# Inventory Management Model Based on Lean Supply Chain to Increase the Service Level in a Distributor of Automotive Sector

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**Abstract— This paper deals with the management of spare parts in the automotive sector using Lean practices in a synergistic manner. Managing cost-effective spare parts is essential for manufacturing and service companies. One of the most difficult challenges in effective management of spare parts is to manage and control the levels of stock. Effective management is essential to achieve the best service level in the automotive industry, unfortunately it is an industry which faces a great uncertainty in the demand for spare parts. The management of spare parts is difficult due to the infrequent profile that characterizes market demand. This creates a challenge among the distributors who need to have a large number of items (part numbers) in stock to avoid loss of sales. This paper shows the results of a case study on demand forecast of spare parts and inventory control, selecting the best policies within each SKU category. The methodologies achieved a reduction of the stock out, savings in purchases of supplies and greater fulfillment of orders that generated an increase of 22.49% in Sales.**

***Keywords:*** *Supply chain management, Lean supply chain, Demand, Inventory management, Service level, Automotive sector, Peru.*

## 1. Introduction

To seek excellence many companies, try to reduce costs, increase customer responsiveness, and optimize the use of assets. However, such efforts do not always work because of the poor connection between the company's competitive strategies and their processes, operations, and supply chain practices [1],[2].

In Lean Supply Chain Management (LSCM), the flow from the raw material to the final consumer is considered integrated [1],[2]. LSCM emphasizes the use of lean practices in a synergistic manner with the goal of creating a high quality system catering to the client's demands with little or no waste [1],[4],[5]. This document aims to analyze inventory strategies in a supplier-distributor relationship in a tight supply chain environment using continuous improvement models [2],[6].

More specifically, within this paper a model with eight phases will be tested for the management of different inventories and their integration of information flows and materials. The aim is to develop a better understanding of the scientific implications and the applicability of this type of approach to realistic cases [1],[7],[8]. The simulated models are expected to generate a theoretical discussion on the different inventory management strategies that exist and the implementation of a lean supply chain [2],[9],[11]. Specifically, this study will assess strategies related to the level of delivery service, delivery time, and stability of production and logistics [1]. Current supply chains must manage highly challenging market conditions due to increased volatility and uncertainty [12][13]. Therefore, an adjusted supply chain leads to a reduced inventory level , shorten delivery time, reduce costs, and stabilize quality thus achieving greater customer satisfaction [13].

Despite the current global economic crisis, the business of spare parts is growing, an opposite trend compared to other companies [7]. Heightened business activity has


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forced spare parts players to face challenging problems such as the growth of demand, the reduction of delivery time imposed by the market, and the efficiency of logistics and warehouse activities. To curtail these challenges, many throughout the industry have eliminated geographic barriers and integrated internet platforms and e-commerce [7]. The document deals with the management of spare parts in the automotive industry sector, focusing on the delivery process within the supply chain and the role of spare parts distributors [14].

In general, the supply chain of spare parts is structured in the following way:

The company under study is the initial level (0), from there, the levels are numbered for each side. On the left side we have three levels.

Supplier, level 3, are companies that supply the components and raw material of the original equipment (OEM) to all the manufacturers of spare parts for cars (level 2), they have distribution centers strategically in different countries where they store the products to later be sold to importers (focal Company) worldwide[7], [11].

On the other hand, on the right side we have two levels, first distributors of spare parts and final resellers (stores, car dealerships, etc.), and finally, level 2 is represented by final consumers as shown in Figure 1[7], [10], [14].

The main task of the distributor is to guarantee compliance with the orders for its customers. Therefore, efficient inventory control is key to the management of spare part supply chains [15]. Unfortunately, due to the high uncertainty and unpredictability of demand for spare parts, coupled with the high cost of stock-outs compared to their value, traditional inventory control methods (quantity of economic order (EOQ) are not efficient [4], [16], [17]. Traditional methods can increase the risk of large holdings or obsolete materials. Therefore, it is important to develop methods with variables that complement each other.

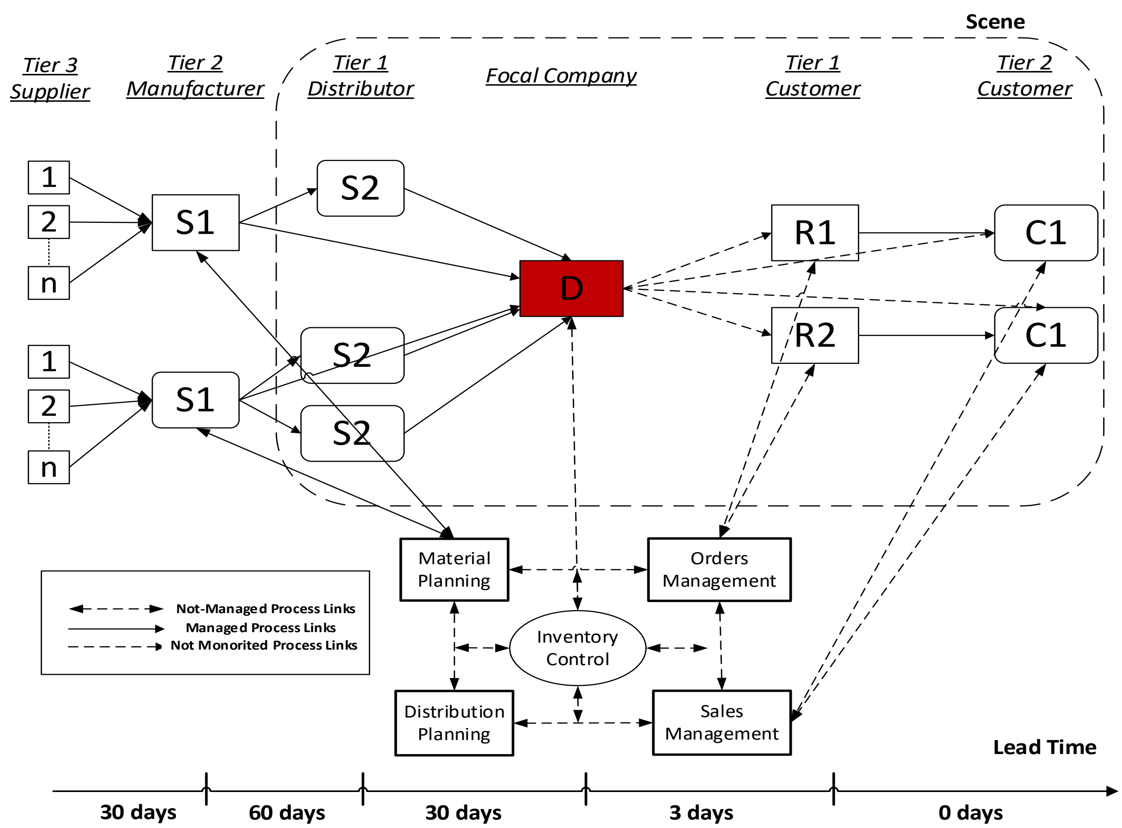


**Figure 1**. Spare parts supply chain [11] [18][19] .

Extensive research has been done on inventory management for spare parts in various industries. Research focused on profitable planning and supply control and produced: (i) an adequate inventory policy that complies with the restrictions and conditions of the system, (ii) estimation of the parameters of the inventory policy, (iii) performance measurement system, and (iv) an inventory optimization method. Using the culmination of this research, a mathematical model is proposed to optimize inventory while minimizing the total cost and guaranteeing a superior level of customer service [2], [7], [21]. The target stock level is chosen as a solution for non-fulfillment of orders due to shortages. EOQ is the amount to satisfy the demand, therefore, becomes the basis for calculating customer service levels[20]. In addition, to measure the performance of the proposed model, the solution of this model is obtained through the extension of Single-Echelon Systems: Integration-Optimality, a continuous review system based on a single level [22].

The proposed method uses a parametric estimate based on the distribution-based inventory policy for the mathematical model. The parameters of the inventory policy are estimated based on compatible demand distributions for slow and fast moving parts [2], [23]. On the other hand, from the point of view of the distributors, this task is very challenging and requires keeping a large number of different items in stock. Each distributor holds a small quantity characterized by an infrequent demand, requiring immediate disposition when necessary [5], [25], [26].

Today, distributors deal with brands such as OE and After Market who suffer from management and storage problems in general. To avoid the loss of sales, these companies are forced to stock a large number of items that have an erratic demand. This incurs high inventory costs and lost sales [7], [26], [27]. From the point of view of the supply chain, the stocks of the same products are usually multiplied among the distributors, which increases the total costs of the supply chain [28].

## 2. Literature Review

A cost-effective supply chain needs effective and efficient stock management to reduce total operating costs. Due to this fundamental activity, the inventory management system for cost-effective supply planning in spare parts supply chains is a widely researched area [3], [15]. Croxton is one of the first researchers who worked in spare parts inventory management. There are several research works on the management of spare parts inventories in a wide range of industries, such as [3], [14], [29].

### 2.1. Supply Chain (SC)

In this study, SC is understood as a network formed by all those parts of a value chain that are oriented to satisfy the needs of the client and the companies [17], [34]. This is enabled through the exchange of information and capital management, as well as cooperation between companies [36]. Today within the global market, interorganizational relations is of utmost importance for effective management of the supply chain [3], [33][30].

As the market has evolved, it has encouraged many organizations to implement different SC initiatives with the ultimate goal of increasing efficiency within them [17], [31]. Supply chains are developed by companies so they can reduce their costs and remain competitive in the business landscape. However, before proposing any initiative in a SC, it is necessary to know the subject in depth. Without a clear and precise understanding of the logistics strategy of the SC, investing in any practice to improve them will not have positive effects [31], [32], [33], [34].

### 2.2. Supply Chain Management (SCM)

The main objective of the SCM is to provide support to suppliers, producers, customers, and personnel responsible for transport by supporting the management of an interconnected business network [31],[32]. SCM encourages the exchange of information between all levels of an organization and promotes the optimization of processes, focused on the overall objective of a company and not on the individual objectives of each area [33],[34].

The reviewed authors argue that the implementation of SCM in addition to reflecting improvements in operational and financial performance, also has a direct impact on customer satisfaction[24],[35]. This is because customer requirements are considered in terms of quality and level of service[36][37]. The effort of a single company to improve its Supply Chain Processes (SCP) is insufficient this demonstrates how necessary it is to have a relational approach and include suppliers and buyers in the company's strategies[1][38],[39]. These processes will create advantages and increase the competitiveness of a company since it will create behaviors between suppliers and buyers that are inherent to the organization [3], [40].

#### *2.2.1. Process view of supply chain*

Ref. [41] the processes involved and those in charge of each process must be clearly observed. The roles and responsibilities of each member and the result must be clearly defined.
The processes in a supply chain are divided into a series of cycles, each carried out at the interface between two successive stages of a supply chain as shown in Figure 2 [33], [43], [42].

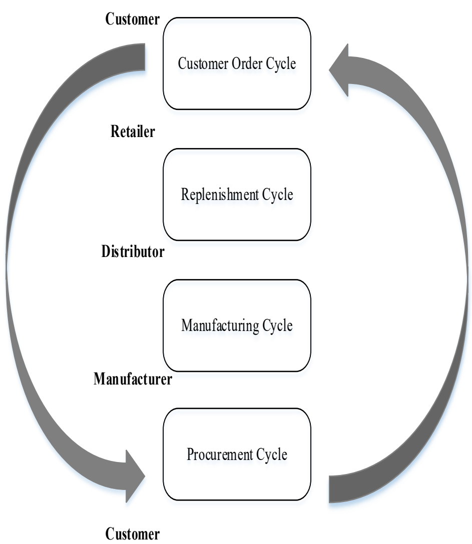


**Figure 2.** View Chain cycle [13][44].

#### *2.2.2. Single-echelon Supply Chain*

The single-step supply chain system is a decentralized system in which each node acts individually [43], [45]. Therefore, optimized inventory levels do not impact of those decisions at other levels of the supply chain [40], [46]. When the retailer or distributor finds a shortage due to the variation in demand, the inventory replenishment can be provided only by a manufacturer or distributor that is further up the chain to ultimately meet the customer needs [22], [48].

In a single-step system, there is a level of storage points that serve the final consumer. Ref. [22], [45]. In this model, each service center functions as an independent storage point for its consumers and is affected by fluctuations in demand. The inventory strategy in a single-step model depends on a variety of possible factors, including the level of customer service desired, order costs, and maintenance costs. The development of a strategy is further complicated by external constraints such as ordering constraints, variability of delivery time, and variability of demand [46]. See Figure 3.

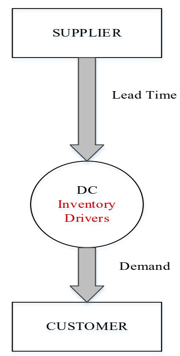


**Figure 3.** View of single-echelon inventory system[46], [49].

### 2.3. Lean Supply Chain Management (LSCM)

The LSC strategy concept advises collaboration with clients and working together to achieve joint objectives [13], [50], [13], [51]. Toyota implemented a similar type of strategy to achieve LSC excellence. Toyota always communicates with its customers and suppliers, and considers their opinions before implementing any change in SCM activities [52], [53]. The LSCM approach moves away from the current "trading mentality", in which profit targets are short term and highly dependent on market prices and the ability to negotiate strongly with suppliers or customers, to a strategy based on a long term commitment to supply chain partners with a cooperative and systematic waste elimination along the chain [54]. Large companies discovered that it was not enough to improve performance only within their organization. The improvement must extend to the entire supply chain [9], [55][56].

### 2.4. Inventory Management

Inventory management is one of the fundamental tasks of supply chain management [57], [49]. Retailers are always trying to reduce the risk of running out of stock by creating an inventory buffer for items with high demand [5], [24]. Retailers are aware of the cost of losing sales, along with the costs of inactive inventory. While retailers deal with rapidly moving goods, they always need to adjust to new supply chain strategies that will increase the speed of products through the supply chain and increase in the accuracy of inventory management[58], [59],[60].

Inventory management is an act of balance, which requires having adequate inventory on hand, but not getting stuck with outdated or out-of-season elements. This involves skillfully balancing requirements and being alert to changing external factors [60], [61]. In a retail context, preferences change constantly, thus maintaining a wide range of inventory is critical [32], [34]. Obtaining lower prices from suppliers by making purchases in volume is desirable, but not if it means ending up with slowly moving inventory that would eventually be sold at a discount or returned [35], [60]. Increasing the turnover rate by keeping stock levels low does not mean sacrificing customer service or incurring excessive shipping costs by speed up orders when stocks are too low. Managers and analysts can use predictive analytics to create models that categorize inventory levels by SKU and identify which products are likely to be out of stock [8], [63].

### 2.5. Service Level

Ref. [1] the service has a critical consequence on consumers' purchases of choice and loyalty, and finally on the demand. It is believed that effective service creates a positive approach to the supplier, thus attracting the client's demand, since the product is available where and when required [65], [66]. Organizations must set a minimum service level, which allows them to calculate the base of inventory that must be maintained in order to ensure product availability that satisfies their customers [67],[9].

Ref. [67], [68] defines that the level of service established will act as a target percentage below which all orders can be supplied with the existing inventory. Assuming that the demand is uncertain and may vary with respect to forecasts, through statistical means it is possible to calculate the security inventory that should be maintained of each article that will satisfy the proposed level of service [49], [69].

Ref.[49] according, it is necessary to understand the relationship between the inventory level and the level of service, a key attribute for all companies that want to increase their profitability. For a company to guarantee a sale they need to have the right product, at the right time, the right amount, and at the right location [22]. It is important that products do not generate excessive inventory cost for stock. Therefore, you must have knowledge of the following table [17], [70]

**Table 1**. Relationship service level and inventory level [47], [66].

| | | Inventory Level | |
|---|---|---|---|
| | | **High** | **Low** |
| **Service Level** | **High** | **A (greater than 85%)** Fulfill customer demand, Carrying significant inventory | **B (70-85%)** Optimum level, Achieve service level with balance inventory |
| | **Low** | **C (70-85%)** Excess inventory and Carrying non-performing inventory | **D (less than 70%)** Shortage and Stock-out |

## 3. Literature search method relevant

The literature collection is a systematic accumulation. Orderly steps were taken to perform the analysis and reflective interpretation of the literature, specifically focusing on answering the research questions; steps are shown in Figure 4 [13], [27]. The intention is not to compile everything related to the role of inventory within the SC, but use the most relevant and interesting information [72]. Presented next, are steps for searching literature that complements our knowledge [3].

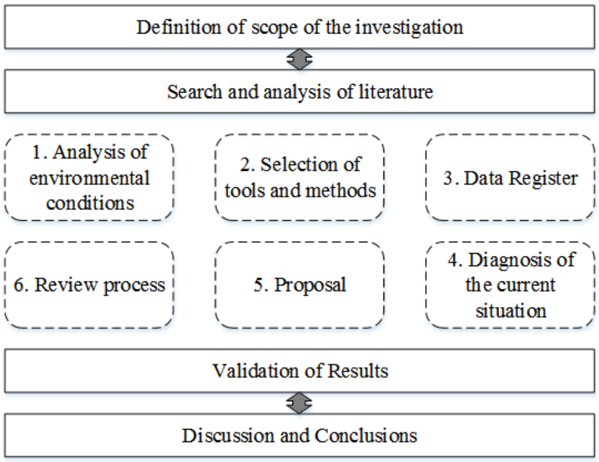


**Figure 4.** Review stage of the literature [41]

**Table 2**. Principal Papers Inventories Classification[41], [75].

| Source | Year | Inventory Management Problem | | |
|---|---|---|---|---|
| | | **Lost Sales** | **Backlogging** | **Non-negative** |
| [21] | 2015 | | X | |
| [16] | 2015 | | X | |
| [61] | 2015 | | | X |
| [76] | 2015 | | X | |
| [77] | 2015 | X | | |
| [47] | 2016 | | X | |
| [8] | 2016 | X | | |
| [14] | 2016 | X | | |
| [27] | 2016 | X | | |
| [78] | 2016 | X | | |
| [79] | 2016 | X | | |
| [80] | 2017 | | X | |
| [46] | 2017 | X | | |
| [81] | 2017 | X | | |
| [82] | 2017 | | | X |
| [26] | 2018 | X | | |
| [83] | 2018 | X | | |
| [44] | 2018 | X | | |
| [66] | 2018 | | X | |

The trends and dynamics of changes that inventories have on the supply chain are identified on the basis of data, such as, Scopus, Elsevier, Emerald and Sage in recent years [73], [74]. This study made use of basic bibliometric method techniques with the support of Vosviewer software.

On the basis of 80 indexed articles, the analysis allowed the evaluation of terms in chronological development of inventory research of the supply chain; the study identified words with crucial importance for this research area [73].

The circles drawn on the map represent a given element. The larger the circle, the higher the occurrence score of the term. The elements are grouped in groups marked with a color according to the year where the greatest occurrence was taken. For more detail see the Figure 5.

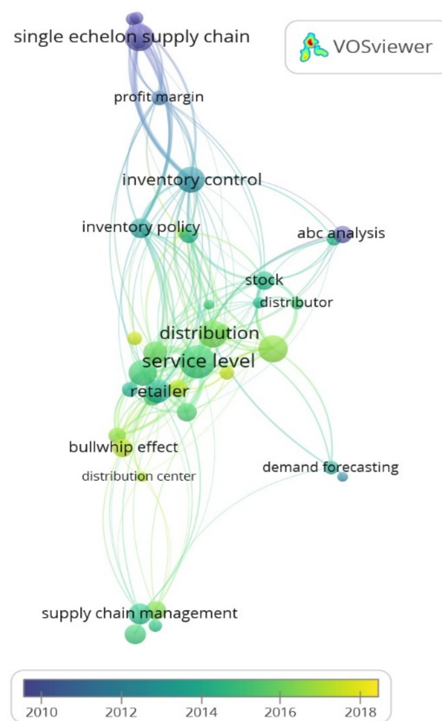


**Figure 5.** Map of the intensity of the relationship between keywords [84]

**Table 3**. Conceptual Methodology for Inventory Issues [6][85].

| Key Terms | Example of Definitions | Source |
|---|---|---|
| Supply Chain Management | Supply chain management focus improve customer focus and financial performance | [35] |
| | Supply chain knowledge allows to improve any initiative outcome | [33] |
| | Supply chain management will create internal process that drive the firm to future integrations. | [86][12] |
| Optimization and Inventory Control | Optimal stock level determination has a great impact on the cost optimization, mainly because of expensive spare parts. In order to optimize stock level of each part, service level can be employed. | [29] |
| | The optimization and control of inventory is the most important function of inventory management and forms the nerve center of any organization. | [87][76] |
| | Existing inventory studies tackle specific management problems such as: The bullwhip effect; Inter-organization coordination in the supply chain; Pricing strategy and policies the inventory. | [88] |
| Lean Supply Chain Management | LSCM is a group of organizations directly linked by the inflow and outflow of products, services, information management and collaborative work to reduce costs and waste efficiently to meet customer needs. | [56] |
| | LSCM integrates the entire flow from raw materials to the final consumer, in which interfaces between companies are seen as the result of economic arrangements of assets governed by various contextual factors, such as level of service, location of raw materials and size of companies. | [89] |
| | LSCM underscores continues improvement of the existing process and activities among supply chain in order to meet customer requirement better than the competitors. | [90] |

## 4. Case study

The company described in this case study sells parts for heavy and light vehicles. The company buys more than 800 items, including oil, air filters, fuel filters, among others. The contribution of the filters in the total value of the inventory is 63%, of which 40% has a higher unit cost and a longer delivery time. The analysis was carried out from January 2017 to December 2017. During this period, there was a decrease in sales, with an associated decrease in the level of service. In the year 2017, the company decreased its total sales by 5% as shown in Figure 6.

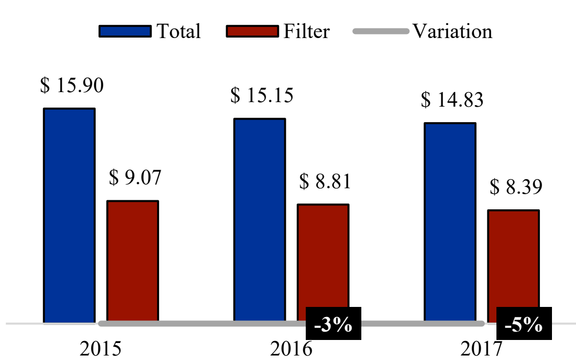


**Figure 6.** Sales variation 2014-17 in millions [39].

Due to the great diversity of products that the company handles, it is not possible to have them all in stock at all times. Storage capacity limits the volume that can be stored. This caused the company to lower its service level, shown in Figure 7. The level of service of the company under study, 74.1%, is below an acceptable or standard level within the sector of companies who market spare parts and consumables for vehicles, from 85% to 95% [43].

The company has been increasing operations over time, propelling demand for more efficient organization in the management of products and resources. More specifically there is a need to reduce the probability of losing sales through issues of shortages and reduce the high costs of possession of inventories due to mishandling of storage indicators, among others [3], [91].

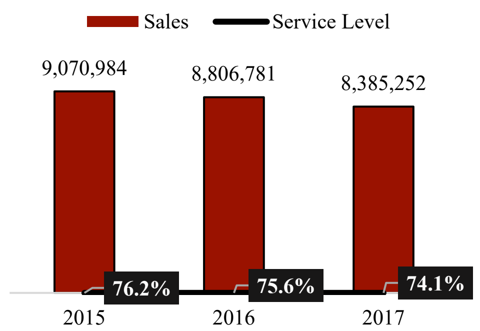


**Figure 7.** Comparative graph of the Service Level [20][92].

For this case study, a single supplier model with different order sizes and unit costs is considered. Regardless of the size of the order, there is a fixed cost for each order. The delay and shortage are considered in the analysis. Currently, the qualitative forecasting model is used to predict demand. The maximum delivery time for imported items is 12 weeks and for local purchase items is 2 weeks. As demand and sales increase, the stock of various products grows. At this time, inventory control plays an important role for the company. Currently, there is no inventory policy, due to capacity limitations, higher value inventory and the inconvenience of ordering different sizes are not considered. At this time, shortages in some products occur frequently, while other items remain obsolete.

The companies that supply the desired items (high demand) are struggling against the flood of frequent orders. The lack of availability of goods directly affects the fulfillment of orders. Therefore, an appropriate policy is required to manage the inventory of the items. In the current situation, the company manager has decided to find a fast, reliable and safe method to request the correct amount of each item with a minimum of total costs and maximum service levels, which is called the optimal inventory level [13], [17], [93].

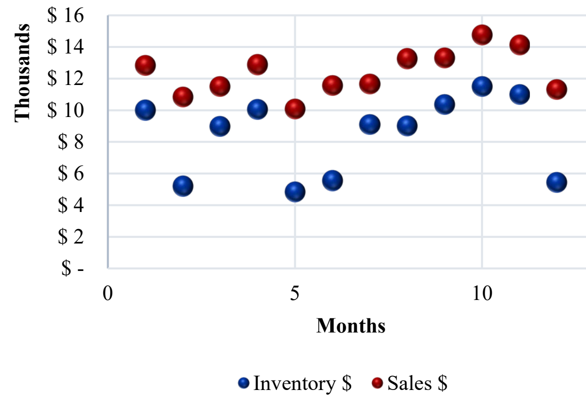


**Figure 8.** Ratio of Sales and Inventory Level 2017

The optimal inventory achieves the perfect balance between our clients' expectations of compliance and our overall financial performance. Figure 8 shows that the level of inventory is directly proportional to sales, this immediately indicates that one of the main causes by which sales decrease is due to the "shortage" factor, which causes losses due to deterioration or obsolescence of the merchandise, it may lead to the purchase of inventory at higher prices, with a significant impact on profits. For this, this paper shows replenishment parameters that drive optimal levels of objective inventory. The replacement method of each element and location determines its specific replacement parameters. Any replenishment method or system contains assumptions and, often, calculations based on input factors, including the delivery time, the quantity of orders (ROQ) and the expected behavior of future demand[29], [94].

### 4.1. Data and information compilation

Data was collected on the unit cost, the historical sale of the whole year 2017, the size of the existing order, the delivery time, and the present value of the inventory of each item. The company buys more than 869 items; therefore, it is difficult to manually control them all, neither should they all be controlled the same way. The selective inventory control technique was applied to categorize the elements using the spreadsheet. Therefore, the combined analyzes ABC (based on annual consumption value of the items), FSN (based on movement of items), HML (based on the unit cost of the items), SDE (based on the availability of the items) and XYZ (based on the inventory value of the items) were used to select the critical elements to control. The principle of the aforementioned analysis is explained in Appendix 2. For the confidentiality of the data, we have used false codes for the 11 elements and we have also not included the unit costs, order costs and maintenance costs of the inventory. For the 11 items, we collected the annual consumption value, the delivery terms, the quantities of existing orders and the existing order points. This is shown in Table 4. A statistical analysis was performed for the annual consumption value using MS Excel. The mean, maximum, minimum, and standard deviation (SD) of the annual demand were evaluated and are shown in Table 5. The SD of the annual demand value is relatively high due to unequal consumption. Figure 3 represents the comparison of the size of the economic lot and the size of the existing lot. Large deviations are observed in the existing order size and at the reorder point, particularly compared to the economic order size and the static reorder point. Therefore, the poor order size of the items leads to frequent stock outs and overstock in the store.

**Table 4**. The details of the annual demand order size, re-ord point and lead time

| Items | Annual consumption | Existing order size | Existing Re-order Point | Lead time (month) |
|---|---|---|---|---|
| 1XA | 11,500 | 9,200 | 2,300 | 2 |
| 2XB | 10,538 | 6,639 | 1,328 | 2 |
| 3XC | 17,610 | 14,264 | 3,522 | 2 |
| 4XD | 9,758 | 7,806 | 1,561 | 2 |
| 5XE | 7,783 | 4,903 | 1,557 | 2 |
| 6XF | 6,351 | 5,144 | 1,029 | 2 |
| 7XG | 5,373 | 4,298 | 1,075 | 2 |
| 8XH | 5,275 | 3,323 | 665 | 2 |
| 9XI | 3,721 | 3,014 | 744 | 2 |
| 10XJ | 4,905 | 3,973 | 795 | 2 |

**Table 5.** The statistical analysis of the average annual demand.

| Items | Annual consumption | Average demand per month | Standard deviation per month |
|---|---|---|---|
| 1XA | 11,500 | 958 | 581 |
| 2XB | 10,538 | 878 | 253 |
| 3XC | 17,610 | 1,468 | 699 |
| 4XD | 9,758 | 813 | 199 |
| 5XE | 7,783 | 649 | 209 |
| 6XF | 6,351 | 529 | 631 |
| 7XG | 5,373 | 448 | 153 |
| 8XH | 5,275 | 440 | 172 |
| 9XI | 3,721 | 310 | 126 |
| 10XJ | 4,905 | 409 | 213 |

The fact that the company assessed in this study handles a wide variety of products and has a commitment with its customers to deliver a service when it is required, makes it necessary to have a high level of service, which in turn means a greater amount invested in inventory. This implies that better management of the inventories is required so that the use of the capital invested in the products can be optimized to reduce costs [95].

Currently, the distribution company does not have any type of inventory control system. Administration does not plan the purchase requirements; it waits for the warehouse manager to indicate what needs to be purchased. In turn, this situation leads to situations where smaller quantities are purchased. This is often because local distributors do not have the necessary cash liquidity, thus the level of service provided to customers is reduced, Figure 9. This results in the loss of sales due to stock shortages. Ultimately this leads to non-compliance with customers, which means that the number of orders not addressed as a result of a deficit in management of supplies and inventories has increased.


**Figure 9.** Sales variation lost due to the number of orders 2017 [44].

## 5. Methodology

The methodology is committed to focusing on the management of the supply chain. Before, companies only focused on adding value to their products, which led to the differentiation of products; now, the focus is on adequately meeting the demand. This new operational emphasis is driven by the evidence that shows that the slightest interruption in the availability of a product generates a serious impact on the financial performance of an organization [70]. The current problems that afflict inventory management are: i) Maintenance policies, ii)

Transportation cost, iii) Maintenance cost, and iv) Cost of order [13], [39]. This project refers only to the latter.

A method to address inventory problems include: i) Direct observation within the industry to identify problems of current inventory management methods, ii) Review the literature, that is, review the theories of concepts and review the findings of previous investigations, iii) Formulate hypothesis and collect data for execution, and iv) Analyze the data and make a report detailing the steps taken in the methodology. This methodology is shown in Figure 10. Inventory control is a way to without negatively impacting customer satisfaction.

A spreadsheet model for inventory control was developed for a real case study of a company that commercializes spare parts and consumables for vehicles. The spreadsheet model incorporates a dynamic reordering point policy logic. Using the results of the spreadsheet-based approach and the analytical approach method, the effective alternative is an ordering policy for a single-step supply chain. It can be developed using statistical analysis of the dynamic reordering point, static reordering point, and policies of existing order.

The flexibility of the optimal ordering policy was evaluated using a randomly generated demand. The objective of this work is to develop the best ordering policy, with a low total cost of inventory that guarantees a better service efficiency in a single-step supply chain. The reduction in total inventory costs obtained from the spreadsheet approach is compared to the analytical approach method.

This document provides a basic understanding about the development of an ordering policy for a single-step supply chain. The proposed philosophy is based on the models analyzed and is an Inventory Management model that creates a Lean Supply Chain. The focus is on Information Systems, Customer Orientation, and Suppliers. The proposed model considers four entities or factors that constantly interact with each other, which are: i) Purchases; ii) Storage; iii) Distribution, and iv) Customer requirements. The client is considered an important part of the chain and work is based on the information customers provide the organizations.

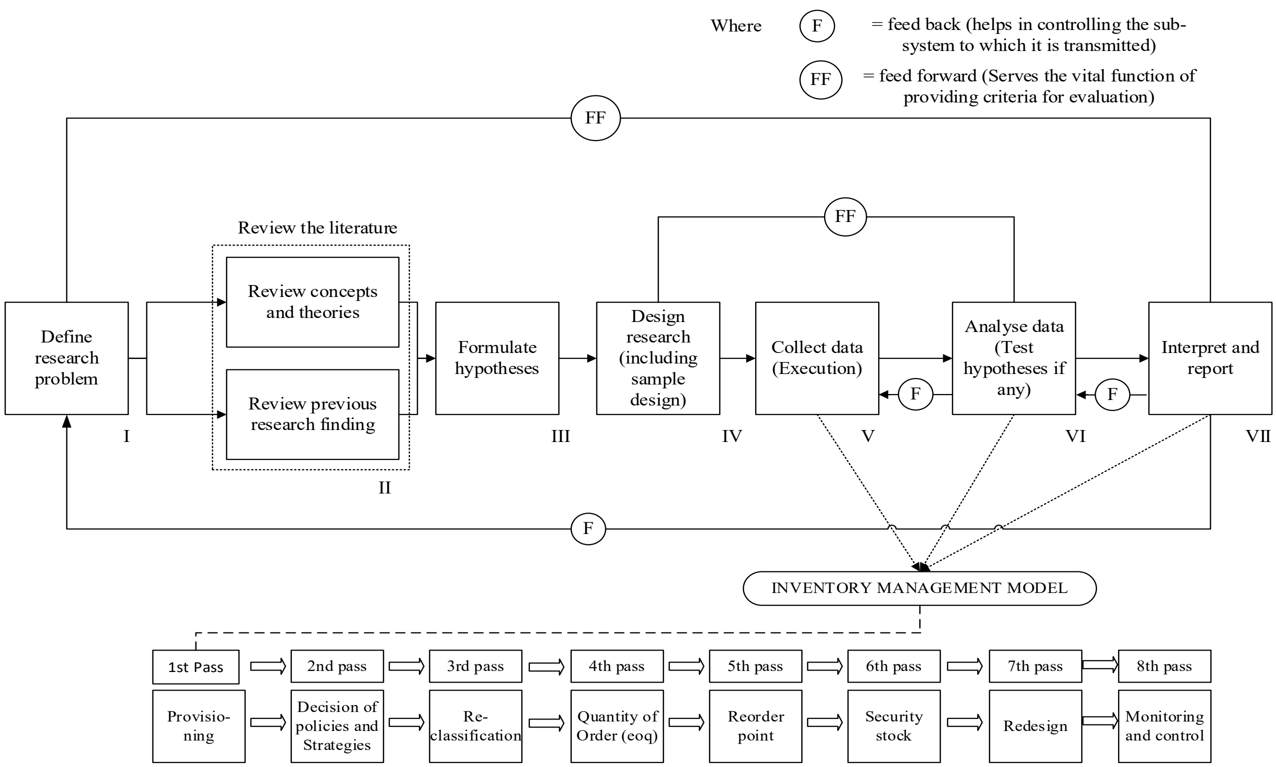


**Figure 10.** Conceptual Methodology for Inventory Issues [44][96][61].

### 5.1. Focus based on spreadsheet

This section describes the steps that were used to determine the variables for the order policy (r, Q) that would have the greatest impact on system performance. This was done using a spreadsheet-based approach. Figure 11 shows a screenshot of the spreadsheet model for the order policy (r, Q). The following equations describe the steps that are involved in the calculation of the required variable ordering policy [16], [80], [97].

To calculate the optimal quantity of the order, the most relevant item 4XX, was used as an example. The following formula mentioned in Step 1 of this research paper was developed.

#### *5.1.1. Step 1*

The quantity of economic order (Q) is calculated using the following relationship:

$$Q = \sqrt{\frac{2 \times P \times K_z}{K_U} + \sigma_{D_L}^2}$$

*Where:*
*P: estimated product demand within a specific time horizon (for example, one year)*
*Kz: unit costs*
*Ku: stock storage costs*
$\sigma_{D_L}^2$*: Variance of demand during lead-time*

#### *5.1.2. Step 2*

The dynamic reordering point (ROP) is calculated using the equation proposed by Mahamani.

$$ROP = D_{sr} \times L_{sr} + k \times \sigma_d \times \sqrt{L_{sr}}$$

*Where:*
$D_{sr}$*: Average demand of the item*
$L_{sr}$*: Average delivery time*
$\sigma_d$*: Standard deviation of demand*
*k: Adopted security factor that specifies the level of customer service*

Protection interval (PI) = Delivery time (LT) + Elemental forecast period.

#### *5.1.3. Step 3*

The inventory at the end of each period ($I_F$) is calculated using the following relationship:

$$I_F = I_I + Q + D$$

If the inventory is greater than zero, inventory costs are incurred. Delay costs occur only when the system faces a shortage. It is assumed that the weekly inventory is zero in case of lack of stock.

#### *5.1.4. Step 4*

Security stocks are the minimum additional inventories. They serve as a margin of safety to meet an unanticipated increase in use. A result of unusually high demand and an uncontrollable late receipt of incoming inventory [61], [98].

$$SS = k \times \sigma_L$$

#### *5.1.5. Step 5*

The cost matrix and the levels of service efficiency are formulated in the spreadsheet by using the following equation:

$$\text{Total cost of inventory (TIC)} = \text{Cost of order} + \text{Cost of maintenance of inventory} + \text{Cost pending payment}$$

$$\text{Total cost of inventory (TIC)} = \text{Number of shipments} \times \text{Co} + \text{Quantity of inventory} \times \text{Cc} + \text{Quantity pending order} \times \text{Cb}$$

$$\text{Level of service efficiency} = [1 - \frac{\text{Quantity of stockouts}}{\text{Total period}}] \times 100.$$

### 5.2. Analytical approach method

In an analytical approach method, the total cost of the inventory is calculated by summing the order and maintenance costs. The system variables of the ordering and maintenance costs and the total inventory cost were evaluated using the equations shown in Table 6. The system parameters were evaluated for the 10 items and tabulated in Tables 9, 10 and 11. Due to the limitations of this method, the level of service efficiency could not be evaluated.

**Table 6.** The equations for calculating the total inventory cost, Source: Based on study

| Politic | Total Inventory Cost |
|---|---|
| **(r, Q) policy** | $\frac{D}{Q} \times C_o + (k \times \sigma_L \times \sqrt{LT}) \times C_C$ |
| **(rk, Q) policy** | $\frac{D}{Q} \times C_o + (k \times \sigma_L \times \sqrt{LT}) \times C_C$ |
| **Existent Policy** | Not applicable |

**Table 7.** The results of the analytical approach of the demand to choose the best method of forecast of the item 1XA,

| | | Dem | ST | ST2 | For | Err | MAD | MSE | MAPE |
|---|---|---|---|---|---|---|---|---|---|
| Jan | 1 | 900 | | | | | | | |
| Feb | 2 | 989 | | | | | | | |
| Mar | 3 | 620 | | | | | | | |
| Apr | 4 | 648 | 674 | 701 | 729 | 758 | 788 | 41 | 9% |
| May | 5 | 767 | 798 | 830 | 863 | 897 | 933 | 49 | 10% |
| Jun | 6 | 732 | 761 | 792 | 823 | 856 | 891 | 47 | 10% |
| Jul | 7 | 866 | 901 | 937 | 974 | 1,013 | 1,054 | 55 | 11% |
| Aug | 8 | 624 | 649 | 675 | 702 | 730 | 759 | 40 | 8% |
| Sep | 9 | 876 | 911 | 947 | 985 | 1,025 | 1,066 | 56 | 12% |
| Oct | 10 | 1080 | 1,123 | 1,168 | 1,215 | 1,263 | 1,314 | 69 | 14% |
| Nov | 11 | 1151 | 1,197 | 1,245 | 1,295 | 1,347 | 1,400 | 74 | 15% |
| Dec | 12 | 505 | 525 | 546 | 568 | 591 | 614 | 32 | 7% |

**Table 8.** The results of the analytical approach of the demand to choose the best forecasting method of the item 2XB,

| | | Dem | ST | ST2 | For | Err | MAD | MSE | MAPE |
|---|---|---|---|---|---|---|---|---|---|
| Jan | 1 | 810 | | | | | | | |
| Feb | 2 | 561 | | | | | | | |
| Mar | 3 | 377 | | | | | | | |
| Apr | 4 | 620 | 645 | 671 | 697 | 725 | 754 | 41 | 9% |
| May | 5 | 723 | 752 | 782 | 813 | 846 | 880 | 49 | 8% |
| Jun | 6 | 899 | 935 | 972 | 1,011 | 1,052 | 1,094 | 47 | 10% |
| Jul | 7 | 884 | 919 | 956 | 994 | 1,034 | 1,076 | 55 | 8% |
| Aug | 8 | 279 | 290 | 302 | 314 | 326 | 339 | 40 | 8% |
| Sep | 9 | 746 | 776 | 807 | 839 | 873 | 908 | 56 | 8% |
| Oct | 10 | 882 | 917 | 954 | 992 | 1,032 | 1,073 | 69 | 14% |
| Nov | 11 | 459 | 477 | 496 | 516 | 537 | 558 | 74 | 15% |
| Dec | 12 | 543 | 565 | 587 | 611 | 635 | 661 | 32 | 7% |

**Table 9.** The analytical approximation results of the policy (r, Q),

| Item | Demand per year | Re-Order Cost/ order | Carrying Cost/unit/year | EOQ | No. of units ordered | No. of orders per year |
|---|---|---|---|---|---|---|
| 1XA | 6450 | 1260 | 2 | 946 | 30,000 | 5.43 |
| 2XB | 5390 | 1080 | 2 | 752 | 4,000 | 2.78 |

**Table 10.** Results of analytical approach of policy r, Q.,

| Item | Max. Lead time | lead time | Demand | Safety stock |
|---|---|---|---|---|
| 1XA | 4 | 2.5 | 6,450 | 440 |
| 2XB | 4 | 2.5 | 4,000 | 992 |

Figures 11 and 12 show the service levels that are determined at the end of each period in both approaches.

**Table 11.** Results of analytical approach of policy r, Q.,

| | Lost Sale | | |
|---|---|---|---|
| Year | Total Orders | Order Quantity | Service Level |
| 2016 | 6,590 | 1,634 | 75% |
| 2017 | 6,450 | 1,729 | 73% |

**Table 12.** Results of analytical approach of policy r, Q.,

| | | | | Lost Sales | |
|---|---|---|---|---|---|
| Year | D estimate | Safety stock | Total | Order Quantity | Service Level |
| 2016 | | | | | |
| 2017 | 5135 | 440 | 5575 | 875 | 86% |

The inventory levels of the order policy (rk, Q) are closer than the order policy (r, Q). The level of inventory in the existing policy is lower than in the other policies, which causes frequent shortages in the system. Figure 14 represents the fulfillment of orders between 2017 and 2018 after the calculations made in Tables 7, 8, 9, 10. It is seen that in the percent of fulfillment of orders in the months where the loss of sale was due to non-fulfillment of orders increasing considerably. Table 7, 8, 9, 10 shows that both order costs and pending orders will reduce the total cost of inventory with the order policy (r, Q).

By implementing the order policy (r, Q), we can achieve considerable savings in total inventory costs. The results of the analytical approach reveal the same thing. Figure 13 shows the comparison of the service level effectiveness of the order policies in the spreadsheet-based approach. The service level of the current policy is lower than that of the policy (r, Q) [4], [17]. This also shows that we can achieve a 100% service level by implementing the policy (r, Q). Due to the complexity of the real system, we could not evaluate the efficiency of the service level through the analytical approach method.

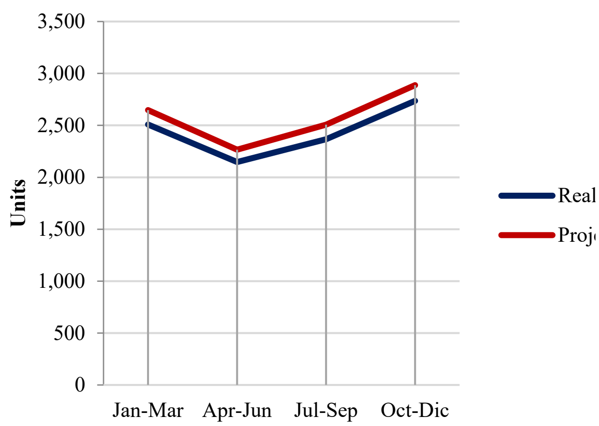


**Figure 11.** Analysis of sales in units of the real with the projected of the item 1XA


**Figure 12.** Analysis of sales in units of the real with the projected of item 2XB

From the previous research, it is not economical to implement the order policy (rk, Q) in the current system. The order policy (rk, Q) is a forecast-based approach. The main limitation of this policy is the error in the forecasting method. The simple exponential smoothing forecast model, with 0.2 as a smoothing constant, was used in the system. The value of the dynamic reordering point of the policy (rk, Q) is older, which will increase the amount of shipments and cause stockouts [16].

Because of this, the policy (r, Q) results in low inventory performance. However, the policy (r, Q) offers good inventory performance with a reliable forecast as shown in Tables 5 and 6. This research showed that by implementing a sorting policy (r, Q), we can achieve a reduction of 18.34% in the inventory with a level of service efficiency greater than 85%.

Ref. [18][63] they mention that the order policy (r, Q) is the best alternative for the current system. According to the policy (r, Q) represents a fixed amount and a static reordering point. When using this policy, it is easy to control the stock level for the 10 items.

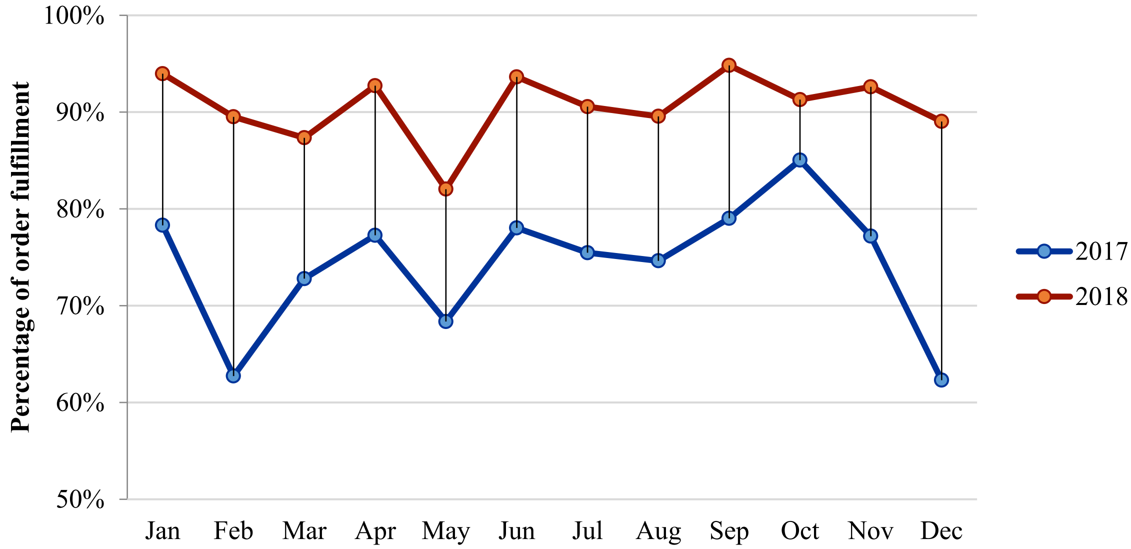


**Figure 13.** Fulfillment of orders for the years 2017 and expected 2018

### 5.3. Expected total cost analysis model

By using the following equation, we can analyze the changes in the total expected cost. It can also be used to determine the expected total revenue which includes the storage cost of the unit product and the shortage costs of the unit product, which offers an additional suggestion for the corporate investment decision. Take the expected total cost as an illustration.

$$EAC(Q,r,l) = A + h\left[\frac{Q}{2} + r - D \times L + (1-w) \times E + r\pi E(X-r) + RL\right]$$

*Where:*

*EAC: Total annual cost per order quantity*
*D: Average demand per year*
*Q: Order quantity, a decision variable*
*h: Cost of inventory maintenance per unit per year*
*X: Demand during the delivery time, a random variable*
*f (x) The probability distribution function of X*
*w: Marginal gain per unit.*

Considering the restriction of the larger budget and the total stock, we obtained the optimal order quantity. A numerical example showed that the method was feasible and effective (see figure 14). In addition, we were able to analyze the changes in the total expected cost with the storage cost of the unit product and the shortage cost of the unit product. This data could provide helpful data for corporate investment decisions.

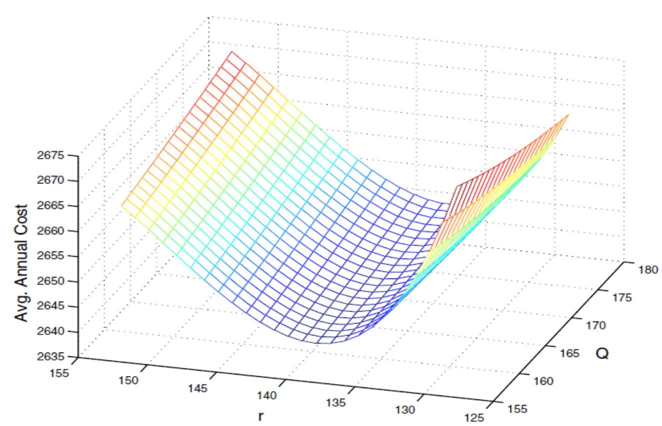


**Figure 14.** Annual Total Cost Chart by ordered quantity [41], [59].

In practice, this model of reducing order costs and ensuring delivery times when there is an uncertain demand from a buyer is compared to real-life inventory systems. For example, in India, small-scale industries spend additional costs on inventory investment and yet, they are expected to reduce the average total cost of inventory. We present the managerial implications of the proposed model based on numerical results and show the effect of the parameters of the model.

## 6. Limitation of the scope of coverage

Ref. [19], [41] Most companies involved in inventory management are faced with making decisions for many individual elements with a wide range of factors to consider, such as demand patterns, vendor shipping modes, delivery methods to customers with some budget limitations, supplier restrictions, and various customer service levels required. Therefore, the following four key questions are posed that inventory management tries to answer [59].

a) How often should the inventory status be determined?
b) When should a replacement order be placed?
c) How large should the replacement order be?
d) What is the minimum level of service in the organization?

Inventory management is often intertwined with operations and supply chain management; however, the problems effects every aspect of the company. Therefore, this document focuses on the management of inventories of a single echelon in the chain.

## 7. Future Research

Ref. [41] This study focused only on the automotive industry and the role of inventories as a single link of the supply chain Therefore, future studies could be carried out using another type of industry or obtaining greater mathematical complexity. For instance, using the perspective of managing inventories with more links, and collaborating the information that exists throughout the supply chain. Future research could also include restrictions that are relevant to each real case in manufacturing and service organizations [36].

## 8. Conclusions

A mathematical model has been proposed to address the optimal management of products (spare parts) with a greater participation in the automotive industry. Companies need to implement improvements in inventory management that lead them to have a higher level of service and profitability. The main objective is to provide an inventory management model for supply chain distribution process, whose main business is based on buying, storing and sales in order to obtain a high level of service. For this, we compare approaches throughout the supply chain related to the company under study.

Inventory control is a way to increase profit margins without altering resources. The contribution of this document is the construction of a conceptual methodology of inventory problems, followed by a spreadsheet model that incorporates a dynamic logic of rearrangement policy. Using the result of the spreadsheet-based approach and the analytical approach method, a better alternative order policy can be developed for a single-step supply chain by statistical analysis of the dynamic rearrangement point, the static rearrangement point and existing order policies. It was evaluated using a randomly generated demand. The objective of this work is to develop the best order policy with a low total inventory cost to guarantee a better level of service efficiency in a single-step supply chain. The reduction in total inventory costs obtained from the spreadsheet-based approach is compared with the analytical approximation method. This paper provides a basic understanding regarding the development of an order policy for a single-step supply chain.

The spreadsheet-based approach was successfully applied to the dynamic policy of reordering points of a single-step supply chain. The analysis of the results shows that the implementation of the policy (r, Q) produces a considerable reduction in total inventory costs and a good level of service efficiency, within the ranges defined in the theory of experts (service level 85% acceptable). Due to an inaccurate forecast, the order policy (rk, Q) did not offer any cost savings. The reduction in total inventory costs obtained from the spreadsheet-based approach was closer to the analytical approach method. The flexibility of the optimal inventory policy that was assessed with randomly generated demand values revealed that the performance of the inventory policy (r, Q) was good within a stochastic environment (reduction of stock breaks by 25%).

The proposed procedure could be applied to all markets and other similar entities, verifying the process and adjusting the estimated levels of the inventory management system to assess its practical validity. Model development was an approach based on a spreadsheet, which is easy to learn and economical. The limitation of this approach lies in the errors resulting from the implementation, known as risks. These can be rectified through the use of quality control and debugging tools.

Other future steps include monitoring through the application of the procedure to other stages of the supply chain that conform to it, to enrich them or adjust them to the selected practical study object. The approach proposed in this study represents an alternative calculation of the optimal inventory for the field and can be considered as a starting point for future extensions.

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