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Fashion Industry 4.0: A Bibliometric Review in the Fashion Industry

Indústria da Moda 4.0: Uma Revisão Bibliométrica na Indústria da Moda

Industria de la Moda 4.0: Una Revisión Bibliometrica en la Industria de la Moda

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Abstract
The fourth industrial revolution, or Industry 4.0 is characterized as information technology enabling complete digital connectivity, bringing together modern human life's physical, digital, and organic elements. In the competitive world of clothing, fashion and footwear, integrated technologies are constantly advancing, and the fashion industry needs to adapt to market standards. Given the above, this research aimed to search the literature in a bibliometric way on the evolution of the current situation of industry 4.0 fashion. In the present study, the research question that guided him is: What are the interventions of Industry 4.0 in the fashion industry? The bibliometric review is a contemporary view compared to the traditional bibliographic review, as the latter only allows an overview of specific subjects and is used as an argument for further research. A total of 16 articles demonstrated an overall performance of the technology in fashion, ranging from fabric production, eco-technology to reduce emissions and pollutants, technologies in production, distribution, marketing, and sales, in addition to having points for the sake of education. The application of IT in the structural organization of the form of production was the most highlighted by the studies and brought innovations in it, such as the application of 3D technology and intelligent and technological fabrics.
Keywords: Industry 4.0; Fashion; Technology; Apparel.

Resumo
A quarta revolução industrial ou Indústria 4.0 é caracterizada como tecnologia da informação para permitir a conectividade digital completa, reunindo os elementos físicos, digitais e orgânicos da vida humana moderna. No competitivo mundo do vestuário, moda e calçados, as tecnologias integradas estão em constante evolução e a indústria da moda precisa se adaptar aos padrões do mercado. Diante do exposto, esta pesquisa teve como objetivo pesquisar a literatura de forma bibliométrica sobre a evolução da situação atual da indústria de moda 4.0. No presente estudo, a questão de pesquisa que o norteou é: Quais são as intervenções da Indústria 4.0 na indústria da moda? A revisão bibliométrica é uma visão contemporânea em relação à revisão bibliográfica tradicional, uma vez que esta permite apenas uma visão geral de assuntos específicos e é utilizada como argumento para pesquisas futuras. Foram 16 artigos que demonstraram um desempenho geral da tecnologia na moda, que vão desde a produção de tecidos, ecotecnologia para redução de emissões e poluentes, tecnologias na produção, distribuição, marketing e vendas, além de contar com pontos para por uma questão de educação. A aplicação da TI na organização estrutural da forma de produção foi a mais destacada pelos estudos e trouxe inovações, como a aplicação da tecnologia 3D e tecidos inteligentes e tecnológicos.
Palavras-chave: Indústria 4.0; Moda; Tecnologia; Vestuário.

Resumen
La cuarta revolución industrial o Industria 4.0 se caracteriza como tecnología de la información para permitir una conectividad digital completa, que reúne los elementos físicos, digitales y orgánicos de la vida humana moderna. En el competitivo mundo de la ropa, la moda y el calzado, las tecnologías integradas avanzan constantemente y la industria de la moda debe adaptarse a los estándares del mercado. Dado lo anterior, esta investigación tuvo como objetivo buscar la literatura de forma bibliométrica sobre la evolución de la situación actual de la industria 4.0 de la

moda. En el presente estudio, la pregunta de investigación que lo guió es: ¿Cuáles son las intervenciones de la Industria 4.0 en la industria de la moda? La revisión bibliométrica es una visión contemporánea en comparación con la revisión bibliográfica tradicional, ya que esta última solo permite una visión general de temas específicos y se utiliza como argumento para futuras investigaciones. Hubo un total de 16 artículos que demostraron un desempeño global de la tecnología en moda, que van desde la producción de telas, eco-tecnología para reducir emisiones y contaminantes, tecnologías en producción, distribución, marketing y ventas, además de tener puntos en para por el bien de la educación. La aplicación de las TI en la organización estructural de la forma de producción fue la más destacada por los estudios y aportó innovaciones en ella, como la aplicación de tecnología 3D y tejidos inteligentes y tecnológicos.
Palavras clave: Industria 4.0; Moda; Tecnología; Vestir.

1. Introduction

Industry 4.0 is a procedure that brings together certain technologies for automation. The concept was launched at the Hannover Fair in 2011 and quickly attracted much attention in Germany and worldwide. The 4.0 concept is related to the fourth industrial revolution in manufacturing, where technological trends such as digitization, robots, and artificial intelligence transform production processes (Bertola & Teunissen, 2018; De Haro & Wang, 2020).

According to Wang; Ha-brookshire (2018), 4.0 is sometimes referred to using other related terms, such as "smart manufacturing", "industrial internet," or "integrated industry", and is often seen as a critical part of the "great transformation" that is currently taking place. The business world is closely associated with other social and organizational megatrends such as digitization, cloud computing, artificial intelligence, and the Internet of things.

The fashion sector in recent years, although slow and timid, reveals a set of issues that challenge the adequacy of the industrial segment to the reality of Industry 4.0. Today, leading brands and their designers are working together with computers and sets of algorithms, not just to design but to predict fashion trends, long before sketches or color samples were part of the discussion (Grieco, 2017; Madsen, 2019).

While the influx of 4.0 technology into the fashion industry has increased productivity and efficiency in every area, optimizing almost every conceivable process, it has also given fashion designers interesting new tools far beyond the famous pencil and sketchbook. The rapidly evolving 2D and 3D tools for clothing design, development, and merchandising have taken not just designers but developers and production and marketing professionals to new heights (Bellemare, 2018).

The ongoing transition of societies and economies to different organizational paradigms deeply informed by digital technologies is at the center of current debates, involving academics and impacting a broad context of disciplines, ranging from the humanities to science and technology (Madsen, 2019).

Given the above, this research aimed to search the literature in a bibliometric way to check on the current evolution status of the fashion industry related to industry 4.0. We applied a uniform data model used by all authors involved in the production process, including logistical information, such as expiration dates, production details like production cycles, and technology constraints.

2. Methodology

Bibliometrics deals with methods to retrieve and statistically analyze measurable information in published scientific articles. Bibliometrics was introduced in 1926 when Alfred Lotka examined the author's productivity patterns and provided the initial rules for bibliometrics (Huang et al., 2020). The bibliometric review was selected because it is a planning method to answer a specific question and allows the collection, selection, and critical consideration of studies. Therefore, the sources of a bibliometric study are articles from original studies available in a database.

Literature can be reduced to subsets based on clustering by similarity when using bibliometric techniques. The criteria generally involve counting the number of times specific markers occur or co-occur, giving rise to information about the cocitation of the author, the newspaper, the keyword, and so on (Safder & Hassan, 2019).

In the present study, the research question that guided it is: What are the interventions of Industry 4.0 in the fashion industry? The bibliometric review differs from the traditional bibliographic review, as the latter exclusively allows an overview of specific subjects and is used as a context for new observations.

The following keywords strings were selected to compose this search: "industry 4.0" AND ((fashion OR textile OR clothing) AND industry), ("fashion industry" OR "textile industry" OR "clothing industry") AND "industry 4.0" and industry 4.0" AND (fashion OR textile OR clothing) (Figure 1) in the Scopus and Web of Science databases, with a search performed with this keyword, occurred in: titles, abstract (abstract), the keyword (keywords) and articles were analyzed for bibliometric publication date, including year, journal, method and for the thematic focus of the research, with all statistical analysis using Microsoft Excel®.

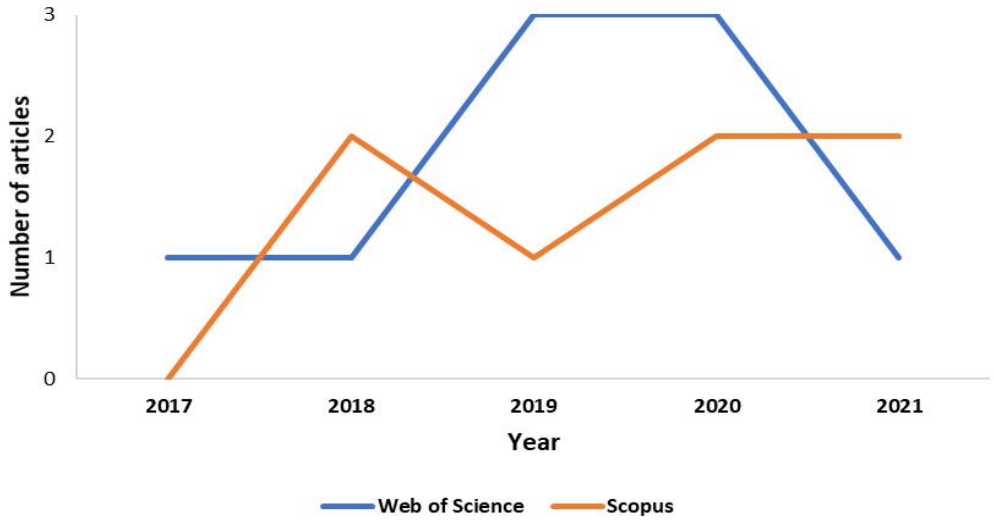
Figure 1. Word cloud with search keywords.

Source: Authors.

3. Results and Discussion

By using the selected descriptors on the Scopus and Web of Science platforms, a total of 24 articles were initially obtained. When excluding all duplicates (n=8), a total of 16 articles were selected for the production of this article. Most articles were found on the Web of Science platform (n=9), and its temporal distribution showed that in 2020 it had the highest production of articles on the topic (Figure 2).

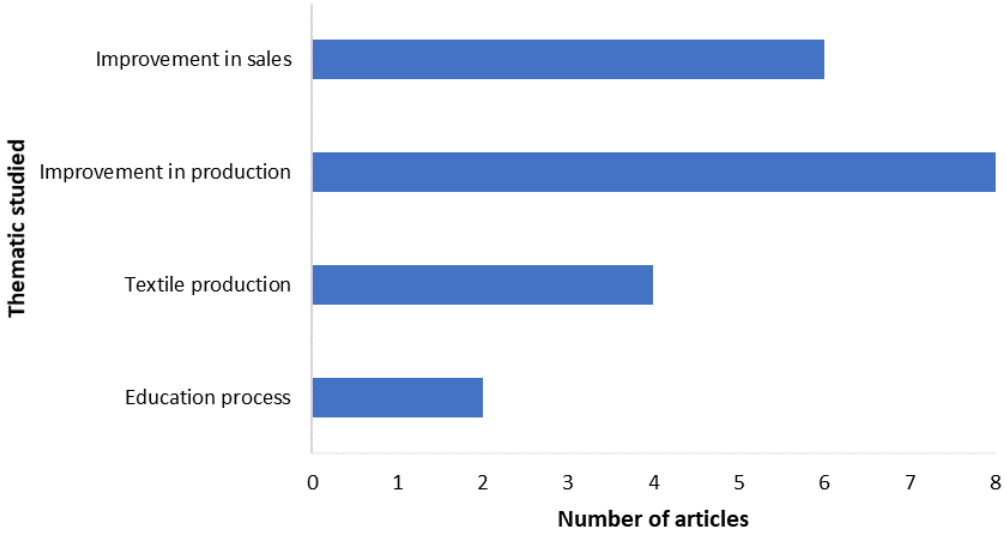
Figure 2. Distribution of articles according to database and years of publication.



Source: Authors.

After evaluating the volume and the authors and their contributions regarding the Industry 4.0 concept in the fashion industry, the next objective is to examine the content of the fashion discourse in more detail. It is possible to include the main themes addressed by the studies in four parameters: industry 4.0 technology applied to improve clothing sales, assisting in the production process to make it more efficient, working in new forms of textile production, and finally, in education. It is important to emphasize that some articles bring more than one of these themes. Because of that, the numbers present in the graph (Figure 3) are not equal to the total number of articles in the current study.

Figure 3. Distribution of articles according to the main theme that each one addresses.



Source: Authors.

The technology applied to improve sales and production often goes well together, and it revolves around better organization and planning so that production and output are equivalent, thus reducing waste. Such a method can be carried out with the application of IT in companies, the use of international strategies of multinational companies (MNEs), e-commerce (Grieco et at., 2017; Hoque et al., 2021; Barzoto & Propris, 2021).

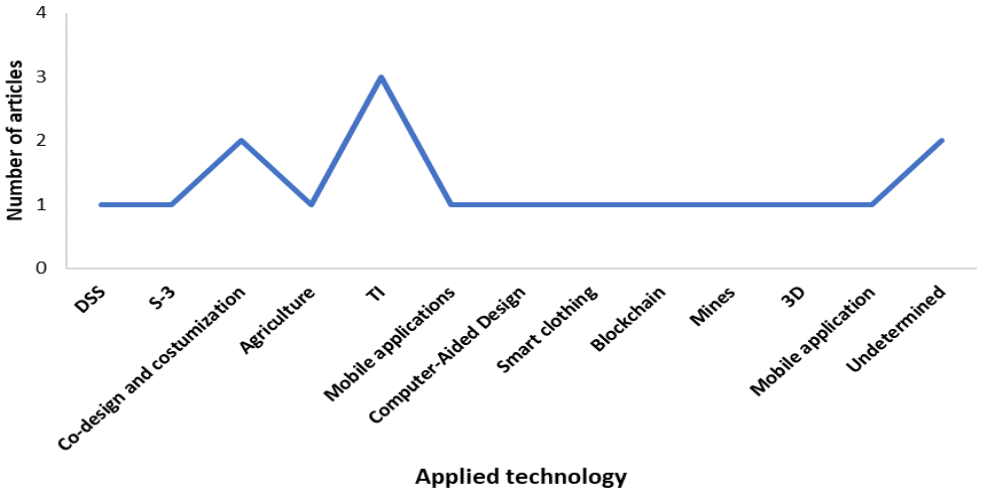
In addition, a better specification of products according to the target's audience is also assisted by the new era of the industrial revolution. In this scope, there is individualization, customization, and specification of products and ways of disseminating this information to potential buyers, in which using algorithms, it is possible to have a better idea of the interests of customers and direct them to products that are more likely to sell for them (Oliveira & Carvalho, 2019; Za et al., 2019; Princes et al., 2020).

The organization of a company is essential regarding both economic and environmental advantages. There is a significant emission of pollutants, especially CO_2, throughout the textile production process, and techniques that improve this management are welcome. Consumers require the improvement of those techniques, as the sustainability issue adds value to the product, in addition to the production of fabric that is more eco-friendly, such as the reused fiber, giving credibility to the production (Bertola & Teunissen, 2018; Fu, et al., 2018; Zyczynski & Wozniak, 2019; Soh et at., 2020).

All these advantages are only being applied and becoming more and more technological, primarily due to the speed with which fashion becomes changeable and disposable. Marques e Ferreira(2020) brought in their research the fast fashion focus, which brings precisely this quick passage from one trend to another, which can generate a lot of waste, a practical and applicable way to try to minimize this waste is the application of 3D technology during manufacturing, so that the actual production is only the final product (Spahiu et al., 2021).

Along with the themes, the techniques and technologies presented significantly varied from article to study, although some studies did not mention precisely which technology is referred to (n=3). In total, eleven models of instruments used in industry 4.0 were observed. Among them, there is the decision support system (DSS) framework, sensitive S-3 paradigm, co-design and customization, refinement techniques applied in the part agricultural, information technology, production and application for Android and iOS,computer-aided-design, smart clothing production, blockchain, the international strategy of multinational companies (MNEs) and 3D modeling (Figure 4).

Figure 4. Distribution graph of applied technologies that were found in the articles.



Source: Authors.

A proper organization of the entire process, without putting innovation aside, such as the possible creation of intelligent and technological clothing known as Internet-of-Smart-Clothing. A final advantage of the technological application is that education is increasingly facilitated during the production and execution of all stages within the clothing company (Fernádez-Caramés & Fraga-Lamas, 2018; Marniati & Wibawa, 2020; Widiaty et al., 2020).

The central differential of Industry 4.0 lies in its ability to anticipate, expand and necessarily modify critical aspects of production and manufacturing. The garment factories of the future will be fully automated, self-service, and self-repairing structures that require minimal human intervention. A truly 'smart' factory is clearly on our horizons, largely thanks to the synergy between the new technologies of Industry 4.0 (Barzotto & Propis, 2021; Spahiu et al., 2021).

Integrating shop floor technologies fast advance to Industry 4.0 standards in highly competitive apparel, fashion, and footwear. The rapid maturity of new technologies enables innovations in manufacturing processes that optimize existing systems and lead to the invention of new processes. A smart garment factory can indeed make iconic discoveries such as creating affordable mass customization a reality by completely reimagining the production workflow to become more agile, modular, and cost-effective (Bertola & Teunissen, 2018; Zyczynski & Wozniak, 2019).

Fashion industry impacts have lately become a focus in the sustainability issue. The current public debate is confused with unreliable and exaggerated claims and a lack of academic research. This is characterized by the globalization of fashion and historical supply chains. This sector has little attention to lifecycle sustainability issues compared to many other sectors (Fu & Liu, 2018; Marques & Ferreira, 2020; Soh et al., 2020). The fashion industry follows a linear model consisting of three main steps: taking (the harvesting of raw materials), making (the production of clothes), and waste (the use and subsequent disposal of clothes).

The focus on quick and cheap delivery coexisted with a lack of focus on social impacts in the supply chain, contributing to disasters such as the 2013 Rana Plaza collapse in Bangladesh. It should also be recognized that the visible disconnect has not had significant economic and employment benefits for countries that increased production but also significant additional impacts in terms of resource consumption and emissions (Fu & Liu, 2018; Zyczynnki & Wozniak, 2019). In this context, the emergence of industry 4.0 is of paramount importance, bringing four fundamental aspects to be appreciated for the fashion industry, and these are listed below:

- Product customization: Production must adapt to customer requirements, which tend to be increasingly precise and individual, allowing the development of innovative business models (Fernández-Caramés & Fraga-Lamas, 2018; Oliveira & Cunha, 2019; Pedro et al., 2019).
- Flexibility: The fashion production chain needs to automatically adapt to evolving requirements (for example, the range of products it must produce or conveyor speed) to allow for productivity gains (Barzotto & Propris, 2021).
- Product traceability: there is a need to identify all the processes through which the raw material, parts, and products were modified/made/assembled (Hoque et al., 2021).
- Optimization of the production process: Thanks to the artificial intelligence devices brought by Industry 4.0 and the information collected and analyzed by machine learning algorithms, it is possible to have an accurate overview of the production process of clothes, shoes, accessories, etc., thus, optimize resources and, for example, predict the following maintenance actions (Spahiu et al., 2021).

Notably, the need to add the fashion branch to industry 4.0 is often questioned by external forces such as the tightening of global competition and the growing demand for individualized products, as indicated by the terms "customer needs" and "custom products," among others. Recent studies reveal that customers increasingly want to adapt their products to

their requirements and, for example, receive the goods on the same day after placing the order (Oliveira & Cunha, 2019; Princes et al., 2020).

Industry 4.0 manufacturing and business environments are fully integrated, intelligent, autonomous, and digitized in keeping with these concepts. To achieve this characterization, Industry 4.0 combines several key technologies, such as cyber-physical systems (CPS), the Internet of things (IoT), big data, 3D printing, radio frequency identification (RFID) technology, and cloud computing. This can indicate Industry 4.0 as a bundle of different technologies than a single concept (Spahiu et al., 2021).

Technology 4.0 is also of great importance for developing environmental sustainability in the fashion industry, with the long-term objective of reducing the effects of climate change. However, existing environmental sustainability solutions are not as open to the public as they should (Fu & Liu, 2018; Marques & Ferreira, 2020).

Another important factor related to industry 4.0 in the fashion industry would be that the fashion industry needs a large part of the technology needed to produce new clothes from old materials. Brands are working to quantify and reduce the environmental impact of textile and textile production clothing. Using new raw materials contradicts circularity, as textile production causes extensive CO_2 emissions. However, brands' efforts at this stage are still significant (Fu & Liu, 2018). While some brands improve input quality, such as the transition from conventional to organic cotton, cotton remains a high water- and chemical-intensive fiber. Furthermore, in the current linear fashion system, brands are not responsible for recycling this piece; they have little incentive to develop textiles built to circulate (SOH et al., 2020).

It was also noted that the fashion arena around industry 4.0 has expanded regarding the number of authors involved. It is often seen as a development in the market for new management concepts and ideas. When new concepts reach a critical mass of followers and become popular, other actors on the supply side perceive a lucrative market opportunity and want to take action (Fernádez-Caramés & Fraga-Lamas, 2018; Oliveira & Cunha, 2019).

It is a challenge to assess demand-side interest in management concepts and ideas. However, one analytics that can be used for this is Google Trends. Such a system can cast insight into consumer behavior in the clothing and textile fashion markets. Previous research could also be observed that it could be used to learn about fashion management ideas and concepts.

Concerning the evolution and trajectory of industry 4.0, the evidence reviewed in this article shows that the concept has seen a meteoric rise in popularity. The concept quickly moved to the forefront of public management discourse. According to the definition provided by Marques e Ferreira (2020), management fashions are those "management concepts that, relatively quickly, gain great participation in the discourse of public management."

Industry 4.0 fits this definition as the concept quickly gained much of the public discourse around management in print, social media, and the conference scene. As the concept became more modern and gained a large following, new supply-side actors (e.g., technology providers and consultants) joined the movement to get a piece of this profitable and growing market. This is similar to a dynamic observed in managerial fashion markets when managerial concepts reach critical mass and become fashion (Barzotto, 2021).

4. Conclusion

We found a few published articles relating the Industry 4.0 and the fashion industry. However, the concept of Industry 4.0 is still relatively new and is expanding and evolving rapidly. Follow-up studies are needed to examine how the diffusion process unfolds over time, particularly in the fashion industry. The Industry 4.0 concept will continue to increase in popularity, especially regarding sustainability.

With the analyzed analyses, it was possible to observe that Industry 4.0 in the fashion sector is getting better and faster with each day and are positioned to elevate the manufacture and production of clothes to a higher level of efficiency, productivity, and competitiveness than ever before.

Future studies should focus on the items related to sustainability in the fashion industry and the application of circular economy as players of the fashion chain.

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