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Inventory Management in Manufacturing Systems: A Literature Review

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Abstract

Objectives: This research seeks to review the literature, based on exploration mechanisms, on the subject of planning and control of inventories in manufacturing systems. **Methods:** The purpose of this research is based on a review of the literature under a scientometric and bibliometric approach, regarding the planning and control of inventories in manufacturing systems, important services such as number of publications, authors, journals, countries and languages. **Findings:** Current issues have been found and they have worked with greater intensity, in this sense. **Improvements:** Provides a broad spectrum to develop new research that contributes to literature.

Keywords: Decision Making, Inventory Management, Systems of Manufacture

1. Introduction

Today, manufacturing systems must be more flexible and dynamic, to meet the frequent changes in demand. This is why inventories become an important charter in the game of logistics management, which involves planning and efficient control of inventory levels, location and administration. In the manufacturing systems, three types of inventories are identified, such as raw materials, in-process products and finishedproducts, according to[1] the investments in the inventories are large and the associated capital control is a potential to achieve an improvement in the system.

Inventory management is a vitally important process in the operationalization of any company, this implies activities related to planning, control and efficient and effective storage of goods, with the aim of generating adequate levels of customer service. According to[2], the planning and control of inventories are activities of transcendental importance for the fulfillment of the objectives of a company, especially in the manufacturing industry. As for planning, it is fundamental because it allows not having risks of having excessive amounts, which in the end are reflected in the costs, in turn not falling into non-existence, which can lead tounexpectedoperational impacts[3]. On the other hand[4] highlights that the control of inventories is applied in manufacturing systems to reduce fluctuations in demand and control the level of inventories.

Manufacturing-type companies are characterized by the production of tangible goods, so, in general, they have inventories, the proper management or not of these can lead to successor failure[5]. According to[6], inventories also arise from the gap between consumer demand and the production or supply of such products. In summary, inventories can be managed internally in a production system through production logistics and externally through supply logistics or distribution.

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One of the main objectives undoubtedly sought by the manufacturing industry is to minimize the total cost of production and inventories along the programming horizon, which has been considered in theresearch as[7–19], however, there are other cases that seek otherwise. In the work proposed by[20,21] the level of allowed inventories is maximized, in the one developed by[22] the máximum fulfillment of the orders is sought and in those developed by[23–25] the expected profit is maximized. It must be considered that, depending on the situation, the mission is not easy and is subject to different types of conditions or situations associated not only with the client's demand, but also with the stochastic, if not also with the random elements that exist outside of the system. Such as weather conditions or performance uncertainty that occur externally. Similarly, there are random elements within the system that are linked to different resources, such as materials, labor, machinery, the environment and the methods in which the activities are carried out. Given the above, a key aspect in the planning and control process is the prediction of the internal variables that generate a high risk of uncertainty around the planning and programming of the processes and the external ones based on the risk of uncertainty basedonthe lawsuit[26].

In this case and because the planning and control of inventories have become transcendental activities, which determine the success or failure of important objectives, an area of opportunity is generated, given that markets are increasingly demanding in relationship with high quality processes and good levels of service, forcing companies to face better standards of quality, technology and competitiveness. A contribution in this regard is provided by the existence of methods for the planning and control of stocks within the internal logisticsof a company[27]. Accordingly, the optimization and simulation of inventories has gained great importance during recent years, given the trends of market behavior, sales and competitiveness[28].

This article presents a review of literature regarding the management of inventories in manufacturing systems. The type of research is of an explanatory nature, where different fields are shown in which research has been developed. In the same way, a scientometric analysis is developed about the number of publications per year, according to the database, the types of publications, authors, countries and language. In this context, there is evidence of the need to generate support tools to improve the management of inventories, providing support to the decisions that must be made at the tactical and operational levels of a manufacturing system.

2. Materials and Methods

The objective is to conduct a review of the literature related to the management of inventories in manufacturing systems, is based on theformulation of eight (8) research questions denoted as (Qn), where «Q» is the question and «n». In a number that corresponds, in a way that allows a reduction in the gaps between the theoretical, investigative and practical foundations. The following questions were then asked:

- Q1: How is the evolution of the number of publications per year?
- Q2: What are the most important types of publications?
- Q3: What are the most relevant journals?
- Q4: What are the most prominent countries and languages?
- Q5: Which are the authors with the most publications and citations?
- Q6: What are the most related words in the subject?
- Q7: What is inventory and inventory management?
- Q8: How is inventory management classified?

3. Results

As a strategy for the search of necessary information, the scientific databases were used as: IEEE Xplore, Science Direct, Emerald, Springer, Taylor and Francis. Using the tools that these databases provide for the extraction and analysis of information. The strategy of initially starts with the general search in database, in this stage all the researches related to the inventory management are searched in the mentioned databases, then a more refined search is made focused with the planning and control of inventories. The results obtained are imported and organized in spread sheet or VosViewer software, where features such as the year of publication, types of publications, journals, countries, language, authors and most relevant words are examined.

It should be noted that the statistical analysis started in January and ended in October of 2018. For this, graphic tools such as the line diagram, bar diagram and network diagram were applied. (Table 1) summarizes the number of published.

Table 1. Review of the subject in different databases

Databases	Total general search in database	Total search with filter according to keywords
IEEE Xplore	503	369
Science Direct	112.790	831
Springer	103.193	70
Emerald	9.846	18
Taylor and Francis	72.654	44

3.1 Number of Publications (Q1)

For the analysis of the number of publications, the decade from the 60s to the present (1963-2018) was taken as the starting parameter. When carrying out a search on the term: «Planning and control of inventories» it can be seen that the first investigations began to appear as of 1963 and that they have been increasing over the years. Figure 1 shows a positive trend regarding the number of publications related to the subject in the different scientific databases such as Springer, Emerald, Taylor and Francis, highlighting a notoriousbehavior in Science Direct and IEEE Xplore.

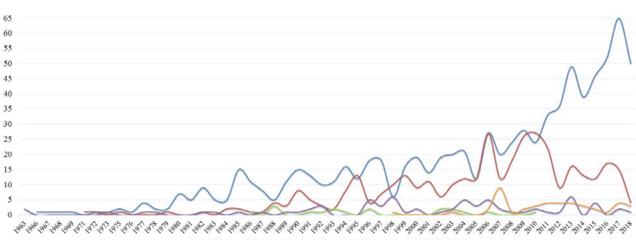

Figure 1. Number of publications per year.

3.2 Types of Publications (Q2)

When verifying the different databases and filtering the search by keywords, out of a total of 1332 documents, 896 documents represented in 67.3% correspond to research articles, 293 documents that are equivalent to 22% refer to publications Through conferences, 98 documents represented by 7.4% correspond to publications through chapters of research books, the rest equivalent to 3.4% correspond to publications developed by symposiums and research books (See Figure 2).

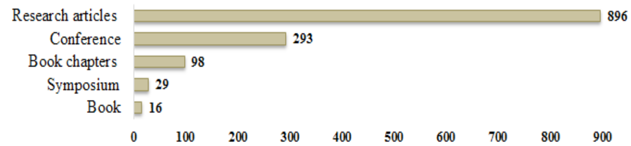

Figure 2. Types of publications.

3.3 Relevant Journals (Q3)

From the information obtained in the different databases, it is highlighted that there are 16 relevant journals which have published more than 10 research on the subject «Inventory planning and control.» As shown in Figure 3.

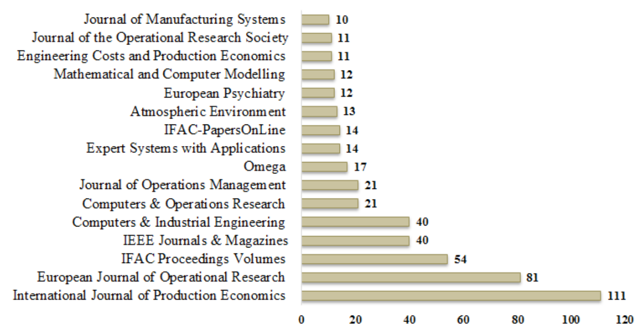

Figure 3. Relevant journals.

3.4 Most Prominent Countries or Languages (Q3)

For an analysis of the most outstanding countries and languages, the Scopus database was used as a search strategy, highlighting among the ten (10) countries that have produced the most publications according to the thematic axis «Inventory planning and control», the United States with 24%, China with 5%, Canada with 3.9%, the United Kingdom with 3.6%, Germany with 2.8%, Taiwan with 2.4%, The Netherlands, India and France with 2.2% and Italy with 1.7%. It should be noted that there is 25.5% of publications that do not denote the country of origin (see Figure 4).

In terms of language, the English language prevails with 93.1% followed by the German and Chinese language with 1.1%, then the French language with 0.3%, Spanish with 0.2% and 1% in other languages. Considering that there is 3.2% of publications that do not identify the language type (See Figure 5).

3.5 Relevant Authors

For the analysis of the authors, the Scopus database was taken as a reference; it was possible to demonstrate that a large number of authors have published publications related to the research topic «Inventory planning and control». This information served as input to be able to use the VosViewer software tool, which allowed to identify the visualization and construction of bibliometric networks. Figure 6 represents the most relevant authors regarding the number of publications developed in recent years. These are represented with larger circles and with a larger font size.

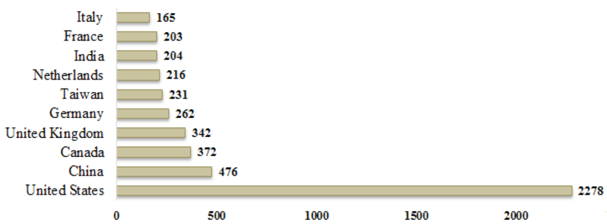

Figure 4. Most prominent countries.

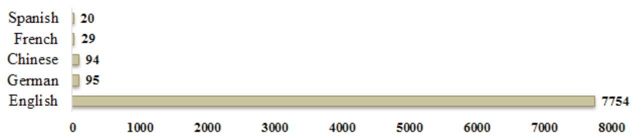

Figure 5. Most prominent languages.

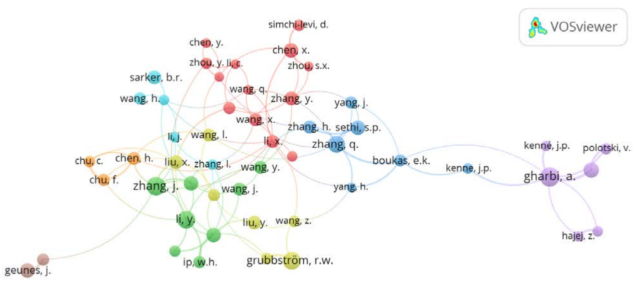

Figure 6. Most relevant authors.

It is evident that authors such as Gharbi, A; Kenne, J.P; Grubbstrom, R.W; Zhang, Q; Zhang, Y. and Geunes, J., are authors considered as main, so they allow the connection or are bridges of communication between eight (8) groups of information networks. However, there are also authors who are in adjacent clusters, who likewise have great value for the quality of their contributions and research, as is the case of Zhang, J. and Sarker, B.R. It is also important to highlight within the research network, the citations that are made to each of the authors, which frames the quality of the contributions and the generation of new knowledge provided to the sciences. Figure 7 shows the most cited authors and with relevant studies with other authors. Highlighting mainly: Gharbi, A; Simchi-Levi, D; Grubbström, R.W; Sarker, B.R. and Chen, X.

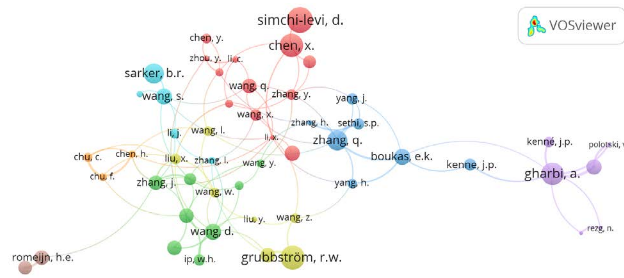

Figure 7. Most cited authors.

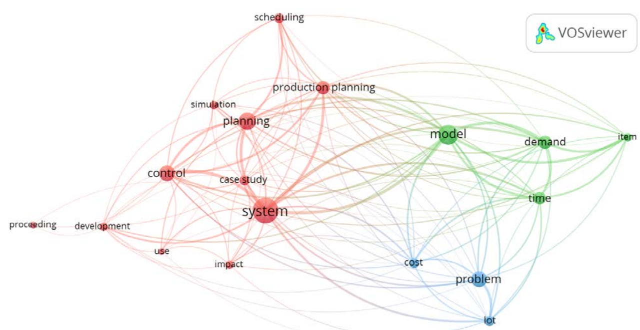

Figure 8. More related words.

3.6 More Related Words (Q6)

Using the VosViewer software, a study of the words most used in the summary of the documents studied was carried out. This tool allowed us to visualize a large number of words related to the subject of inventory planning and control. In Figure 8, most of the occurrences are related to system, planning, programming, control, model, demand, problem and simulation.

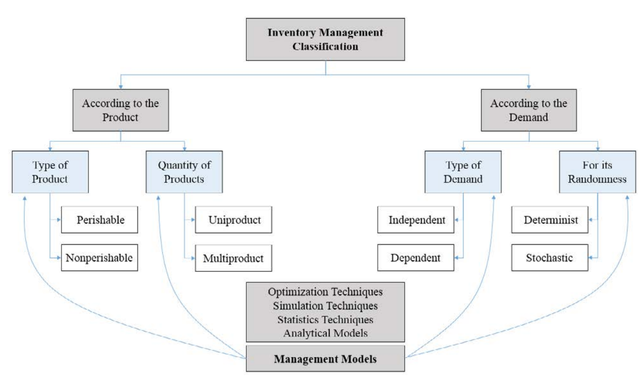

Figure 9. Inventory management classification.

3.7 Inventory and Inventory Management (Q7)

A clear definition of inventories is found in[29] who defines inventories as «accumulations of raw materials, supplies, components, work in process and finished products that appear at numerous points along the production and logistics channel of a company; therefore inventory management derives from the importance of these stocks for the company and the need to exercise control and managethem» According to[30], inventories constitute a resource in terms of stored goods that organizations use to satisfy a demand in the future. Similarly[30] consider that «inventories are the stocks of a piece or resource used in an organization» and that therefore an inventory system is the set of policies and controls that monitor inventory levels and determine those to maintain, the moment when it is necessary to replenish it and how big orders should be.

On the other hand, according to[31–33] in a manufacturing system, inventories can be classified according to their condition during processing in: 1. Inventories of raw materials that include the basic elements that go into the production of the product, another autor such as[34] defines it as the product that has been purchased, but has not yet been processed. 2. Inventories of products in process to which they applied direct labor and indirect costs inherent to the production process and are waiting between one operation and another. According to[34] this inventory «consists of components or raw materials that have undergone some kind of transformation but have not yet been completed». 3. Inventories of finished products that includes the items transferred by the production department to the warehouse because they have reached their full degree of completion, a broader concept isfound in[34] who states that this inventory is one in which there are products that have undergone a process of transformation and have an added value. It is the product that expects to be delivered to the customer. Finally 4. Inventories of materials and supplies that include consumer items intended to be used in all operations of the industry such as spare parts and items for the repair and maintenance of equipment.

Agreed with[35] the inventory within a manufacturing system complies with certain functions such as: 1. Avoiding the shortage that may occur due to the fluctuation of demand as well as delays in the supply of merchandise, 2. Benefit from the reduction of costs by volume during the acquisition or manufacture, taking advantage of discounts, 3. Having a sufficient level of stock to cover the needs and demands of the clients in precise periods to avoid loss in sales, loss of image and confidence of the customers, 4. Absorbing the inventory that is not consumed by the demand.

Inventory management is one of the most complex functions of an organization due to the multiple uncertainties that surround its environment, if there is certainty about the future, the amount of inventory that should be maintained to cover future needs could be unequivocally established, perhaps even not it would be necessary to maintain no amount, however, there are several variations that surround all the organizational work, which is why this is not possible[30–36]. Similarly[37] state that the management of inventories is based on techniques, methods, controls that allow the company to have the merchandise of the products at the desired levels in order to optimize costs for the level of maintenance and replacement. The main problem arises when the demand is unstable, there are methods that serve the company to avoid unforeseen security inventories through mass purchases. More recently[38] define that inventory management is one of the most relevant and challenging activities for any manufacturing organization and should be executed as efficiently as possible to ensure success in today's competitive business world. The development of inventory models for the supply chain is an important area of research that has been explored in recent years. The results of these research efforts have shown that decisions taken in an integrated and collaborative manner translate into greater benefit for all members of the supply chain, compared to scenarios where each member makes decisions individually[38,39]. In short, the management of inventories in a manufacturing system, should be responsible for planning to coordinate, direct and control efficiently, everything related to the management of inventories from the acquisition of raw materials to the production of finished products.

3.8 Inventory Management Classification (Q8)

It is possible to classify the inventory management taking into account two general aspects 1. The product and 2. The demand, whereas in the literature there are different techniques or models that allow an adequate management, the classification scheme would be the next (See Figure 9).

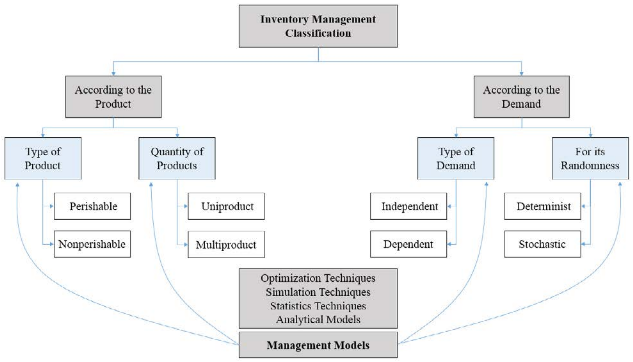

Figure 9. Inventory management classification.

3.8.1 According to the Product

According to the type of product, the management of inventories are classified into perishable and non-perishable products, reviewing the literature it is found that one of the first analytical models that appeared was the EOQ (Economic Order Quantity) model, which basically tries to relate the costs of maintaining the inventory with those of making the order, finding an economic quantity of order that optimizesthecosts generated[40], this model presents some assumptions and is that the demand must be deterministic and the products must be non-perishable. Many of the inventory models found in the literary review assume that items can be stored indefinitely to meet future demands; however, certain types of products may deteriorate or become obsolete over time. The problems of inventory management for perishable products, in general, are difficult to deal with[41,42], this is due to their short life cycle, the variability of demand and the high standards demanded by the customer. More recently[43] establish that in the type of perishable products is more complex inventory management due to its distribution, quality, speed and efficiency given that non-compliance with dates and times, generate economic losses and public health problems. According to the techniques and models used for the management of inventories with perishable products, optimization techniques, simulation techniques and analyticalmodels are found in the literature (See Table 2).

According to the quantity of products, in the review of the literature it is found that the most common case addressed by researchers is when a variety of products are presented, because it generates greater complexity. Highlighting some models where multivariable product demands are considered[44–46]. From another perspective, a widely used approach is the ABC control method, which consists of classifying the products that make up the inventory according to certain criteria, so that, according to their importance, different inventory administration policies for each group can be applied. Such that the efforts and costs of administration are proportional to their relative importance[47–50].

The ABC method of inventories initially based the classification of the products on a single criterion based on the use of the anual dollar (ADU) of each of the references[51]. In the review of the literature it has been shown that researchers have used different types of additional criteria, such as[52] that presents a decisión support system for the analysis and control of inventories through three different types of analysis based on: Price, quantity and importance, in a broader way[53], incorporates some new criteria such as inventory cost, partial criticality, delivery time, obsolescence, the number of annual requests, scarcity, the durability, the size of the order, the response capacity, the distribution of demand and the cost of penalty for exhaustion. In the same way there have been investigations where they use methods that support the problem of classification of products that together withthe ABC method, as shown in Table 3.

Table 2. Review of models according to the type of products

Model Management	Techniques	References
Optimization	Mixed integer linear	In[64–65]
	Mixed integer nonlinear	In[67–74]
	Multi or Single objective	In[75–79]
	Dynamic programming	In[79–84]
Simulation	Discrete simulation	In[85–88]
	Montecarlo simulation	In[88–91]
Analytical	Continuous and periodicreview EOQ (Economic Order Quantity)	In[92–101]

3.8.2 According to the Demand

Depending on the type of demand, they can be classified into two categories, independent and dependent. According to[54–56] for the case of articles with independent demand, it is advisable to apply a philosophy of replenishment of the stock, using the systems of periodic and continuous review and for the case of items with dependent demand it would be convenient to use a philosophy of requirements through the use of Material Requirements

Planning (MRP) systems. The periodic review is where the inventories are checked at regular intervals and the order is placed to increase the inventory level to a specific limit[57,58]. Periodic review models are commonly used in the planning of inventories, especially those that include a stochastic component[59–63].

Table 3. Investigations with ABC inventory classification

Combination of methods	References
ABC method and Hierarchic Alanalytical Process (AHP)	In[102–105]
ABC method and Optimization method	In[53,106–117]

According to the random component of the demand, this can be deterministic and stochastic. The deterministic demand is one that is known with certainty or in an anticipated way and the stochastic demand is one that generates uncertainty and is not known properly. For proper management it is necessary to apply forecasting techniques based on the collection of historical data. Table 4 shows a list of articles investigated regarding inventory management considering the element of randomness in demandin recent years. It is evident that a large part of the investigations are oriented in greater volume to deterministic environments and in a smaller scale, stochastic type investigations.

Table 4. Investigations with inventory management according to demand

Type of demand	References
Deterministic Demand	In[118–130]
Stochastic Demand	In[131–140]

4. Conclusions

In this study, a review of the literature is presented, based on the main scientific data bases. Based on a proposed methodology, the solution was sought to some questions formulated and raised for research. Taking as a time horizon research developed from the 1960s to the present (1963-2018). According to the above, it can be concluded that databases with more volume of publications in terms of the subject studied is Science Direct and IEEE Xplore. It is also important to highlight that of 1332 documents studied, 67.3% correspond to research articles.Regarding the most relevant authors for the amount of publications stand out researchers: Gharbi, A.; Kenné, J.P.; Grubbström, R.W.; Zhang, Q; Zhang, Y. and Geunes, J. and for greater number of citations stand out: Zhang, J. and Sarker, B.R.

From the literary environment, it should be noted that inventory management is one of the most complex functions of an organization due to the multiple uncertainties surrounding its environment, if there is certainty about the future, the amount of inventory that should be maintained to cover the situation could be established unequivocally. Future needs. In this research, a review of the literature on definitions around inventories, management and classification was carried out.

In general terms, it could be shown that the research field has been broad, taking into account the time horizon and the different classifications in which they have been investigated. Considering that there are different techniques or models that allow an adequate management taking into account two aspects such as product and demand.

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