Defense 4.0 - A Bibliometric Review and Future Research Agenda

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Abstract

This paper presents a bibliometric review of 303 studies on Industry 4.0 (I4.0) in the defense sector obtained from the Web of Science (WoS) platform, published in 227 academic circles, authored by 1211 academics. The objective was to broadly and comprehensively identify the concept of I4.0 within the defense sector and identify future research paths. The documents were analyzed using the Bibliometrix tool in the R software. Based on citation analysis metrics, we revealed the most influential articles, journals, authors and institutions. Using the bibliographic coupling methodology, we identified four research clusters: (1) Additive Manufacturing, 3D printing, spare parts, (2) Internet of Things, Deep Learning, military, (3) Machine Learning, suicide, prediction and (4) Systems, Artificial Intelligence, Expert System.The clusters were analyzed in detail and then a research agenda was proposed.

Keywords
Industry 4.0; Defense sector; Cluster analysis; Bibliometric review; Research agenda

1. Introduction
The technological advances in supply chain management brought about by I4.0 have been the object of study in the academic field and in the industry motivated by the temporal rupture of how logistics was thought before such advances and how it would represent a significant point of strategic advantage (Masood & Sonntag, 2020), however, digital transformation is not just about implementing new technologies in isolation, but about evaluating the benefits and challenges arising from such implementation, suited to the company's reality, both in terms of structure and business purpose (Zeller et al., 2018).

Having pacified the understanding that I4.0 represents a disruptive milestone for the industry, when we turn our eyes to the defense sector, we can see the relevance of a more detailed study in this area that depends heavily on technological advances, investments in Research and Development (R&D), robust engineering practices and a trained and qualified workforce to face the country's defense challenges. These challenges stem from a variety of sources that include the pressing need to quickly adapt to an ever-changing operational and threat environment (de Mattos Nascimento et al., 2022), in addition to tight budgets, aggressive schedules, and a risk-averse organizational culture (Zimmerman et al., 2019).

The defense and security problems of the present day are much more complex than those of other times, due to their global impact and the possibilities of the new digital technologies applied, as well as the “smart” weaponry used (Marín, 2020). If, according to Sony and Naik (2020), the topic I4.0 is still little studied, although there has been a great growth of studies on it in the recent years, its application within the defense industries is an even more obscure subject and, after evident importance demonstrated, it deserves academic attention in order to find gaps in the literature that allow more specific research.

The results of this study have several academic and industrial implications. For academics and practitioners interested in I4.0 in the defense industry, it provides a comprehensive overview of the research domain that introduces readers to key studies, authors, universities, concepts, and methods. Defense industries and the Armed Forces can use the concepts and methods identified to improve their strategic planning from the perspective of I4.0 and to have a starting point if they want to implement these technologies within their organizations. In addition, it will allow the identification of gaps yet to be explored and trends in this area of knowledge.

The remainder of this study is structured as follows: Section 2 describes the reviewed literature on which the study was based; Section 3 presents the methodology; Section 4 explains data collection and analysis; Section 5 presents the results and discussion; and Section 6 brings the conclusion.

1.1 Objectives

The general objective of this study was to broadly and comprehensively identify the concept of I4.0 within the defense sector and identify future research paths. Thus, we approach three specific objectives for the research. The first is to confirm the existence of the concept of I4.0 in the defense industries as an autonomous research domain. The second is to identify the main journals, articles, institutions and authors within this research domain and to find the collaborative network of universities and authors. The third is to map the conceptual structure of I4.0 in the defense industry, identifying and exploring research clusters.

2. Literature Review

Originated at the initiative of the German government in 2011 in the search to leverage the competitiveness of its industries, Industry 4.0 (I4.0) is a concept that brings with its technological innovations such as the internet of things (IoT), big data, additive manufacturing, computing in cloud, artificial intelligence and cyber systems physicists (Yin et al., 2018). Other initiatives, such as “Smart Manufacturing” in the US, “Made in China 2025” and “Future of Manufacturing”, in the UK, have also gained notoriety and have similar concepts to those introduced in Germany (Liao et al., 2017).

Schuh et al. (2014), make a comparison between previous Industrial Revolution and I4.0. They claim that the 4th Industrial Revolution has a broader influence on the entire value chain to maximize productivity, efficiency, innovation, creativity and sustainable performance (Machado et al., 2021; Caiado et al., 2022), which is significantly different from previous Industrial Revolution, which predominantly changed the effectiveness of activities based on the “shop floor” rather than extending benefits to support functions such as design, engineering, supply chain, finance and marketing.

The goals of I4.0, according to Massod and Sonntag (2020), are to provide mass customization of information technology-enabled manufactured products; make automatic and flexible adaptation of the production chain; tracking parts and products; facilitate communication between parts, products and machines; apply human-machine interaction paradigms to achieve IoT-enabled production optimization in smart factories; and provide new types of services and business models of interaction in the value chain (Nascimento et al., 2018).

Anand and Nagendra's (2019) study brings the status of India's defense manufacturing sector (Defense Research and Development Organization - DRDO), Artillery Factories (OFs), Defense Public Sector Enterprises (DPSUs) and Industry Private, including MSMEs) controlled by the State from the perspective of I4.0 technologies. In this way, the approach refers to a very specific niche, making an understanding difficult to allow the application of the findings in the defense sector of other countries. The research by Kuo et al. (2019) developed a comparative analysis of innovation policy amidst the industrial revitalization of I4.0 between China, Germany and the USA, focusing on the differentiation of specific policy instruments announced by these governments denoting a bias much more oriented towards the national policy of these countries than towards the impacts of I4.0.

When looking at the research by Bibby and Dehe (2018), there is a study that analyzed a company specifically, and its generalization is difficult when trying to understand the consistency of the I4.0 in a broad and comprehensive way. The present study is more comprehensive than previous studies in terms of dissemination of findings, it has a greater methodological suitability for a little studied topic and sheds light on the conceptual aspects of I4.0 in the defense sector, creating a "background" that will allow the realization of new research on the subject.

The literature search process of the present study was broad, robust, transparent and reproducible, according to Arksey and O'Malley (2005). We reviewed publications that studied I4.0, and related terminology, and the defense industries to identify the I4.0 concept within the defense sector and future research avenues.

3. Methods

Bibliometrics is a research methodology that has been widely applied by researchers, as it is essential to detail the literature and develop an integrated theoretical framework between two or more studied topics. It is a system that uses statistical tools to achieve an accurate and reliable qualitative approach (Brika et al., 2021).

We followed three paths to the findings resulting from the research. The first was data collection, the second the bibliometric analysis of these data was carried out and finally the visualization of the findings.

4. Data Collection

A search was carried out in the Web of Science (WoS) database, which, according to Aria and Cuccurullo (2017), is a reliable platform, which resulted in 303 articles.

The search made use a comprehensive initiative for a general mapping of the literature (Scavarda et al., 2020). For this, we use two axes of words: the first composed of "Additive Manufacturing", "Artificial Intelligence", "Augmented Reality", "Big Data Analytics", "Blockchain", "Cloud Computing", "Digital Twins", "Embedded Systems", "Machine Learning", " Virtual Reality", "Internet of Things" and "3D printing", since for Masood and Sonntag (2020) these are words that reflect the technologies belonging to I4.0, and "digital transformation", "digitalization", "digitization" and “Cyber-Physical System”, as we found in the work of Caiado et al. (2021) in which such terms are related to I4.0. The second, connected to the first by “and”, was composed of the words "defence industry".

The words of the groups were separated by the Boolean “OR” and the findings were limited to the English language and documents such as articles and review articles: (TITLE-ABS-KEY ("Additive Manufacturing" OR "Artificial Intelligence" OR "Augmented Reality" OR "Big Data Analytics" OR "Blockchain" OR "Cloud Computing" OR "Digital Twins" OR "Embedded Systems" OR "Machine Learning" OR "Virtual Reality" OR "Internet of Things" OR "3D printing" OR "digitization" OR "digitisation" OR "digitalisation" OR "digitalization" OR "Cyber-physical system" OR "digital transformation") AND TITLE-ABS-KEY ("defence industry" OR "defense industry" OR "defense sector"OR "defence sector" OR "army" OR "navy" OR "air force" OR "national defense" OR "national defense" OR "defense company" OR "defence company")) AND (LIMIT-TO (DOCTYPE , "ar ") Or Limit-TO (doctype," RE ")) and (Limit-TO (Language," English ")).

4.1 Data Analysis

Data were analyzed using the bibliometrix tool, which is programmed in an open-source R environment and language, suitable for data processing at various stages of the study (Aria & Cuccurullo, 2017).

Having extracted the complete bibliographic data of the 303 studies from the WoS database, we tested Lotka's Law, verified the authors with the greatest relevance, the words-the most mentioned keys in the articles, the thematic evolution of the words present in the titles of the studies and the clusters by the words-keys.

5. Results and Discussion

This study reviewed research on I4.0, in the defense sector, published between 1990 and 2022. We reviewed a sample of 303 relevant studies published in 227 publications in the last 32 years, written by a total of 1211 authors, with a average of 10.06 citations per document. Most authors are part of multiple-authored studies (1180 authors, or 97.4%), while only 2.6% are single-authored studies (31 authors).

5.1 Research domain

Lotka's Law (1926) evaluates the number of authors by the number of publications through the fundamentals of the inverse square law in which the number of authors who make "n" publications in a given scientific field is approximately 1/n2 of those who perform only one publication and that the proportion of those who make a single contribution is around 60%. For the present study, Lotka's Law can be seen in Figure 1.

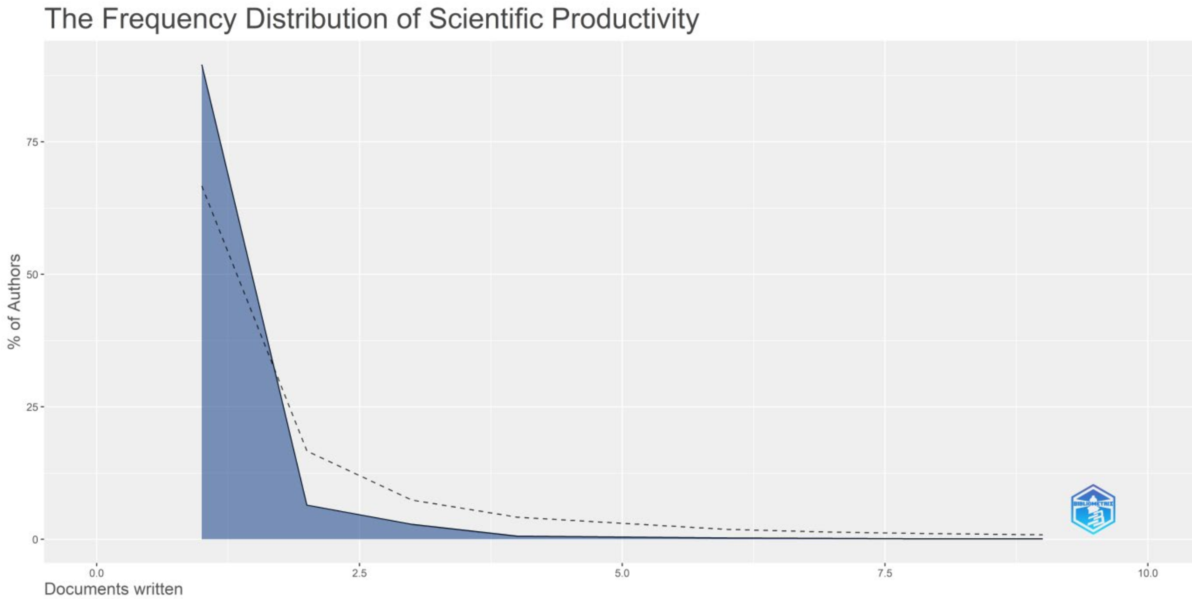

Figure 1. The Frequency of Scientific Productivity

From the Figure 1 we can see that 89.6% of the authors made only one publication, 6.4% two and 4.0% made three or more publications, reinforcing the idea that this is a research domain that, although autonomous, is still little studied and that has a high degree of authorship concentration.

5.2 Main works

When analyzing the main studies from the perspective of the number of citations per year, which we can see in Figure 2, we realize once again that the subject object of this study is still little addressed within the academic doctrine.

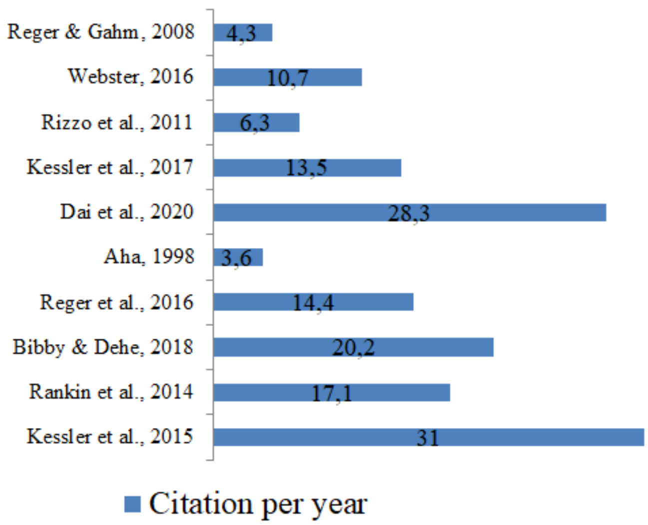

Figure 2. 10 most cited articles per year

After reading the abstracts and identifying which studies address I4.0 within the defense sector, only (Bibby & Dehe, 2018) is in the list of the 10 articles with the highest number of citations per year from the extracted database.

5.3 Trend Topics

In this topic we seek to assess the trend of keywords. To this end, we initially verified the keywords that most appeared in the studies (Figure 3) and made a comparison with the appearances over the years (Figure 4).

Figure 3. Cloud with the keywords with the most appearances

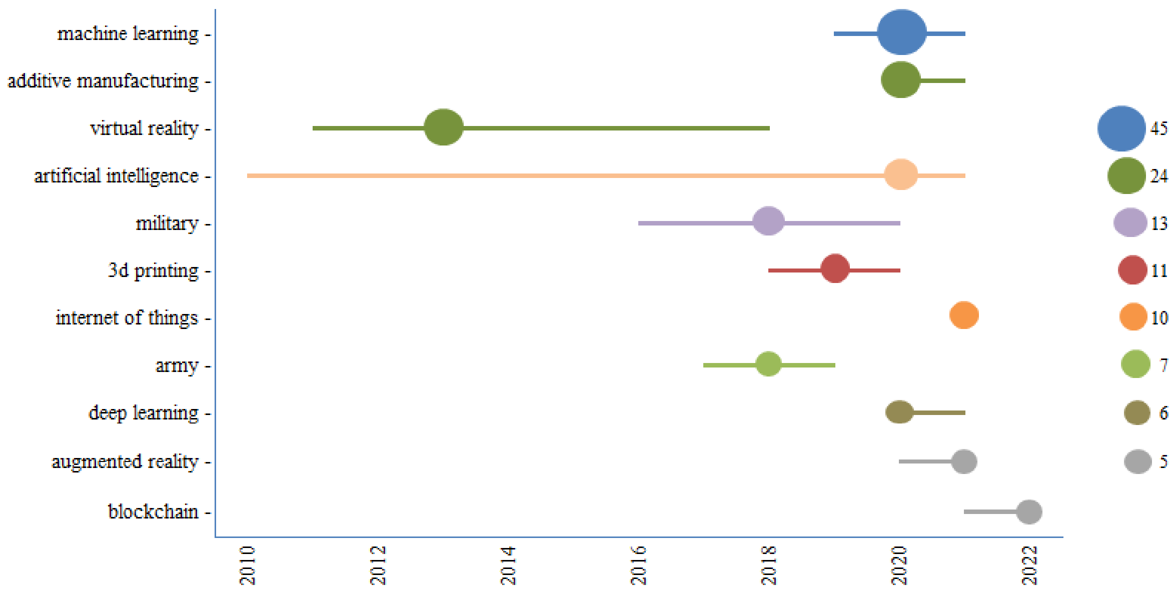

Figure 4. Trend topics

Led by "machine learning" that appears 45 times, "additive manufacturing" and "virtual reality" are tied with 24 times. Then, with a frequency of 21 appearances, we have "artificial intelligence". We still have "military", "3d printing", "internet of things" and "army" with 13, 11, 10 and 7, respectively. The words "deep learning", "prediction" and "security" appeared 6 times each, followed by "augmented reality" and "blockchain" with 5 appearances.

In view of this information and when looking at Figure 4, we realize that the most frequent words, with the exception of "virtual reality", gained prominence from 2018 onwards, denoting the contemporaneity of the theme and the existing gap within the defense sector.

5.4 "Three-Field plot"

Interconnections between journals, research topics and countries can provide useful inferences. Thus, we present a three-field plot in Figure 5, which shows the interactions between the most relevant publication sources (left), authors' keywords (middle) and countries (right).

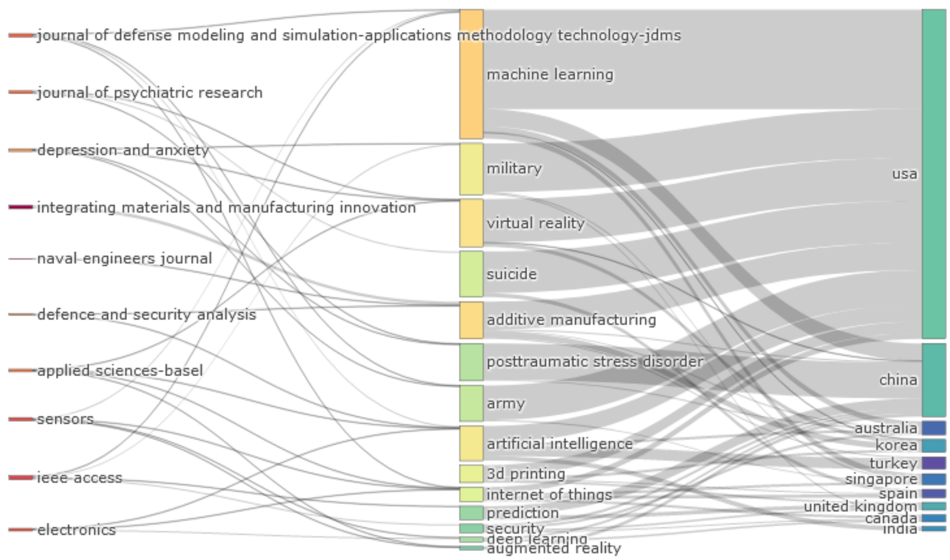

Figure 5. Three-Fields plot

5.5 Research Clusters

Bibliographic coupling of data from keywords, through the Bibliometrix, resulted in four cluster: Cluster 1 - (Additive Manufacturing, 3D Printing, Spare Parts); Cluster 2 - (internet of things, deep learning, military); Cluster 3 - (machine learning, suicide, prediction); and Cluster 4 - (systems, artificial intelligence, expert system).

The content of the bibliographically coupled studies were critically analyzed in order to map the concepts of I4.0 within the defense sector, as we can see in Figure 6.

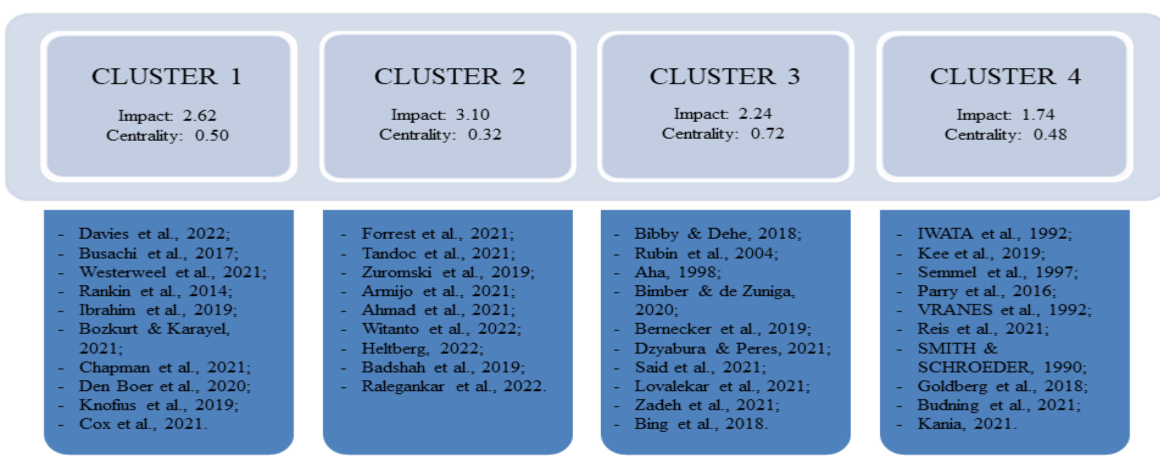

Figure 6. Cluster

Comparing the clusters, we noticed that all of them have words that refer to I4.0 between their couplings. Also, all of them indicate that they are topics of great relevance and contemporaneity due to their degree of centrality (C. Chen, 2005).

We carried out a complete reading of the coupled studies in order to identify those that could contribute to the suggestion of future research topics divided by cluster. This analysis resulted in the research agenda set out in Table 1.

Table 1. Research Agenda

Research topic	Cluster	Justification
What are the practical implications of 3D printing in the manufacture of products aimed at the defense industry?	1	The studies present in this cluster show a great applicability of additive manufacturing in the design of products for the most diverse sectors. Knowing the implications of implementing this technology in the defense sector would meet the expectations of a dynamic and error-averse sector.
How can blockchain be used to integrate the various industries that make up the defense sector?	2	The studies present in this cluster demonstrate that blockchain has the ability to optimize processes and facilitate coordination between different companies with a high level of security. Such characteristics are fundamental for the defense sector that, given the nature of the transactions it carries out, the integration of the agents involved in the process in a safe way is essential.
How can Internet of Things (IoT) and Deep Learning concepts affect the logistics operations of the defense industries?	2	The logistics of defense industries need rapid adaptability and flexibility to meet unforeseen scenarios characteristic of a sector linked to the security of a country. In this way, the concepts of IoT and deep learning, as discussed in the studies of this cluster, are promising for the sector.
Case study to map the maturity level of I4.0 in defense industries.	3	A set of studies will allow you to have an overview of the I4.0 in the Defense Sector and therefore empirical evidence on the impacts that the technologies inherent in I4.0 generate on the operational performance of companies.
Challenges for the implementation of I4.0 technologies in defense industries.	4	According to the studies of this cluster, the implementation of artificial intelligence brings numerous challenges for companies. A study covering other technologies would provide a more concrete view on the subject and could be used by companies in the defense sector as a reference for the implementation process.

6. Conclusion

This study comprehensively analyzed the concept of industry 4.0 through bibliometric techniques already consolidated by the doctrine as an adequate and relevant research design.

We found that the concept of I4.0 in the defense industries is an autonomous research domain. We identified the main journals, articles, institutions and authors within this research domain and found the collaborative network of universities and authors. We mapped the conceptual framework of I4.0 in the defense industry, identifying and exploring research clusters. Finally, a research agenda was proposed that, although not exhaustive, will allow the subject to be dissected to the point of obtaining a consolidated theoretical framework.

As a result of this study, it became clear that this is a field of research still unexplored by researchers and that it needs a lot of attention given the importance of a country's defense industries for both its national sovereignty and its economy.

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Biography

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