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Inventory Management In Manufacturing Organizations

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Abstract

Inventory management in organizations is one of the most important issues that should be treated as seriously as possible since it is directly related to customer satisfaction and cost reduction. This article provides a literature review of inventory management models in the industry, which isclassified into three sections, item classification models, demandforecasting models and inventory management models. The models identified in each of these sections are presented intables, and the relevant information for each. Among the results obtained, it can be concluded that despite thegood participation of multi-criteria classification, the traditionalABC classification with a single criterion is still the most used, that the most used forecasting methods for demand forecasting are time series and that the most studied inventory managementmodels are those implemented when independent demand is considered.

Keywords: Inventory management, forecasting, Inventory classification, Inventory models, Inventory policy.

1. Introduction

Most companies worldwide must manage their inventories efficiently to be competitive in customer service. The general objective of inventory management is to guarantee the timely availability of the needed elements (raw materials, materials in process, finished products, supplies, spare parts, etc.) in the desired conditions and the right place. Considering that inventory management is a cross-cutting activity in the supply chain, strategies should be implemented to achieve effective inventory management to avoid undesirable consequences, such as the whip effect, a low level of service and increased inventory management costs [1]. Likewise, Ronald and Ballou [2] state that the main objective of inventory management is to ensure that the product is available at the desired time and in the desired

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quantities. Usually, this is based on the probability of the ability to fulfill from the current stock. It is common to hear logistics administrators, managers and analysts state that inventory management is one of the main problems they face. For example, one of the typical problems is the existence of excess and shortages of inventories: "We always have too much of what is not sold, and many out-of-stocks of the products that rotate the most". The interesting thing about this problem is that it occurs in practically any company in the industrial, commercial or service sector, which manages, in one way or another, raw materials, components, spare parts, inputs and finished products, products and raw materials in process or in transit, keeping units in inventory to a greater or lesser extent [3].

ABC analysis separates inventory items into three groups, considering their annual cost volume usage [4], [5]. The 80/20 analysis, also known as Pareto's principle, was described by the economist and sociologist Vilfredo Pareto and specified an unequal relationship between inputs and outputs. The principle states that 20% of what goes in or is invested is responsible for 80% of the results obtained. In other words, 80% of the consequences are derived from 20% of the causes; this is also known as the "Pareto rule" or the "80/20 rule"[6]. It is a well-established categorization technique based on the Pareto Principle to determine which items should be prioritized in a company's inventory management. In discussing this topic, today's operations and supply chain management textbooks focus on dollar volume as the sole criterion for performing the categorization [7]. Similarly, [8] states that different classification approaches achieve different classes as well as different performances of all inventory systems. This evidence trivially demonstrates that a single classification approach does not provide robust results. A company's inventory depends on several criteria, such as unit price, annual demand rate, critical nature, scarcity, and durability [9]. According to [10], A classification technique can be selected according to the number of criteria and the availability of historical data. For example, ABC analysis on one criterion usually uses value. Matrix for two criteria, usually use value and lead time. Multiple criteria decision-making methods, i.e. AHP, multiple attribute utility theory (MAUT), weighted sum, for multiple Criteria; artificial intelligence for supervised classification: new items are classified according to inferred rules extracted from a training set of historical items.

On the other hand, sales forecasts become an important source of information to forecast demand as realistically as possible [11]. Sales forecasting is essential in production, transportation and decision-making at all company levels [12]. Forecasting has become profoundly important due to shorter lead times, increased customer expectations, and the need to deal with limited resources [13].

Forecasting methods can be classified into the qualitative, historical projection, and causal. Qualitative methods are fundamentally subjective and are used without historical data [14]. They are practically based on the analyst's experience, surveys or comparative techniques to generate quantitative estimates. They can be vital in the case of demand forecasts for new items [3]. Methods based on historical data, considered the time series method, consist of using analytical techniques to determine trends and seasonal variations. Forecasts made using these methods are based on the premise that the trend that has been occurring will be maintained, thus obtaining predictions that are pretty accurate in the short term. Among these are the techniques of the simple moving average, weighted moving average, exponential smoothing, trend-adjusted exponential smoothing, multiplicative seasonal method and time series with seasonal and trend influences, among others [14]. The forecasting system to be chosen depends largely on the demand pattern observed through historical data, therefore [15] Generalizing a forecasting method by category causes distancing of it from the actual demand. In most cases, minimal differences between their errors give the choice of the best approach; occasionally, when updating the information, the choice of the method varies concerning a period in the past.

The basic purpose of inventory analysis in manufacturing and services is to specify 1) when more parts need to be ordered and 2) how large the orders should be. Many companies often establish longer-term supplier relationships to cover their needs for perhaps an entire year. This changes the questions of "when" and "how many to order" to "when" and "how many to deliver" [16]. Most SMEs in the manufacturing sector failed to accurately synchronize demand and supply, leading to overstocking or stock-outs. Manufacturing companies use various inventory management systems, but they raise issues that affect their performance. The extent to which these techniques are used and their effectiveness in the industry has been the main reason for the research. There is a great disparity between theoretical and practical inventory management systems applied in manufacturing industries, and there is a need to bridge the gap between the two [17].

In [18], they reviewed the literature on inventory models oriented to the spare parts system, showing how the different characteristics of inventory systems with deteriorating products have been addressed. In [19], they present a review of inventory models with perishable products, where they examine the main characteristics studied by the scientific community in the development of mathematical models that seek to define an optimal inventory policy for deteriorating products.

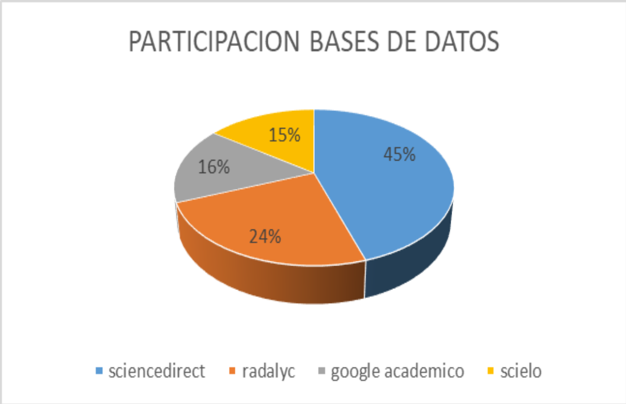
This article presents a literature review of the different inventory management models applied in the industry, considering the importance of inventory classification and models for treating demand variability for a correct definition of inventory policies. Section two describes the methodology used to search and classify referenced articles. In section three, we can observe the literature for inventory management models, which were classified as models for inventory classification, Models for demand forecasting and inventory policies. Finally, section four presents the authors' conclusions.

2. Method

For the development of this review, articles related to the subject of inventory management were consulted since they provide the different models and methodologies recognized by journals as high-quality material. For the search process, the following inclusion criteria were taken into account: scientific articles published between the years 2011-2021, articles published by journals recognized in Publindex as high-quality material, articles that present problems related to inventory management in the industry that such issues can be solved using some methodologies and tools available in industrial engineering, for the validation of this criterion the summary was read, since in most of them the problem to be solved, methodologies and conclusions can be visualized.

The search for each of the articles was made taking into account mainly the Boolean operator "and" and the combination of words that could cover some of the inclusion criteria mentioned above. These words correspond to inventory management and industry, inventory forecasting and industry, inventory classification and industry, inventory models and industry, and inventory policy and industry, as well as these terms, but in Spanish. Fifty references were included, which were related thanks to the Microsoft Excel tool. Figure 1 shows that 45% of the referenced articles were consulted through the ScienceDirect database, 24% from Redalyc, 16% from Google Scholar and 15% from Scielo.

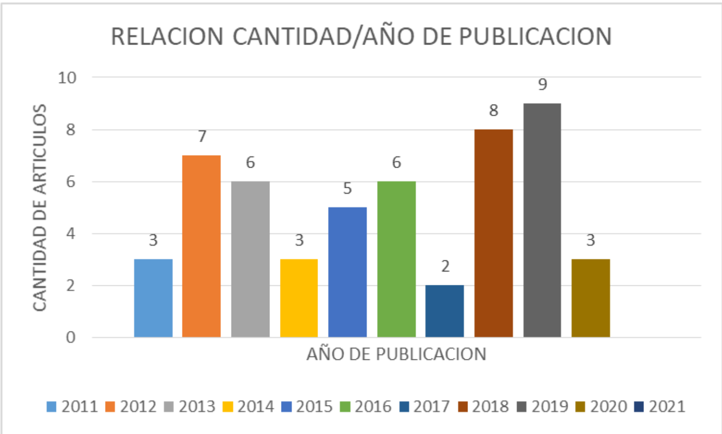
Figure 1. Participation of articles by the database.



The search process was initiated in the direct science database, taking into account the search equation formulated above. Then, after validating the number of existing articles, the results were filtered, considering inclusion criteria such as date of publication, type of article and subject matter. This procedure was applied for each of the databases, but with the difference that not all of them have the option of filtering in as much detail as science direct does.

Figure 2 shows the relationship between the number of articles found and the year of publication. It can be identified that the years 2018-2019 are the years with the highest number of publications concerning the topic consulted.

Figure 2. Number of articles per year



3. Results

3.1 Inventory classification models

Among the articles that applied models for inventory classification, [6] presented a proposal using ABC analysis to classify items, taking into account the unit price as the only criterion. While in [11] the classification criterion was the sales volume, and in [20], it was the investment. Among the articles that developed the ABC multicriteria classification, we found that [21] presented an inventory management system for perishable products with a multicriteria approach taking into account the rate of change of the order rate, the average inventory and the fulfillment rate. Likewise, in [22], they proposed a methodology for inventory management where they applied the ABC multi-criteria classification but taking into account criteria such as cost of sales, turnover, inventory level and average inventory. Similarly, in [23] they present an example where it can be seen that the magnitude of the values assigned to the different criteria has a high impact on the classifications of items under a multicriteria approach, so it is a factor that should be considered in this type of analysis. On the other hand, [24] presents a study in a spare parts warehouse where they performed the multicriteria classification using the fuzzy AHP method, which consisted of two classifications, the first to establish the most representative groups of items in the inventory, where criteria such as total cost and criticality were taken into account, and the second to identify within these groups the critical items for the control system where they used the criteria of total cost and rotation.

In [25], they develop the multicriteria methodology in a food bank where they integrate the AHP and TOPSIS models, and the AHP is used to weigh the considered relevant criteria. TOPSIS to evaluate these criteria in each of the alternatives that request support. In the model proposed in [26], they develop the multicriteria classification a little more straightforward compared to the other methods or, as the author states, in a more effective way. In this case, the weights assigned to each criterion are equal. Therefore, it is considered that all have the same importance. Differently in [27], they propose the Gaussian mixture model to deal with the multicriteria ABC inventory classification problem where they not only provide a classification free of subjectivity processes but also provide a competitive total inventory cost with the maximum service level. In [15], they proposed a new classification based on physical inventory, where they concluded that, due to the particularities in turnover, it is convenient to perform a category for each point. In [8], they proposed a five-step procedure for inventory classification and control, where they compared two item classification models, such as the ABC analysis and the scoring method, where the best solution was given by the scoring method. While in [28], they proposed the Part Grouping Heuristic, which automatically classifies all MRO (maintenance, repair and operations) parts into appropriate groups to focus the consideration of proper technological innovation. Based on the consulting research, Table 2 relates the criteria to the frequency of use in item classification models.

Table 2. Criteria used for inventory classification.

Criterium	%	Author
annual income	20%	18,49,44,6,7,29,37,35
annual demand	12%	16,23,28,29,35
turnover	12%	5,9,17,34,11
unit cost	10%	17,23,37,9
replenishment lead time	10%	28,23,34,11
sales volume	5%	4,34,
unit price	5%	29,34,
inventory level	5%	5,34,
average inventory	5%	5,11
annual investment	2%	2
cost of sale	2%	5
weight	2%	17
volume m3	2%	17
criticality	2%	9
maintenance cost	2%	35
comparability score	2%	34

It can be seen that the most commonly used criterion for inventory classification in the consulted research is annual revenue with a frequency of use of 20%, followed by the two criteria that were used with a significant frequency: annual demand and turnover.

Table 3 shows the tools used by the articles consulted for the classification of items in the inventory management models, where it can be seen that the most used technique is the ABC analysis, with a frequency of use of 44%, and in second place is the ABC multi-criteria analysis with 28%. According to the results, it can be seen that despite the importance expressed by different authors on the use of techniques that evaluate more than one criterion, the traditional classification based on the Pareto principle with only one criterion continues to be the most used in the industry.

Table 3. Methods used for the classification of inventories

Tool	%	Author
ABC analysis	44%	4,18,49,44,6,7,16,2
ABC multi-criteria analysis	28%	17,11,23,5,37
ABC analysis - scoring method	6%	28
ABC multi-criteria analysis - AHP	6%	29
ABC multi-criteria analysis - Fuzzy AHP	6%	9
ABC multi-criteria analysis- Gaussian mixture model	6%	35
Part grouping heuristics	6%	34

3.2 Demand Forecasting Models

Forecasting is a vital tool in the decision-making process of different organizations [29]. For this reason, they should consider the implementation of practical techniques for demand forecasting [30]. In [24], they present a proposal for the problem of inventory control in a spare parts warehouse, where they analyze the demand and the respective forecast, taking into account the time series analysis methods. As a result, they obtain that to forecast the future demand for type A items, and they should use the Croston method. Something similar is proposed in [31], but the forecasting method used is double exponential smoothing and double moving averages.

Similarly, in [22], they evaluate the time series methods where the most appropriate method for demand forecasting is the Winters method. Likewise, in [32], they determine the demand forecasting, but in this case, they do it using the exponential smoothing method. In [33], they forecast the demand of an automobile manufacturer in Brazil by evaluating models such as SMA - Simple Moving Average, SBA - Approximation and Syntetos-Boylan Bootstrapping. On the other hand, in [34], after assessing the demand behavior they define that for type A items, the appropriate forecast is the double exponential smoothing for type B, the simple smoothing and type C, the moving average. In [35], they use time series forecasting models to investigate the relationship between the forecasted results and the whip effect, [36] which is one of the causes of the fluctuations experienced by the demand projection as it moves away from the market along the Supply Chain, as a consequence of lack of coordination and synchronization between the intervening agents (Supplier, manufacturer, distributor, wholesaler, retailer).

In [37], they examined conventional forecasting methods such as last value forecasting, moving average and more complex models such as the Prophet model and neural network model, where they calculated the associated margins for all models and, based on these, concluded that the neural network approach was suited most of the kitchens in the present analysis. On the other hand, in [38], they study the forecasting of intermittent demand for a specific type of replacement part in the Brazilian refrigeration systems industry. The results are calculated using classical out-of-sample intermittent forecasting methods such as Croston, Syntetos-Boylan Approximation (SBA), Shale-Boylan-Johnston Correction (SBJ), Multiple Aggregation Forecasting Algorithm (MAPA) and models based on Artificial Neural

Networks (ANN). The comparative analysis of the results shows that forecasts based on ANN models present the best performance. In [15], through simulation, they evaluated forecasting methods such as moving average, simple exponential smoothing, Croston method and Winters method to determine the most appropriate method for each element where they concluded that due to the particularities in the rotation and demand behavior, it is convenient to use moving average for forecasting and to use a monthly forecasting period.

In [39], they propose a framework for modeling and forecasting the export sales of a middle-eastern company using an artificial intelligence technique called Genetic Programming and a sensitivity analysis to evaluate the model's predictive quality. In [40], supply chain management improved overall performance and efficiency through forecasting executed with ANN modeling. They claim that it can handle high-volatility data with higher accuracy, thus overcoming the shortcomings of traditional forecasting models. Finally, in [41], The paper presents a new hybrid spare parts demand forecasting method dedicated to mining companies, combining information criteria, regression models and artificial neural networks.

As can be seen in Table 4, the most used type of forecast for demand forecasting is quantitative, with a frequency of 61%, followed by causal methods, with 35%. In the quantitative techniques, it can be seen the importance of identifying the type of behavior of the demand and the use of performance measures when defining the type of forecast. Also, it could be seen how this artificial intelligence tool called neural networks has been used considerably when there is high variability in demand. As mentioned above, the application of each of these forecasting methods depends on some variables such as market characteristics and historical data on total sales.

Table 4. Methods used for Demand Forecasting

Type of forecast	%	Forecasting method	Author
qualitative	4%	survey	1
quantitative	61%	double moving averages	17,7
		Winters	5
		single exponential smoothing	6,7,16
		double exponential smoothing	7,17
		Holt-winters	4,16,41
		Croston method	9,2,16
		Simple moving average	16,27
causal methods	35%	Syntetos-Boylan bootstrapping	20,27
		Multiple Aggregation Forecasting Algorithm	20
		Genetic Programming	30
		Sarima	41
		regression models	45
		Artificial Neural Networks (ANN)	20,45,39

3.3 Inventory policy models

In [24] [42] [22] they present a proposal for the application of the continuous inventory control policy (s, Q) that contributes to cost minimization and meets a service level previously defined by the organization. On the contrary, in [10] they proposed an EOQ model with periodic review for the manufacture of transformers where the results obtained showed that the costs of maintaining the inventory are minimized for a service level of approximately 90% for each of the items. Likewise, in [43] they proposed a periodic review (RS) system, considering it the most appropriate to offer greater flexibility in its initial implementation and follow-up process, being also favorable in terms of time and costs.

Similarly, in [44], they developed a service model for a periodic review inventory system with lost sales by comparing the optimal and periodic replenishment policies. On the other hand, in [45] they present new models that allow constant lead times of any duration when the demand is compound Poisson and conclude that both the optimal policy and the policy with restriction to the maximum order size give good results. However, in [46], they consider an inventory model for a continuously deteriorating item, the demand is uncertain, and the replenishments require a positive lead time. They propose an iterative method to minimize the cost function where they perform numerical experiments to investigate the efficiency of the proposed model, the results show that the developed model should provide a very good approximation of the optimal policy. On the other hand, in [47], they propose to examine deterministic inventory models for independent demand. The main conclusion is that the single lot method, used by FACES management, compared to the lot-by-lot, EOQ, SM, CUM, BPF and WW models, is the most costly and, consequently, the least indicated.

In [48], they studied the application of a supplier-managed inventory (VMI) system model in the animal nutrition industry. As a result, they obtained that the application is valid but presents resistance on the part of the company's customers to make the schedule of the next purchase. Similarly, they show the application of VMI in a Colombian food distribution company. They compared two methods and concluded that the more straightforward method (the average of three periods) is the one that yielded better results. Finally, they stated what is important to analyze, in a particular way, each company and its market characteristics, to determine which is the most appropriate VMI model to be used.

On the other hand, considering the dependent demand in [5], the proposed research results show that the system of two containers based on bar codes has improved the performance for reducing operations and efficient working time. Likewise, they present an MRP model in the manufacture of medicines in the company Laboratorios Oriente in Santiago de Cuba, which is solved using the WinQSB software and conclude that this tool was handy and feasible in inventory management. Differently, they investigated a case study but compared MRPII and Demand Driven MRP (DDMRP), where they used a discrete event simulation to evaluate the impacts on system behaviors of both methods. The results show that DDMRP develops properties recognized to generate flow management policies. Still, they were obtained while the demand was not stable at all. In fact, DDMRP continuously adapts the damping level to demand trend changes but appears sensitive to huge unanticipated demand.

Similarly, in [52], they make a comparison, but this time between MRP and JIT control systems and the organizational structure of information processing that determines the delay in decision-making. They found that JIT is suitable for small batches and large variety production and MRP for large batches and small variety production. On the other hand, [53] considered the problem of dynamically updating the manufacturing lead time estimates used in MRP systems, using simple and iterative algorithms to replace the fixed lead time estimates of MRP systems. Again, the results show a significant improvement in the proposed approach.

However, in [54], they developed a hybrid inventory management model consisting of a "Pull Signal" (PS) and two profitability formulas (CEF), where PS is an inventory ordering algorithm that triggers purchasing and determines the quantity and timing of supplies being pulled from production. In addition, the two formulas decide which components should be treated as critical. Finally, they conclude that it is most useful when production time is short, purchasing time is long, and demand patterns vary. They claim that it was successfully implemented by a Canadian company in the computer industry and significantly improved a reduction of 27% in total inventory values in only 11 months and, in addition, customer service, cycle times and even warehouse management. In [55], they develop a model where they consider that the demand is known and that only one order can be placed per period. They present an optimization model and a heuristic solution algorithm for the lot size of a single item. First, they formulated the problem as a mixed integer programming (MIP) model, where they used the linear programming software LINGO to obtain the optimal solution for small examples. But as the MIP model becomes too difficult to solve for large problems they propose a heuristic method, based on the Silver-Meal algorithm, where they conclude that the heuristic method provides near-optimal solutions and is much faster than the MIP method.

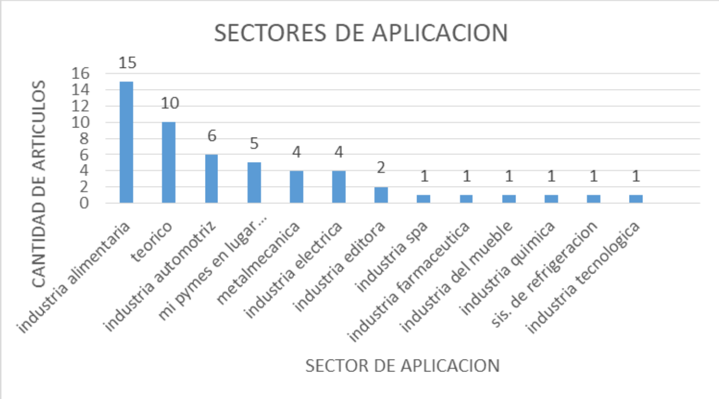
As can be seen in Table 5, 82% of the documents consulted presented models based on independent demand and 18% on dependent demand. It was also found that the most widely used model is the EOQ with continuous revision and that the models that have been used the least are those used for deterministic models with independent demand. It was possible to see the importance of each of these models depending on the characteristics of the demand with the presentation of the different models,.

Table 5. Classification according to the demand and the models used

DEMAND	%	Nature	MODEL	AUTHOR
independent	74%	Probabilistic	EOQ (continuous review)	49,28,9,2,3,5,32
			EP (periodic review)	28,18,43,19
			EOQ (optimal policy - the policy with maximum size restriction)	15
			VMI (vendor-managed)	14,46
			hybrid model	53
		Deterministic	Silver-Meal heuristics	54
			lot-by-lot, EOQ, SM, CUM, BPF and WW	33
dependent	26 %		MRP / ERP	50
			MRP II, demand-based MRP	51
			MRP - just-in-time	52,1
			MRP	55
			kanban	12

According to the articles consulted, Figure 6 shows that the food industry was one of the sectors in which inventory management models have been studied the most.

Figure 6. Number of items per Application Sector



4. Conclusions

We considered the importance of good inventory management in organizations. Therefore, three types of models have been consulted: inventory classification models, demand forecasting models and inventory models. We identified the criteria most used to classify inventories. The decision of which criterion should be used depends on the type of inventory to be classified and the economic activity of the company. The most used technique was the traditional ABC classification due to its ease of implementation, unlike the ABC multicriteria classification, which is much more complex due to the implementation of more than one criterion and the consideration of subjectivity at the time of assigning weights to each criterion.

On the other hand, the most used forecasting methods were presented, where it can be identified that the most implemented methods are time series; in general, in order to determine the forecasting method to be used, the behavior of the demand presented by the item, the data history and the performance measures must be taken into account. Finally, the most used techniques were presented in the inventory management models. Despite the availability of technological tools such as simulation and artificial intelligence techniques, the most implemented models are the EOQ models with continuous review.

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Appendix A. An example appendix

Authors including an appendix section should do so after References section. Multiple appendices should all have headings in the style used above. They will automatically be ordered A, B, C etc.

A.1. Example of a sub-heading within an appendix

There is also the option to include a subheading within the Appendix if you wish.

Makalenin Türkçe başlığı buraya yazılır…

Özet

Türkçe özet.

Anahtar sözcükler: anahtar sözcükler1; anahtar sözcükler2; anahtar sözcükler3

AUTHOR BIODATA

Insert here author biodata**.**