Service Level of Pharmaceutical Supply Chain Applying Optimal Policy: Case Study in Lima, Perú

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Abstract— Low service level is a serious problem for distribution companies in the pharmaceutical sector of Peru, mainly due to the uncertainties in the supply chain, coming from suppliers and customers. An important contributing factor is the inadequate management of inventories, since they do not know in advance the amount and right moment to place the order, thus generating a negative economic impact. Faced with this scenario, the proposal of this study is based on the development of an optimal supply policy for the sector considering two echelons (distributor and retailer), with the aim of increasing the service level and, therefore, the performance of the supply chain. The proposed method was solved analytically, and the solution has been illustrated with data obtained from an enterprise in the pharmaceutical sector using a sensitivity analysis; in turn, it was observed that as the service level increases, a greater total profit of the chain is obtained.

Keywords— *Supply chain, Optimal policy, Iinventory Management, Service level, Two-echelon, Pharmaceutical Model.*

1. Introduction

In the pharmaceutical sector, it is observed that there is constant importation, frequent movement of merchandise and regular intervention by foreign supplier that all impact the final delivery time of the products. The delivery time of foreign suppliers is a critical factor [1],[2] because the main countries of which Peru imports from are the United States (15.7%) and Asian countries (14.3%), the latter being the furthest geographically and with the time of longer shipping [3],[4].

In Peru, there are 504 registered drugstores, which explains the high competitiveness that together with globalization and mas consumption cause companies to seek a competitive service level [5],[6] through a high level of inventories [7], together with security stocks to counteract the uncertainty [8],[9].

However, as the bullwhip effect increases [10],[11], the distortion during the transmission of the order makes it difficult to identify the demand and increase the stock required [7],[12].

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On the other hand, if a minimum inventory is maintained, there is a risk of stockout [13] and the company is exposed to losses as a result of running out of one or more items [14]. This scenario is more critical for pharmaceutical products [15] such as Medical Devices (latex gloves, gauze, syringes) [16] and perishable items [17].

In an ideal inventory management system, it is important to maintain a coordinated strategy for all members of the chain [9], including managing variables referring to suppliers, manufacturers, wholesalers, retailers, customers; however, the warehouse is usually not aware of the service level of the retailer [18], and hence the performance of the entire chain as well total profitability will suffer [6],[19],[20].

The main motivation of this research is to demonstrate that the proposed solution is applicable to this sector (Global Market) and also can increase the total profitability of the supply chain [21],[22] of a pharmaceutical company, considering two echelon (distributor and retailer) [23],[24],[25] by increasing both levels of service and decreasing the cost of their inventories [26],[27].

Our results show that the efficiency of the supply chain was increased between 26.75 and 45.54% according to the service level (95 and 98% respectively).

The article is organized as follows: Section two consists of an overview of the main inventory models in the supply chain and their applications. Section three gives the methodology adapted from [28] that seeks to determine the optimal procurement policy for the sector. The case study in Lima is then presented together with the results of the investigation. Finally, the limitations, conclusions of the investigation and future recommendations are discussed.

2. Literature review

The research process began with the search, compilation, analysis and trends from academic journals that were published by the main publishers such as Science Direct, Scopus, Wiley, Francis & Taylor, Emerald Insight, Springer, among others.

We searched for terms such as "supply chain", "service level", "two echelon", "inventory management" in any of the titles, summaries or keywords. We limited our sample to articles that were published in English. The assignment of articles to the applied research methodology was limited to those published in recent years.

Table 1 illustrates the most relevant articles for our research of the 67 accepted papers and the belonging to the different topics based on conceptual and empirical models.

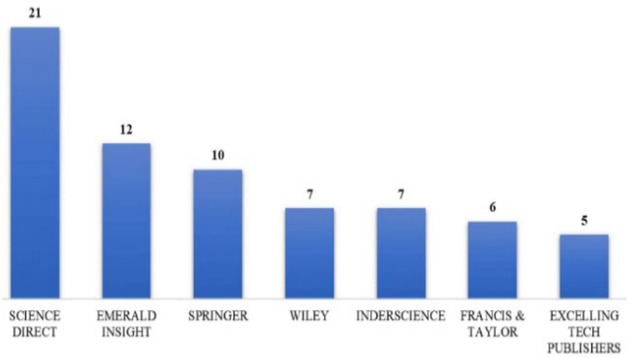

Figure 1. Research applied by databases, Source: Adapted from [29]

The two-echelon supply chain generally consists of distributors that sell their products wholesale to retailers, which in turn sell to end customers [18]. In addition, in the literature the service level [5] is defined as the probability of no shortages during replenishment time [30],[19]. Ref. [31] state that current trends seek to optimize costs associated with inventory, strategy, distribution and the overall supply chain, so that companies seek to make decisions based on their business strategy [29],[32] and adopt appropriate replacement policies, including the quantities (Q) and the order point (R) [18].

The characteristics of this article are classified in relation to decision policies, assumptions, limitations and solution methods compared to others found in the literature, see the Table 2. This paper considers a two-echelon supply chain that includes a distributor and a retailer [33],[34] where a replenishment policy (R, Q) is proposed for both and the total profit of the supply chain is evaluated.

The VOSviewer software was used to perform the bibliometric analysis that includes analyzes of co-citations [35] and helps to recognize the work developed on a topic and its evolution. The results are presented in Figure 2. The graph presented is a frequency map that shows the relation of the articles based on the authors cited in the bibliography through an iterative process, it provides the most repetitive topics and also the proximity and association between them under some relationship criterion. Next, we will detail the three most relevant topics in the literature review.

2.1. Supply chain

A supply chain is a system [36],[37] that includes suppliers of raw materials, production facilities, warehouses, distribution services, retailers and consumers, which are generally connected through a forward flow of physical products and backwards flow of information [38],[39],[4]. Supply chain management refers to the management and optimization of resources and flows between the business partners [12]. Supply chain management can directly influence inventory management, through the delivery times [40],[4] and the service level policies[41],[42]. One of the most relevant problems is the service level, since it involves the rate of pending orders, variability of the demand and the lead time, achieving that, as the delivery time of suppliers is reduced, the service level increases [15].

Ref. [43] raise the existence of three sources of uncertainty in a supply chain: suppliers, manufacturing and customers [9]. The first and second lead to variability in the delivery time and the third is responsible for variability in the order time or quantity. That is why, in response to varying demand, it is necessary to develop "time compression" and flexibility throughout the entire supply chain [44] and a good coordination of efforts is required based on the best available information, communication, and planning tools [45] to efficiently manage the risks in the chain [22],[46].

CONCEPTUAL	PAPERS	TIME OR INVENTORY DEPENDENT DETERIORATION RATE	♦	♦	♦
			Afshar-Nadjafi (2016); Rahimi, Baboli & Rekik (2016)	Nemtajela & Mbohwa (2017); Soni & Chauhan (2017); Sabet, Yazdani & De Leeuw (2017)	Babai et al. (2018); Chaudhary, Kulshrestha & Routroy (2018)
		SERVICE LEVEL	♦	♦	♦
			Salam, Panahifar, & Byrne (2016); Kurdhi et al. (2016); Kapoor & Shah (2016)	Abdul, Qianli & Zhang (2017); Wanke et al. (2017); Li, Sun & Huang (2017)	Truong & Hara (2018); Tsai & Ho (2018); Smet, Aghezzaf, & Desmet (2018)
EMPIRICAL	PAPERS	REPLENISHMENT POLICY	♦	♦	♦
			Felfel, Ayadi & Masmoudi (2016)	Li, Sun & Huang (2017); Serrano, Oliva & Kraiselburd (2017); Hyeon, Jong & Kim (2017);	Pasandideh, Niaki & Ahmadi (2018); Alawneh & Zhang (2018): Smet, Aghezzaf & Desmet (2018)
		TWO ECHELON INVENTORY MANAGEMENT	♦	♦	♦
			Protopappa-Sieke, Sieke & Thonemann (2016)	Noori-daryan & Taleizadeh (2017); Gharaei, Pasandideh & Arshadi (2017); Xu (2017)	Rahdar, Wang & Hu (2018); Esmaeili, Naghavi & Ghahghaei (2018); Phouratsamay, Kedad-Sidhoum & Pascual (2018); Wang, Miao & Yu (2018)
		YEAR	2016	2017	2018

Table 1. Timeline of topics reviewed in the literature, Source: Adapted from [21]

Paper	Value term / Metric	Concept / Value driver	Research method
Shen et al. (2017)	Strategic partnership / Shortage	Cooperative inventory influences the probability of shortage / Cost, shortage	Conceptual model, case example
Esmaeili et al. (2018)	Two-echelon inventory / Profitability	Policy (R, Q) improves the profitability of the chain based on the service level / Profitability, service level, customer orientation	Conceptual model
Kritchanchai & Meesamut (2015)	Product availability / Shortage	Policy (s, S) reduces the shortage of items / Cost, shortage, incomes	Conceptual model, case example
Li & Yu (2014)	Strategic partnership / Profitability	Two-echelon cooperative supply chain increases the product life cycle / Profitability, life cycle	Conceptual model, case example

Table 2. Value of selected articles, Source: Adapted from Ref. [39] [16]

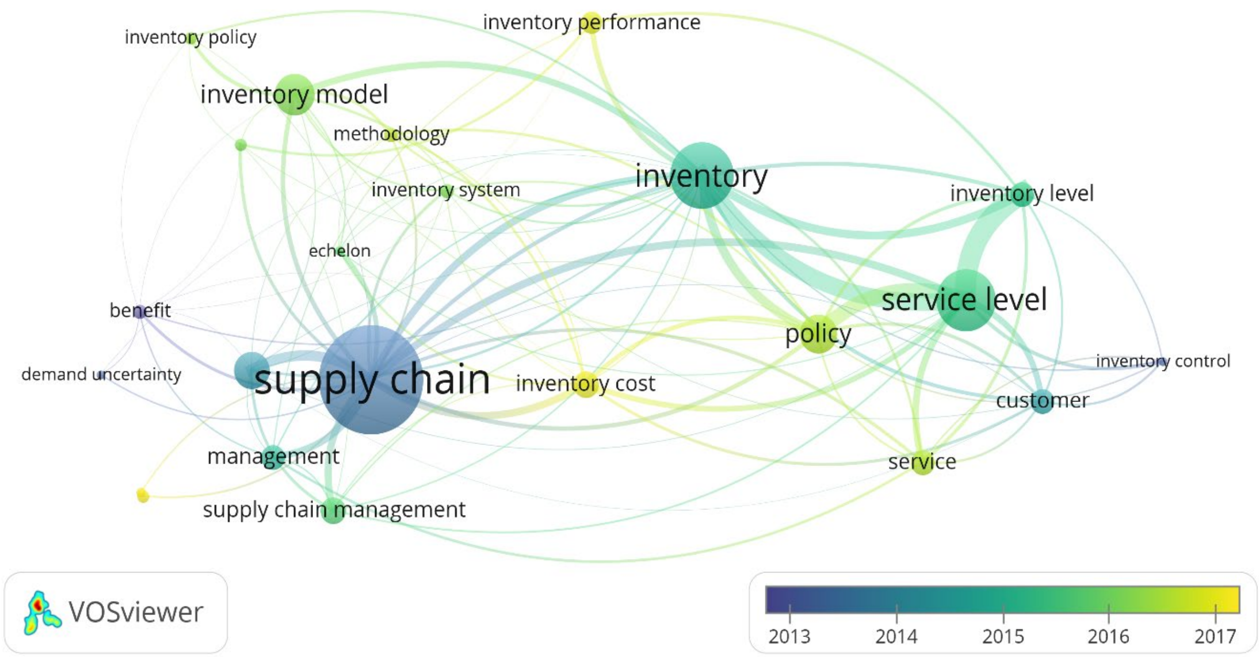

Figure 2. Most frequent topics in the literature review, Source: Adapted from [35]

Nowadays, companies must focus on the coordination of the supply chain and its proper management, which depends on the appropriate selection of partners and the assignment of tasks, demands or services [25], since suppliers can increase their utility by competing and cooperating with others [47],[25],[48].

Against this scenario, ref. [49] mention six different parameters that must be taken into consideration during the development of their model: retail maintenance costs, flexibility costs, demand variability of both the retailer and distributor, delivery time and its variability both to the warehouse and to the retailers in order to maximize the total profit of the chain.

2.2. Inventory Management

Inventory management includes all processes related to replenishment time, maintenance costs [51], asset management, inventory forecasting, inventory valuation, inventory visibility, physical inventory, service level [21], availability of inventory, returns and defects of the product, optimal inventory levels, quality of inventory, among others [52],[41]; that is, it is about having the right inventory levels, at the right prices to ensure high customer satisfaction through the right procedures and processes that are profitable for the organization [53].

Various problems of inventories have been studied throughout the reviewed literature, and the most common are those exposed by [1] determining the optimal quantity of the order, the time of order [54] and the reduction of the total operational cost as a result of adequate management [55],[56]; however, this begins to become more complicated when integrated with the uncertainty of the demand [53]. In the investigation there were models where the delivery time [2] is used and the quantity of the orders as decision variables and the objective is to discover an optimal inventory strategy that minimizes the expected total cost [40,][27], also stochastic simulations where the input variables can be defined by random variations, thus causing random outputs [57] and an EOQ model in order to determine the requirements to replenish the stock [16].

On the other hand, most multi-echelon models consider two-echelon supply chain, with the exception of the EOQ model [21]; likewise, the pressure objective is based on reducing shipping sizes and increasing the frequency of delivery, thus defining the efficient way to supply customers is a complex task [58]. Among the most found policies are those shown [16] in Table 3.

Many authors refer to two extremely important issues: the level of customer service and inventory levels, which are directly related to each other [21]. This is why inventory management involves a balance between customer service (or the availability of the product) and the cost of the inventory [12]. In addition, the purchasing behavior of the clients not only depends on the unit price of the articles [29],[32] but also on the service level offered by the retailers [6].

Generally, the metrics or key performance indicators (KPI) used in inventory management are space utilization, cycle time, productivity management, service level, cost and inventory, and others [59]. Unlike the previous one, ref. [61] focuses on the client and the metrics mentioned are: complete delivery, on time, in perfect conditions and with the correct information.

Faced with this relationship, the models proposed in the literature guarantee that the service level is satisfactory when an optimal policy is applied. For example, ref. [23]

developed a system of two-echelon inventories considering service level restrictions, where they ensure that the customer's waiting time is no longer than promised. Likewise, it is demonstrated that in this two-echelon model, the service level of the retailer is an important driver of the improvement of cost and, therefore, the total profits [49].

3. Methodology

The literature reviewed in the previous section emphasized the importance of having a methodology to guide research. Therefore, the research was based on a three-phase approach [63]: strategic, tactical and operational.

Excellence is defined by [64] on how to have a competitive supply chain, because getting the deliveries to be complete, with the right information, in the right place and on time is a hallmark of high quality service [60]. Using a supply chain strategy to segment the business in supply chain networks [62] in order to optimize each channel network [65] and achieve its strategic objectives [28], it constantly seeks to align channel resources and determine the expected return.

The model proposed by ref. [28] was taken as a reference and adapted with the necessary steps to be able to implement a correct inventory management for the sector under consideration and this at all levels: strategic to operational [38].

4. Case description

The company under study will be called "ABC Druggery ", which is a drugstore, a term that is defined by the General Directorate of Medicines, Supplies and Drugs (DIGEMID), as a company that is mainly dedicated to import, warehousing, sale and distribution of pharmaceutical products and medical devices.

In the empirical part of the research, data was collected through a series of meetings, as well as through reports of purchases and dispatches from the site. In this study, we focus on high consumption value (Class A) products [66]. The current situation and inventory policies of previous studies were compared to find a suitable policy for these types of products.

INVENTORY REVIEW POLICY	SIMBOL	DESCRIPTION
PERIODIC REVIEW	R, s, S	During each "R" review cycle, if the inventory is less than or equal to "s", it is reset to the "S" level
	R, r, Q	During each review cycle "R", if the inventory is less than or equal to the reorder point "r", a constant quantity Q is replenished
	R, S	During each revision cycle "R", it is reset to the upper level "S"
CONTINUOUS REVIEW	s, S	When the inventory is below the "s" order point, it is reset to the "S" level
	r, Q	When the inventory is below the reorder point, a constant size order Q is placed [49][59][18]

Table 3. Review of inventory policies, Source: Adapted from [39] [16]

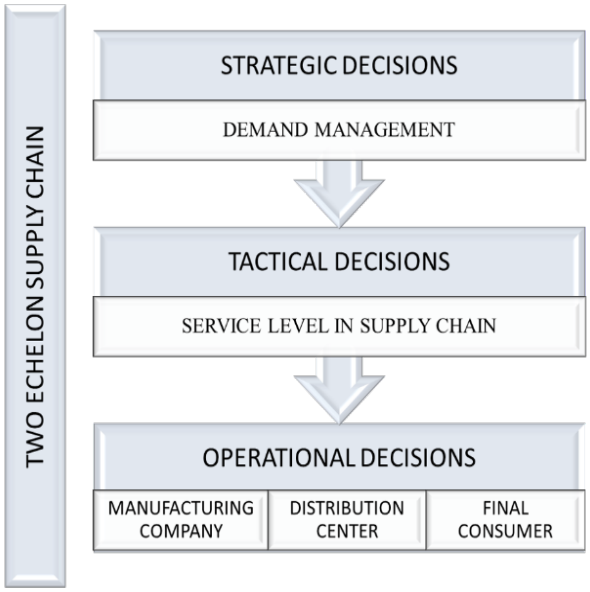

Figure 3. Supply Chain Strategic alignment and processes, Source: Adapted from Ref. [33]

ABC Druggery has three different types of clients: drugstores, pharmacy and apothecary services. The second type refers to the pharmacies that are inside hospitals or clinics that patients use when they are treated in those places. The third type deals with chains of pharmacies, to which the distribution is made to their main stores and these in turn market for national consumption.

The company has suppliers from Malaysia and China, which supply most of the products, mainly latex gloves (58.59% of total value sales). Figure 3 shows the supply chain of mentioned product.

For this study, the supply chain shown was delimited to just two levels consisting of the distributor and a retailer. The structure of the distribution of latex gloves in the company is presented in **¡Error! No se encuentra el origen de la referencia.**, where it has a manufacturing plant located in Malaysia as the main supplier and a local supplier in event of shortages that may avoid the non-fulfillment of orders; however, the price of the latex items are greater than that offered by the traditional channel.

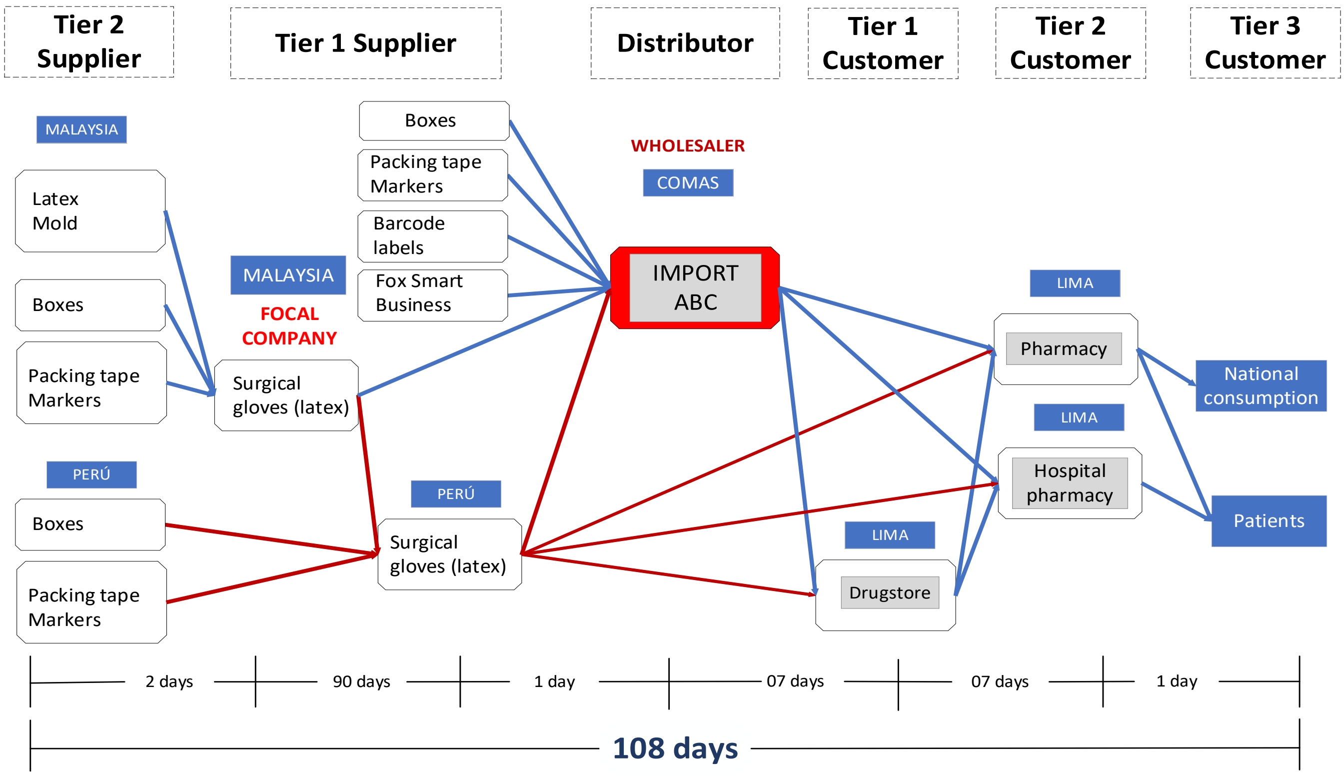

Figure 4. Supply chain, ABC Druggery, Source: Adapted from [39] [16] [62].

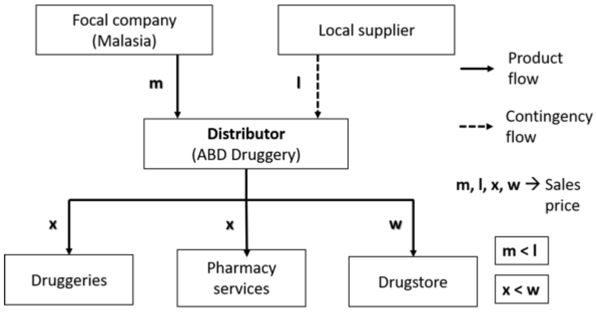

Figure 5. Structure of the supply chain, Source: Adapted from [46]

4.1. Current State

Undoubtedly, the service level is a relevant factor that involves the client, which is why it is intended to understand the current situation of the company in the perfect order indicator and compare to optimal, what was indicated by the experts. According to Table 4, the current service level of the company is below the desired target of 95% - 98% [19].

On time	Complete	Damage free	Accurate invoice	Perfect Order Indicator
92.05%	100.00%	100.00%	98.18%	90.37%

Table 4. Indicator of the perfect order for the distributor, Source: Adapted from [61]

On the other hand, the purchasing department requests the quantities from the supplier based on stock depletion, personal criteria and availability of the focal company, which shows that the inventory levels of the case study in Lima, Peru, are varied and without adequate planning. An inventory management scenario without planning is shown in Figure 6, where the quantity of orders is not calculated and the application time is variable.

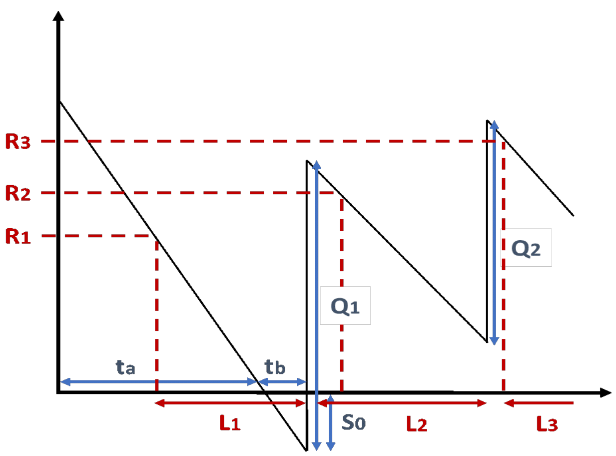

Figure 6. Unplanned inventory management, Source: Adapted from [18]

The financial implications of an "imperfect order" are significant for every company since there are costs of return, replacement of products, cost of labor for multiple shipments, loss of sales, and cost of lost customers [61]. Such is the case of the company under study that has a service level of 90.37%, over 4% points under the optimum according to [19] (40.04% of the total purchases of 2017), which represents an unnecessary and avoidable cost in case of having adequate planning.

4.2. Future State: Perfect Order

As seen in Figure 7, in order to align the corporate strategy with the main objective of the chain for the product, the model proposed by [64] was used, where it was possible to determine the best practice to follow [67]: the implementation of an optimal policy (R, Q) [59],[49] that involves two levels and thus achieve a faster delivery to the client.

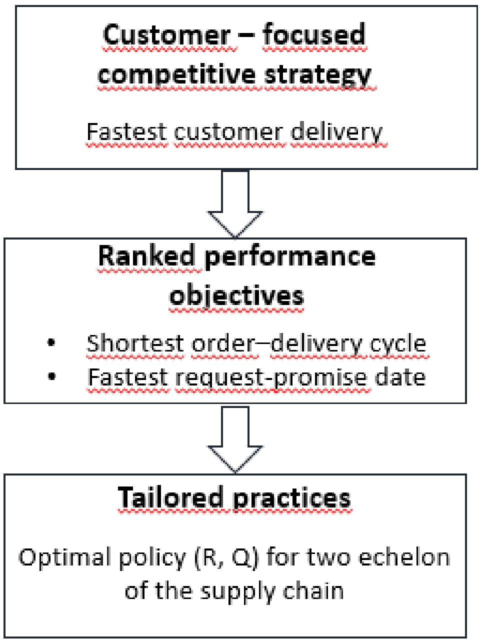

Figure 7. Supply chain aligned with a strategy focused on the customer, Source: Adapted from [64]

Table 5 shows the different parameters to be used as part of the solution. Apart from the profit of the distributor and retailer we have the cost factors related to the company, such as; the cost of pending orders, order cost, maintenance cost, opportunity cost, among others.

Input parameters

VARIABLE	DESCRIPTION	VARIABLE	DESCRIPTION
π_r	Retailer's profit	π_0	Warehouse's profit
p_r	Retailer's sale price	p_0	Warehouse's sale Price
W	Retailer's purchase cost	W	Warehouse's purchase cost
D_r	Retailer's demand	D_0	Warehouse's demand
C_r	Retailer's order cost	C_0	Warehouse's order cost
Q_r	Retailer's lot size or EOQ	Q_0	Warehouse's lot size
h_r	Retailer's maintenance cost	h_0	Warehouse's maintenance cost
γ_r	Retailer's opportunity cost	γ_0	Warehouse's opportunity cost
S_r	Retailer's backorder	S_0	Warehouse's backorder
SS_r	Retailer's security stock	SS_0	Warehouse's security stock
$D(SL)$	Demand dependent on the service level	A	Coefficient of variation of demand
SL	Desired service level	SL_0	Current service level
N	Number of times to order the same Q quantity	Z	Service Factor
∂	Standard Deviation	E	Lead Time
R	Reorder Point	I	Carrying cost

Table 5. Adaptation of model variables, Source: Adapted from [18]

With implementation of an optimal policy, it will be possible to determine how much to request based of the demand at the time to order [68], and the computed safety stock in case of an unforeseen occurrence with the demand. The implementation will allow an improvement in the backorders and will optimize the service level.

Based on this increase, the profit that corresponds to the distributor and retailer can be found, and a sensitivity analysis [57],[24] will calculate how much the profit increases for the two-echelon supply chain, his because [50] indicate that significant cost savings are obtained within the provider network, which is applicable for other scenarios if they adopt such practices.

Description of policy and profit

According to ref. [19], mention that the optimum service level (SL), according to the sector and the product, is typically between 95% to 98%. The profit of the distributor will be evaluated for each point of increase in the level of service where the different demands, costs, lots, among others will be entered.

As a result of the demand obtained, the profit of the distributor as well as the retailer will be applied with the parameters corresponding to the costs. On the other hand, we have the alpha ($\propto$), this alpha means the variability of demand from one month to another, 0.2-04 is the range to which the variability of the company under investigation belongs, because it is not very high but it impacts in some way on the profit of the company according to [18].

As a first point we have the formula of demand dependent on the service level:

$$D(SL) = (1+\propto (SL - SL_O)) \times D_O \text{.................................}[40]$$

In the same way, was utilized a policy (R, Q) to establish the optimal order quantity:

$$\text{EOQ} = \sqrt{2DCo} \,/ (I\ x\ C)$$

The number of times to order the same Q quantity per year:

N* = D / EOO

It is required to have a security stock that allows it to fulfill its function in case demand varies unexpectedly, where at a higher service level the security stock is directly proportional:

$$\text{SS} = \text{Z x } \partial \text{x } \sqrt{E}$$

On the other hand, determining the optimal point to make the purchase order is essential so that the model does not generate high costs and work efficiently:

$$\text{R} = (\bar{D}\ x\ E) + (\text{Z x } \partial \text{x } \sqrt{E})$$

Finally, as part of the model, the distributor's profit for the two-echelon chain is determined:

π_0 = Total profit - Total cost of purchases - Total cost of ordering - Total cost of maintenance - Total cost of depletion of stock

$$\pi_0 = (p_0 - w)D_0 - C_0 * \frac{D_0}{Q_0} - h_0 * \left(\frac{(Q_0 - S_0)^2}{2Q_0} + SS_0\right) - \gamma_0 * \frac{D_0 * S_0}{Q_0}$$

And in the same way the profit of the retailer:

$$\pi_r = (p_r - w)D_r - C_r * \frac{D_r}{Q_r} - h_r * \left(\frac{(Q_r - S_r)^2}{2Q_r} + SS_r\right) - \gamma_r * \frac{D_r * S_r}{Q_r} \text{.......}[18]$$

5. Numerical Results and Discussion

5.1. Sensitivity Analysis

The model was run using the following parameters shown in Table 6. Demand variability, coefficient and the range of the desired service level were used to determine the order quantity for: the company under study, the retailer, and the profit of the two-echelon supply chain.

α	**0.2**			**0.3**			**0.4**		
NS	**Qo**	**Qr**	**∏t**	**Qo**	**Qr**	**∏t**	**Qo**	**Qr**	**∏t**
0.95	32,250	12,828	677,866	32,322	12,839	681,058	32,396	12,849	684,255
0.96	32,281	12,841	710,791	32,370	12,858	714,834	32,460	12,875	718,882
0.97	32,313	12,854	743,586	32,418	12,877	748,510	32,523	12,900	753,435
0.98	32,346	12,867	776,185	32,465	12,896	782,018	32,586	12,926	787,857

Table 6. Optimal values of the supply chain for different values of service level and sensitivity coefficient, Source: Adapted from [24]

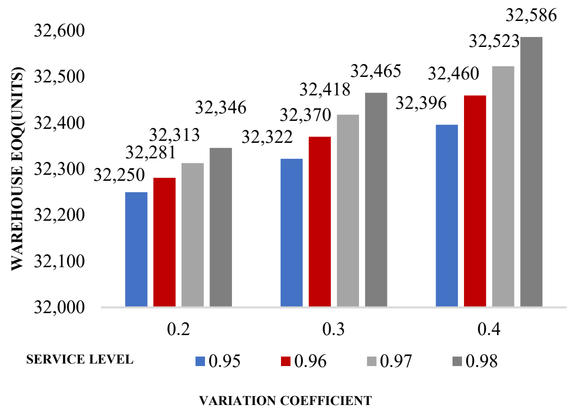

Figure 8. Variation of EOQ according service level. Adapted from [24]

For the present investigation, the analysis was performed for the coefficients 0.2, 0.3 and 0.4 because it was found in the ranges of the variability around the increase in demand. The main variation is the quantity to be ordered according to the service level and the demand coefficient.

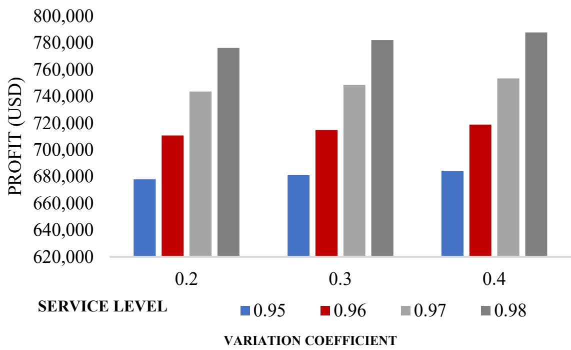

Figure 9. Variation of Profit according service level, Source: Adapted from [9]

As it can be observed, in Figure 9, a measure where both the service level, and the coefficient of increase in demand increases, the profit of the distributor and the wholesaler follow the trend.

On the other hand, the associated costs can be analyzed according to the service level. One of the main reasons why the cost is reduced at each point is because the backorders decrease. As seen in Figure 10.

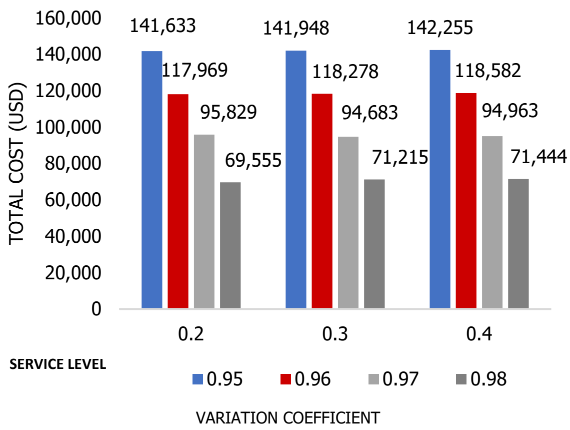

Figure 10. Total Cost according service level, Source: Adapted from [29]

Throughout the supply chain the efficiency increases for each service level that increases; the maximum value reaches 45%, as showed in the Figure 11. As indicated at the beginning, the objective of the company is to be able to reach 95% of the level of service that is optimal for the sector and subsequently, to improve the chain and reach up to 98%, which is the best scenario according to the analysis.

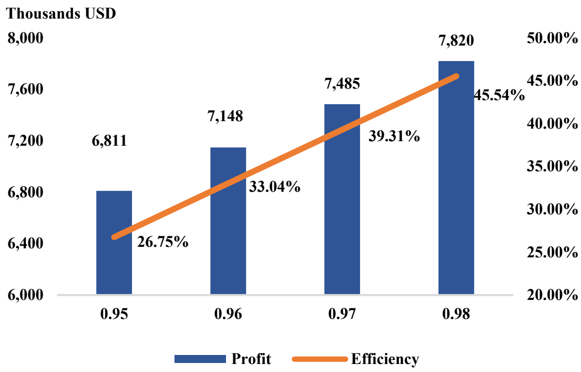

Figure 11. Profit Supply Chain vs. Efficiency, Source: Own Elaboration

6. Limitations

It is necessary to state that this investigation focuses on a single product, the *Latex Surgical Gloves* because they generate the most sales and profit to the company.

It is very important to be able to define the interested parties in the research. Interest level contributes to the willingness to improve the supply chain.

Another limitation in this investigation is the variations of the delivery times, which can generate different results in terms of service level. Usually, exact delivery times are established without considering the risk in the supply chain and/or external factors such as; vehicle congestion in the city, vehicle repairs, etc.

7. Conclusions

This applied research confirms the initial hypothesis because it increases the profit of the company and the supply chain by applying the optimal procurement policy; in this way, both the distributor and the retailer have improved performance.

This study focused on the service level because it is the decision variable with the greatest impact on the client throughout the supply chain. Within this, the correct quantity to be ordered was evaluated, which is one of the four important factors to make a decision with strategy. Two echelons were taken as reference, ABC Druggery and a retailer.

The company previously realized high costs due to the shortage of the analyzed product resulting from local purchases rather than imported goods. Finally, it can be concluded that this method provides a greater profit in the supply chain.

7.1 Managerial implications

On the other hand, the feasibility of the project is highlighted due to the adaptation of the model in the pharmaceutical sector, determining in a certain way, what are the costs incurred and profits.

Applying the model, it was possible to analyze the increase in the service level in the supply chain, which generated greater profit for the interested parties.

7.2 Future Research

As a main recommendation, future research on the model can be implemented in different sectors and evaluated on its efficiency with respect to similar proposals. The investigated model can also be implemented as part of a more complex supply chain comprising multiple distributors and retailers to evaluate their performance and profit, in addition to additional tiers of modern supply chains.

Additionally, contracts with suppliers could be applied to have a schedule already established over a certain period. A program of inventory control could be implemented to maintain better management, and that can be coupled with the solution already applied in the research which will maintain the optimal service level inventory.

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