the veterinary clinics in the area by implementing customer service, following up on the next dog and cat vaccines with the clients.

Acknowledgements

To Lic. Luisa Carmen Salas García for opening the doors to the veterinary clinic "El Trébol", as well as giving access to data and information for the elaboration of this article. To Dr. Ricardo Torres Mendoza for providing his support and advice during the elaboration of the simulation and his comments and review at the time of writing this article. Finally, to Dr. Jenaro Nosedal Sánchez for his comments and review in the drafting of the article.

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