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- Industrial Engineering –

-Industrial Engineering-

- Fast Fashion Production Industry: Trends And Challenges -

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Fast Fashion Production Industry: Trends And Challenges

Master's thesis in
Industrial Engineering

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Abstract: Innovation and need are usually the catalysts for industry. Fast fashion (FF) was born to meet the "whims" of consumers who want to stay trendy, stylish, and fashionable at all times. A new fashion arrives on average every season; hence, this industry has to deliver what its customers expect on time. Fast fashion is a business strategy that aims to produce fashionable products and meet consumer demand through an accelerated and efficient supply chain. Several characteristics distinguish the FF industry, including a leagile supply chain strategy (lean and agile), a fast mode approach, and the use of technologies (RFID, artificial intelligence, augmented reality, blockchain, contactless shopping, internet of things) to identify demand data for FF supply chains. Fast-mode products require supply chain strategies that address their complexity. Besides their rapid activities, these industries harm the environment. With the Green requirements of consumers, the FF industries are confronted and forced to change so that their environmental impact is reduced. This work highlights current fashion trends and the challenges of the fast fashion production industry through the pillars of sustainability.

Key-words: Fast fashion, supply chain, technology, sustainability, Trends and challenges

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1. Introduction

Dressing is generally considered a self-expression form of adornment, but it encompasses a broader range of functions beyond its aesthetic significance. Using clothing has contributed to creating and accumulating various needs [1]. In addition, a complex system has emerged around the use of clothing, highlighting its critical role in the functioning of contemporary society. The fashion industry system, with striking figures, generates a part of 3 trillion dollars of the global economy and a contribution of 2% to the world's gross domestic product [2]. Moreover, they are the world's key industries of value creation and the most profitable [2].

The economic models of the fashion industry have undergone significant transformations throughout history, particularly during the Industrial Revolution. The origins of fashion were characterized by bespoke and personalized clothing production, each piece being unique and associated with specific brands. However, with the advent of the first and second industrial revolutions, there was a shift towards mechanization and automation, facilitating the mass production of fashion goods [3]. This marked a significant departure from traditional clothing production methods, enabling the fashion industry to produce and distribute garments on a massive scale. Then there was the third industrial revolution, characterized by the optimization of process time and the substantial media coverage of brands by information and communication technologies, which has given rise to the phenomenon of the FF industry defined as a business model, offering consumers novelty in the form of products at low prices and trend-led [4], more frequently than traditional models[5].

The production of FF involves managing a complex supply chain, responding to volatile demand, maintaining medium to low inventory levels, and operating on short lead times ranging from two to four weeks [1]. Furthermore, the industry faces the daily challenge of accurately predicting demand levels without risking overproduction, which can lead to significant risks in managing the supply chain. Therefore, appropriate strategies are implemented to anticipate these risks, like diversification of suppliers, digitalization[6], or leagile strategy, which combines lean and agile principles to create a more flexible supply chain through vertical information integration [1] and enhance the resilience of operations.

The FF industry is characterized by a fast supply chain to achieve matching supply to demand [7] and focuses on producing more fashionable garments with a lower price and quality, which has significant consequences on sustainability. For example, it is responsible for nearly 10% of the carbon emissions on earth, including emissions from producing raw materials, apparel manufacturing, freight transportation, and energy used in retail stores [4]. In addition, the fast fashion model involves rapid processes that result in significant environmental impact, including waste and depletion of natural resources, and labor issues, with more than 60 million workers victims of labor exploitation [8].

The industry faced persistent criticism about its negative impact. This is why they protest to adopt more sustainable practices such as circular economy or sustainable sourcing. The leaders of this sector provide information about their processes to be more transparent to mitigate FF's negative environmental and social impact. Clever use of technologies is also implemented [9] to improve efficiency and productivity with AI or trend forecasting software allowing companies to copy designs and make products quickly with low costs to keep up with the latest trends. The fast fashion sector has a significant impact on this climate emergency. It is judged by excessive use of materials and water, labor exploitation, and human rights violations. These companies also face the overproduction challenge that should be reduced while adopting new technologies such as Blockchain, IoT (Internet Of Things), AI(Artificial Intelligence), and AR (Augmented reality) in their supply to meet sustainability and customer needs and remains among these market leaders [9].

In the fast fashion industry, a supply chain encompasses the full range of processes from raw material processing to distribution, a complex system comprising several actors and affecting the environment, economy, and culture. To cover as much of this area as possible, we carried out a systematic review of the literature covering the fast fashion supply chain by scanning the sustainability dimensions and the business aspect, operational and technological, to synthesize information on the challenges and recent trends of this industry. The selected literature allowed us to structure the article in the following way: section 2 presents the research methodology of the systematic literature review; section 3: summarizes the trends observed in the literature through the most common practices of the fast fashion industries; section 4 synthesizes the challenges facing the fast fashion industry. Finally, section 5 concludes the paper and presents its

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perspectives.

2. Methodology

This article follows a consensual literature review method, specifically the systematic literature review, defined as: "a research method and process for identifying and critically appraising relevant research, as well as for collecting and analyzing data from said research" [10]. The steps can be structured as follows;

2.1. Research Questions

Among the preliminary phases in writing a systematic review is the determination of the study's goal. In our case of research, the main objective is to analyze the new trends; and the challenges of fast fashion throughout the supply chain, from where these relevant questions arise:

a. What are the specifications of the fast fashion industry?
b. What are the current trends in the fast fashion supply chain?
c. What are the challenges which these industries are facing ?
d. How can the fashion industry move towards more sustainable and equitable practices?

2.2. Search Keywords

Fast fashion, fast fashion supply chain, Trends, Challenges, sustainability, Circular economy, Technology

2.3. Sources Selection

In the source selection process, we conducted initial research on major electronic libraries, including Google Scholar, ScienceDirect, IEEE Xplore, Springer, Wiley online platform, and Taylor & Francis. These libraries are known to have extensive collections of academic and professional literature across various disciplines, making them valuable resources for research. Subsequently, we identified relevant articles from university platforms such as SNDL and Mydauphine (an online platform designed for Paris Dauphine University students). In addition, we also identified articles from the website of the Deggendorf Institute of Technology, a research and education institution in Germany. Using major electronic libraries and university platforms, we could access various scholarly materials and identify relevant sources for our research.

2.4. Inclusion And Exclusion Criteria

To conduct relevant and current research, we considered several inclusion criteria to select the articles that will focus on this study and others to eliminate articles that seem less relevant for this work, named exclusion criteria. A primary consideration for source selection was the recent publication date and the number of citations, focusing on including all relevant journal articles, book articles, and chapters to ensure comprehensive results. In addition, we sought articles that addressed the environmental, technological, and economic aspects of fast fashion and explored challenges facing the fashion industry in terms of sustainability or process optimization. Empirical studies on fast fashion companies were also a selection criterion in our research. However, articles addressing industries outside of fashion and those focused only on theoretical studies in mathematics or computer programming were not within the scope of our investigation and were therefore not included in our review. By incorporating these inclusion and exclusion criteria, we sought to ensure that our research was relevant and current while providing a holistic understanding of the fast fashion industry and its impact on society and the environment. Besides, we considered the articles including the terms apparel, textile, fashion, and garment industry because they are similar to fast fashion in operations and raw materials, in addition to the fact that many articles do not differ between these terms and use fast fashion examples such as ZARA or H&M to represent fashion or apparel industry.

2.5. Studies Selection

We collected 40 articles and ten blog sites to select the most relevant articles. We summarized the contributions, the limitations, the number of citations, the source, and the publication date of each one in a grid; By implementing the process depicted in Figure.1 and utilizing the established inclusion and exclusion criteria during the grid-based analysis, a comprehensive total of 15 articles as presented in Table.1; have been identified as satisfying the pre-established selection criteria and have subsequently been incorporated into our study. Furthermore, to augment our investigation, we extracted statistical and trend data from

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published reports on the websites of Fast fashion organizations and foundations.

2.6. Data Extraction And Analysis

Upon careful examination and analysis of the 15 articles that were selected, the Figure.2 present a classification of the articles based on the extracted trends and challenges, derived from a comprehensive review of the literature.

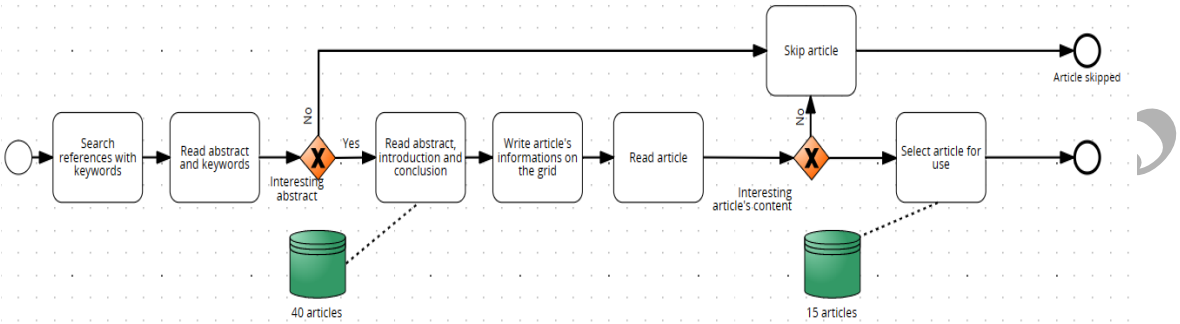


Figure 1: The Process Of Selecting Articles

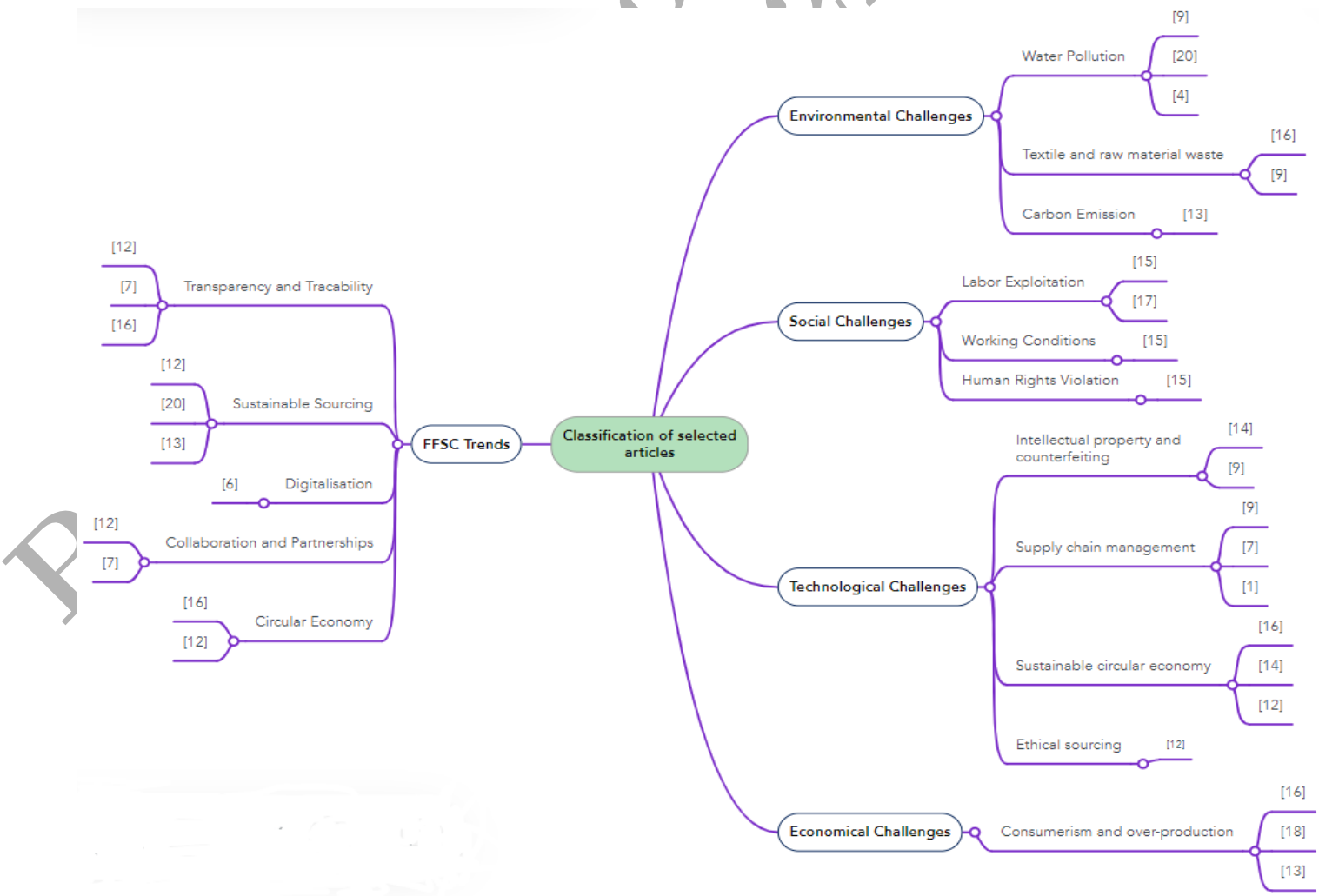


Figure 2: Classification Of Selected Articles

Ref	Year	Number Of Citation	Source	Contribution	Limitation
[1]	2020	64	International Journal of Retail and Distribution Management	• This article provides a comparison of ultra-fast fashion and fast fashion • Ultra-fast fashion differs from fast one in applying agile, lean, and responsive supply chain techniques, lead times inventory, manufacturing location, and forecasting model.	• the use of a limited sample; • A lack of use of technological capabilities; • Technology is seen as a tool rather than a capability that may create a competitive advantage.
[6]	2022	8	Taylor & Francis Oline	• This article thoroughly overviews the fashion industry's digital transformation; • It discusses how digital technologies influence the fashion supply chain and how they affect the three sustainability dimensions; • It delivers a data analysis of digitalization on different phases of the fashion supply chain.	• A lack of 3DVD technologies' environmental effects along the entire fashion supply chain compared to the traditional one.
[5]	2020	33	Annals of Operations Research	• This study proposed an agent-based model of the garment market that accounts for appropriate parties, their activities, and how they interact; • studied the benefits of a fast fashion supply chain approach over a traditional approach (and vice versa).	• It is impossible to draw managerial conclusions from this sample application for a particular fashion industry; • The consumer component of this business model might then be expanded to look at additional research issues.
[11]	2021	6	Global Journal of Flexible Systems Management	• reviewed the slow fashion and fast fashion strategies and specifications; • provides guidelines that companies may apply to handle Slow and Fast strategies simultaneously.	• The research strategy is limited to the six largest Brazilian retail companies operating both. Therefore, the conclusions are valid only for large companies operating both strategies in emerging markets.

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[12]	2022	25	Cleaner Logistics and Supply Chain	• provides rich evidence on circular solutions adopted by the largest companies in the fast fashion industry (H&M, Inditex, PVH, OVS, Gap inc, VF Corp); • The sustainability reports of these six global players were analyzed using a global circular value chain model; by which the company's solutions were classified; • The article also evaluated the involvement of companies in sustainability and deduced their degree of implication in circularity trends.	• the study is based on a single data source; • the risk of subjective evaluation despite the use of standards.
[7]	2022	2	Sustainability (Switzerland)	• This essay provides a preliminary analysis of the different transparency applications in fast fashion (domestic laws, norms, and organizational values); • The business case for sustainability has also been discussed extensively in the literature; • It demonstrates that private governance is still insufficient for tackling the more significant sustainability issues raised by fast fashion.	• This article does not provide a statistical presentation of Transparency at a specific time; • A few data and measurement methods are used in this study; • The rising longitudinal data on Transparency should be used in future studies to understand better how and why transparency changes within brands.
[13]	2022	22	Cleaner Logistics and Supply Chain	• This study addresses a significant gap in previous literature surrounding SSCM in fast fashion supply chains; • It offers several necessary steps for enhancing SSCM strategies to invest in long-term sustainable infrastructure and renewing the fibers used in clothing.	• This paper was limited by the information provided in annual sustainability reports; • It was not practical to estimate the gas emissions or waste by the supply chain of the fast fashion leaders, which operate with over 800 suppliers in different countries, based simply on the brand's sustainability reports.

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[14]	2020	120	Computer in industry, Elsevier	• This research uses blockchain technology to create a system architecture for fast fashion's circular supply chain management; • It demonstrates how circular supply chain management (CSCM), quick fashion, and BCT is related.	• The use of blockchain technology in the circular economy is still in its early stages; • This technology must be improved for smaller pilot projects before being implemented in a big fast fashion supply chain; • The deployment of blockchain-based systems is frequently complicated since it needs data input from numerous stakeholders and must include a group of oganizations.
[15]	2021	18	Journal of Supply Chain Management	• This article proposes a more humanistic approach to studying working conditions along supply chains by proposing supply chain management with a humanized perspective to achieve decent work; • It also identifies four characteristics of the sustainable supply chain that could be counterproductive if we integrate the social dimension.	• The article focuses only on the way to approach decent work in research on sustainable supply chain management, calling it the humanizing research program.
[16]	2023	1	International transactions in operational research	• describes the influence of blockchain technology on business operations and sustainability in the fashion industry; • challenges hindering blockchain adoption for sustainability; • conduct a Case study analysis of the Greater Bay Area (GBA) apparel industry and The application of blockchain technology in the global fashion industry.	• The selection of literature is limited to articles indexed by Science Citation Index (SCI) and excludes publications from other databases; • The study focuses on the fashion industry in the GBA (greater bay area).
[17]	2021	8	Cogent Business and Management	• This study shows how apparel multinationals should incorporate circular economy concepts into their production and operations;	• used small-scale case analysis; • conduct qualitative approaches to analyze secondary data.

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				• describes how the circular economy model generates value and market competitive advantage. The options provided could assist companies in orienting their corporate strategy toward the sustainability issue.	
[9]	2022	9	Scientific Programming	• This article combines different technologies such as IoT, AI, blockchain, and AR/VR to meet the challenges of the fashion industry, including predicting fashion trends, recommending clothing based on environmental conditions, predicting health; • discusses the contribution of Industry 4.0 to achieving the UN Sustainable Development Goals (SDGs).	• the article explores the opportunities of advances in digital technology in the fashion industry based on theoretical hypotheses; • the applications of technologies are studied only for healthy clothes.
[18]	2022	13	Production and Operations Management	• the paper conducts a qualitative research method based on (econometric analysis, OR optimization models, and game-theoretic approaches) that proposes the challenge of developing innovative business models to assist fast fashion firms and charities in collaborating to generate the most revenue and increase the firms' capacity in the reverse supply chain; • discusses general FF trends (FF market, textile waste collection, secondhand clothes market, online shopping,..).	• does not provide a broader perspective on the implications of the circular business model between fast fashion and charities on the environment, society, and the economy as a whole.
[3]	2021	28	Fashion and Textiles	• explores the current landscape of 4.0 technologies; • investigates the potential of Industry 4.0 technologies in addressing the challenges posed by the fast fashion industry, such as hyper-personalization, environmental sustainability, and productivity.	• the sample of study concern only Western countries.

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[19]	2021	10	The International Journal of Advanced Manufacturing Technology	• proposes a digital twin approach as a tool to support decision-making in fast fashion companies; • suggest a digital twin model that can replicate the complete manufacturing process and give real-time data analytics, allowing fast fashion companies to optimize their manufacturing processes and respond swiftly to changing market demands.	• lack practical implementation and testing of the proposed digital twin approach in a real-world fast fashion company; • the proposed digital twin approach may require significant financial and technological investments, which may not be feasible for all fast fashion companies.

Table 1: Overview Of Selected Articles

3. Trends In Fast Fashion Supply Chain

Fast fashion supply chains have undergone notable transformations in recent years, driven by the increased emphasis on sustainability and ethical practices from industry stakeholders and consumers. The changes witnessed within the industry are multi-faceted and encompass a range of trends;

3.1. Transparency And Traceability

Transparency for fast fashion industries is one of the biggest trends to show their brand image and reputation. It consists of providing all information about the company's supply chain and their implementation of sustainability to the customers and suppliers on social media or websites [7]; traceability gives information about the company's manufacturing processes [12]. Transparency can be increased by using blockchain technology. ZARA is on its way to integrating this revolution with Radio Frequency Identification (RFID) to enhance real-time supply chain transparency and data sharing [16]. Also, Fast fashion retailers are looking to partner with international MSSN (multi-stakeholder sustainability network) because those with the most partnerships are considered more transparent. [7] According to several criteria, H&M is the most transparent fast fashion brand, including MSSN partnerships. Meanwhile, traceability can be increased by providing information about certifications and reports concerning the product's manufacturing processes, greenhouse gas emissions, raw material origin, and extraction and recycling [12].

3.2. Sustainable Sourcing

Sustainable sourcing for the fast fashion sector is a way of getting raw materials and producing new garments to reduce negative impacts on the environment and society while ensuring the long-term availability and sustainability of the resources used. This involves sourcing materials and goods from sellers prioritizing sustainability, moral labor standards, and diligent environmental management throughout their supply chains[16]. Some integrate recycled fibers into the operating range of garments like recycled cotton, ecologically grown cotton, recycled polyamide, and recycled polyester filling (ZARA) [20]. In contrast, others entirely use recycled materials, like (H&M) which uses 100% fiber from organic cotton farming [12]. Furthermore, brand owners now prefer domestic sourcing with convenience and avoidance of risks; (Everlane) even publishes its suppliers on its website to be more transparent about their raw material source [13]. In addition, blockchain technology can be used to verify original fabric sellers, dyeing processors, and certified garment manufacturers for the execution of sustainable operations[16].

3.3. Digitalization

Industrial digitalization involves structuring, shaping, and influencing transformation along different Supply chain processes overlapping sustainability dimensions. The digital transformation of the fashion industry affects the entire value chain in which radical changes occur in customers relationships and in supply-chain

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operations due to the adopting of 3DVD technology [6]. Thirty-six companies see digitalization as generating digitally transformed processes and positive sustainability outcomes[6]. The digital transformation is accomplished by working with external consultants to form strategic alliances with computer-generated imagery (CGI) expert agencies and digital fashion-design offices to digitize a portion of their business or by incubating digitally-born startups (e.g., Hatch and Stitch 3D in PVH). or developing internal competencies (e.g., UTG, Emilio Pucci, Miroglio Fashion, Pespow)[6]. the transition to an economic model including digitalisation has several advantages for companies, such as the dematerialisation of resources, the optimisation of operational processes, the reduction of lead time in an eco-efficient way in specific processes and it boosts innovation and creativity in product creation, The applications implemented in the final stage of the supply chain exhibits reduce feedback and enhance the customer experience by effectively aligning the products with their specific needs[6].

3.4. Collaboration And Partnerships

The fast fashion industry has demonstrated a growing concern for the environment, which has prompted a shared vision among stakeholders both within and outside the sector. This emerging trend creates potential for strategic collaborations and partnerships to achieve mutual sustainability goals. As suggested by prior research [12], pursuing sustainable practices in fast fashion necessitates a collective effort and shared responsibility from various actors along the supply chain. Collaboration is a combination of strengths to having fewer weaknesses. For example, the Foundation Ellen MacArthur[21] Other collaborations are taking place with organizations outside the sector, such as citizens wishing to participate in recycling [17], universities, or startups offering innovative solutions to improve processes by reducing environmental impact. In Appendix A, a concise summary of exemplar instances of collaboration is provided.

Collaboration and partnership require alignment of both parties' objectives and involve interventions throughout the supply chain. To assess the success of these linkages, companies such as H&M and Inditex use quantitative indicators of clothing collection and reuse initiatives to evaluate their partners [12].

3.5. Circular Economy

The fast fashion industry has traditionally embraced linear economy models [17] that engender significant post-consumer waste and pollution. Nevertheless, adopting circularity is increasingly acknowledged as a viable solution to mitigate this onerous environmental impact while safeguarding the company's profitability. The circular economy is a closed-loop system in which products are used, reused, and transformed into other types of resources [12]. However, integrating a circular economic model throughout the supply chain of fast fashion products can be complex [17] because it must consider all actors' intentions throughout the product life cycle, from design to disposal. The action of creating value from upcycled/downcycled products to generate a new offer becomes the focus of interest of several fast fashion companies, including H&M and Inditex (the most prominent fast fashion retailers in Europe in terms of sales), OVS, Gap Inc. (the largest clothing retailer in the United States by sales in 2020), PVH (the third largest clothing retailer in the United States) and VF Corp (3rd place in the 2021 transparency index, after OVS and H&M). Through their annual sustainability reports[21] [22] containing sections distinguishing the circular economy, these companies highlight an inter-organizational vision and clear actions throughout the supply chain to reduce resources and waste. The set of processes allows the organization of the solutions of circularity (like recycling, certification at the source, reduction of materials, reuse, transformation, and resale) approached by the previously mentioned industries [12]. The reports, as mentioned earlier, facilitate the identification of trends pursued by companies operating within the realm of circular economy, particularly concerning their supply chain processes and collaborations with esteemed organizations. Notably, the reports highlight the commendable efforts of Inditex and H&M in this regard. Furthermore, examining reference[12],indicates that specific industries prefer implementation strategies bolstered by quantifiable metrics and well-defined objectives, exemplified by Inditex, H&M[16], PVH, and OVS. In contrast, other industries, such as GAP Inc., have articulated their commitments to pursue circularity without specifying the corresponding implementation methodologies.

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4. Fast Fashion Challenges

Fast fashion supply chains encounter numerous challenges that impede their capacity to enforce sustainable and ethical practices. Considering the three sustainability pillars and acknowledging the significance attributed to technology, this section will allow us to answer the question.c. by presenting the challenges extracted from the selected articles into four subsections;

4.1. Environmental Challenges

- Water pollution :
  Fast fashion uses 79 trillion liters of water annually[9], and 11.000 L of water is needed to produce only one pair of jeans. In addition, most indigo[1] is synthetic, with dyeing frequently releasing toxins into waterways and lakes [20]. Furthermore, since cotton is farmed by irrigation on arid land, producing fiber may account for over 88% of the overall water scarcity effects of typical clothing within its whole life cycle, which makes the distribution of water scarcity impacts even more extreme[4].
- Textile and raw material waste :
  The fast fashion industry contributes 35% of micro plastic pollution and generates > 92 million tons of textile waste annually [9]. To reduce this waste, companies can change the composition of their products and make them with only one type of garment for each type of product which will increase the recycling capacity; Currently, some companies are changing their strategies concerning the raw materials used for their products from the design phase of the product. Some turn to other durable and recyclable raw materials (Intedex) or reduce the number of garments used in the production of their product (OVS) [12]. Some leaders use 100% fiber from organic cotton farming (H&M), while others buy their cotton from Better Cotton Initiative BCI (OVS, Gap). Methods like adapting acetate fibers partially derived from plastic debris (H&M), natural yarns made from the low-value agricultural residue (H&M), natural and biodegradable substitutes for foams made from polyurethane in clothing (H&M), techniques for transforming cellulose-rich materials into biodegradable completely circular material (PVH), and studies into ionic methods for the extraction of natural components from synthetics (Inditex) are among the scenarios[12]. Using sustainable and recyclable raw materials is a preliminary phase to avoid waste and planet exploitation. This is why to boost the recycled content of the cardboard boxes used to transport clothing from suppliers, Inditex introduced its "Green to Pack" program. H&M and PVH are two different businesses that have joined Canopy's Pack4Good initiative to obtain wood-based packaging sustainably. H&M also committed to removing single-use plastics or replacing them with FSC-certified paper. To move clothing from vendors to retailers, Inditex developed a single hanger. While Gap deployed a hanger recycling system at over 100 locations, OVS established a closed system that involved reusing hangers and sending them to producers for recycling when they malfunctioned [12].
- Carbon emissions :
  Fast fashion presents about half of the CO2 emissions of textiles industries, knowing that in 2018, the GHG emissions of these retailers were estimated at 2.1 billion metric tons. If this sector continues to produce at this rate, the GHG emissions can attain 2.7 billion metric tons by 2030, the temperature will increase, and the environmental crisis will grow [13]. Fast fashion industries are aware of this harmful problem and are using some alternatives to face it and reduce their impact on the environment. For example, Everlane uses renewable energy at 100% within the company, but little information is given about the type of energy its suppliers use [13].

4.2. Social Challenges

The fast fashion industry is characterized by rapidly changing trends and frequent release of new collections [23], which requires constant restocking and meeting consumer demands. However, this model has been associated with significant labor violations and exploitation, such as overwork, underpayment, and poor working conditions, including forced and child labor [15]. Developing countries with weak labor laws and inadequate human rights protection often bear the brunt

[1] shade of blue, that comes from an organic dye derived from Indigofera plants

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of these violations, with 97% of fast fashion garments produced in such locations. To address these social challenges, adopting a more sustainable and ethical sourcing model that prioritizes transparency, traceability, and fair labor practices [22], Shifting towards a sourcing model that is flexible, fast, sustainable, digitally enhanced, and consumer-centric is necessary. The implementation of blockchain technology has been proposed as a tool to collect and assess information on working conditions in the fashion industry. By using blockchain technology to collect and analyze data [16], companies can better understand the working conditions and environmental impact of their supply chains, allowing them to take corrective action where necessary and identify areas for improvement [14].

4.3. Economic Challenges

Fashion retailers face the overproduction problem. To satisfy all their customers' inquiries, they produce more garments than they sell; it is estimated that only 60% of the inventory is sold, and the unsold one is sent to a landfill[13]. To face this challenge, the four R's, "recycling, rental, repair and resale"[13], are beginning to take hold and be adopted by the famous brands in this field. First, H&M uses its mass point of sales to collect used articles of clothing from customers to recycle them. For the second "R," companies propose a rental option for customers to use garments for a while and then return them to be rented by others. This offer can be found at "Banana Republic's Style Passport," "Rent the Runway," and "Style Lend companies." The third "R" presents repair services for clothes, and the Patagonia industry uses them. Finally, there is excellent potential for resale for startups that want to get into resales, like Depop, which gains a big part of the market with online resale or the retail of secondhand clothes. Charities can also benefit from this opportunity by collecting unwanted garments and selling useful ones [18]. The garment factory can benefit from synchronizing market demand and upstream fabric availability by implementing blockchain technologies in fashion supply chains to reduce over-production. This creates a centralized order-production coordination platform that connects all the ERP system modules of different supply chain members. A solution of this type emphasizes the collaborative decision-making process for production and inventory circulation. As a result, over-ordering can be effectively prohibited, and sustainable production can be increased with accurate and transparent demand information [16].

4.4. Technological Challenges

In order to align with the United Nations Sustainable Development Goals (SDGs), particularly the ninth goal, and to achieve the 2030 Sustainability Goal, the FF industry must expedite the modernization of their infrastructure in tandem with its production pace. This can be achieved by integrating advanced digital technologies such as the Internet of Things (IoT), Artificial Intelligence (AI), blockchain, Augmented Reality (AR), and Virtual Reality (VR). It is expected that clothing will become "smart" in the future, enabling individuals to express their personality through their attire and monitor their bodily state, health, and daily activities via the integration of IoT and AI into their garments. Forecasting demand in FF is a complex task involving consideration of various factors such as trends, needs, and media influence. However, even trend forecasting could be accomplished with the integration of AI. Thus, the fast fashion industry must adapt to this technological shift and embrace the opportunities that come with it to successfully achieve its sustainability goals and contribute to a more sustainable future [9].If the challenges of today's sustainable supply chain become the competitiveness field of tomorrow, the combination of IoT and blockchain would be an excellent demarcation component, above all by responding to the Transparency and traceability expected by the public [7] allowing for effective real-time tracking and traceability of fashion activities, which allows us to consider the amount of material consumed and produced, and to set up a circular economy [14] in the fast fashion. Pollution will also be reduced regarding waste and transport if we integrate augmented reality to facilitate the adjustment, size, and selection of colors or patterns from anywhere in the world. The VR technology will also help the development of products and individuals and promote the retail experience in the virtual world. In optimizing energy consumption in the fast fashion industry, a key challenge is implementing technology across all systems [9]. The widespread adoption of such equipment represents a significant step forward in achieving sustainability objectives regarding environmental and social impact. The integration of technologies can also meet other critical challenges of the fast fashion industry, including the protection of intellectual property, optimization of supply chain management, or adoption of the circular model with more sustainability;

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- **Intellectual property and counterfeiting :**
  The fast fashion industry poses a challenge to enforcing intellectual property rights, particularly in combating the prevalence of counterfeit chic. To address this issue, an asset-based protection strategy is necessary. However, the legal treatment of counterfeit goods and pirated designs creates inconsistency within the industry. Blockchain technology has emerged as an effective tool for supporting supply chain traceability and securing confidential information in certain companies [14]. In this context, it can also help protect intellectual property rights. Recent research suggests that the widespread deployment of Blockchain technology in the fast fashion industry could improve security and Transparency and, ultimately, better intellectual property protection [9].Therefore, adopting Blockchain technology to optimize information flows and ensure better protection in the fast fashion industry is essential.
- **Supply chain management :**
  The FF industry is characterized by a supply chain that includes various processes, from raw material processing to the distribution of finished products. This supply chain includes suppliers of materials, production facilities, logistics operations, and customers [1]. The main challenges faced by FF companies are the need to match supply and demand as closely as possible, manage a complex and volatile supply chain [7], and reduce the negative impact of their production on the environment and society. The FF industry heavily relies on the effectiveness of its supply chain, which serves as the backbone of its operations. Therefore, this supply chain must be continuously managed, monitored, and optimized to maintain high-performance levels. To achieve this, FF companies can leverage an IoT-based traceability architecture [9], which incorporates various technological tools such as RFID[24], sensors, and other digital solutions. The proposed architecture comprises six stages: generate, read, communicate, aggregate, consult/trace, and analyze. First, textile goods are created and combined with sensors and tags to enable supply chain tracking during the creation stage. Next, a reader collects data from sensors and tags during the read stage, including geographical location and environmental information sensed during tracking. Finally, the tracked information is provided to the relevant authorities using the system's communication protocol during the communication stage. This approach can facilitate greater control and visibility over the supply chain, allowing for more efficient management and potential cost savings [9]. Blockchain technology can potentially transform supply chain management in the fast fashion industry. A decentralized, distributed ledger enables secure and transparent transactions without intermediaries [14]. Furthermore, in supply chain management, blockchain can create a shared, tamper-proof record of all transactions throughout the supply chain. This can improve supply chain transparency and traceability and enhance stakeholder accountability [16].
- **Sustainable circular economy :**
  As a practical approach to achieving sustainability goals in supply chain practice, blockchain technology is critical in reducing product recall and materials waste, improving product lifecycle visibility, tracking carbon emission footprint, and facilitating recycling operations[16]. In Appendix B, a further demonstration of the augmented potential in blockchain-based system architecture is presented.

5. Conclusions

This work explored the new trends of the fast fashion supply chain and its significant challenges as it also provides the specifications of this industry. A fast supply chain can be characterized as the mass production of garments with lower prices and quality operating on short lead times. Companies compete to satisfy as many customers as possible; by promoting the brand by adapting new trends in their business strategies and supply chain management, such as sustainable sourcing and implementing the circular business model. To assure traceability and Transparency, FF leaders start revealing information about the company's activities to customers; by publishing reports; making partnerships and collaborations with organizations, universities, and startups that work on sustainability.

FF industry Challenges can be classified into four main categories; the three pillars of sustainability (economic, environmental, and social) and the technological challenge that is very important currently for the industry; through which FF industries can sat-

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isfy the other challenges; and at the same time increase their profit and remain among the market leaders, first, due to fashion activities, water pollution, plastic pollution, and carbon emission increase over time. This is why future studies can focus on raising awareness of this situation and on adequate measures that should be taken. Furthermore, some techniques could be adopted to reduce textile waste, such as incorporating durable and recyclable raw materials; and changing energy sources to renewable energies to minimize greenhouse gas emissions. Secondly, the FF industry has been condemned for its unethical treatment of workers, particularly in developing countries with weak human rights protection. One possible solution to this issue is to utilize blockchain technology to gather data on working conditions, assess the information, and implement appropriate measures to address any issues [16]. Finally, fast fashion retailers encounter the challenge of overproduction as they strive to fulfill the demands of their customers, which can be optimized by using the four R's "recycling, rental, repair, and resale" [13]. Thus, this literature review showed that adopting innovative technologies such as blockchain, IoT, and AI provides a promising solution to improve supply chain traceability and Transparency, reduce environmental impact, and improve labor conditions. Nevertheless, implementing these technologies poses significant challenges that need to be addressed, including the cost of implementation, technical expertise, and resistance to change within the industry [16].

Future work will be dedicated to proposing a new business model that integrates digital twin technology, making it more sustainable and efficient for the fashion industry. We will explore combining this model with other innovative approaches, such as the ultra-fast fashion business model, which effectively addresses overproduction concerns by leveraging e-commerce platforms with direct customer engagement [1]. By incorporating digital twin technology, companies can create virtual replicas of their products and processes, enabling better understanding of customer preferences and faster response to market changes. This integration will reduce the need for excessive production, minimize waste, and contribute to a more sustainable and agile fashion industry.

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A. Appendix A

Collaboration And Partnership	Companies Committed To Collaboration	Targets Of Collaboration
Make Fashion Circular by [21]	• Inditex • H&M • Gap • PVH	• Foster collaboration between industry stakeholders, policymakers, and consumers to create a circular fashion economy; • Develop business models that use renewable and safe inputs, and promote recycling and composting; • promote circular design principles.
Sustainable Apparel Coalition [25]	• OVS • VFC	• Select environmentally friendly materials; • Develop and promote the Higg Index; • Provide guidance, resources, and support to companies for sustainable business practices; • Advocate for policies and regulations that promote sustainability in the fashion industry ; • Work with consumers to increase awareness and demand for sustainable clothing.
University of Catalonia	• Inditex	• Develop filters for domestic washing machines to address the issue of microfiber pollution.
Fairbrics Startup [26]	• H&M	• Develop a negative carbon polyester to reduce the impact on carbon emission.
Aquafil company	• OVS.	• Develop a closed-loop process that transforms nylon waste such as fishing nets into new nylon yarn (recycled polyamide).
Moda Re [27]	• Inditex	• Promote the use of recycled materials and circular production processes; • Develop solution for the fashion industry to minimize waste and reduce environmental impact.
The Renewal Workshop startup	• H&M	• Create a circular economy for the fashion industry by reducing waste, extending the life of apparel and textiles, and promoting sustainability and responsibility throughout the entire supply chain.

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Accelerating Circularity Project [28]	• **Inditex** • **VFS** • **Gap**	• **Stimulate circularity;** • **Research, map, manage and report on the development and performance of circular supply chains.**

Table 2: The Collaboration And Partnerships Of Some Fast Fashion Companies

B. Appendix

Challenges	Potential Blockchain Solutions In CSCM
Sustainability Sourcing	• **A flow of data on certified suppliers meeting strict sustainability standards [16];** • **Accessibility of supplier information through Blockchain nodes.**
Sustainable Production	• **Strengthen the role of intellectual capital[16];** • **Monitoring and tracing events in real time in terms of environmental and social responsibilities;** • **Audit the quality and safety of the chemicals, water and land;** • **Collect environmental data such as light, humidity, and temperature to detect working conditions, worker state and working hours;** • **Evaluation using the data collected [14].**
Post-production	• **Quality and brand verification;** • **Identifying end-of-life equipment that can be repurposed and remanufactured in other products to maximize the utility of fast-fashion products and minimize the amount of waste that ends up in landfills.**

Table 3: The Potential Of Using Blockchain Technology In The Challenge Of Circular Fast Fashion Supply Chain.

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ملخص

عادة ما تكون الاحتياجات هي المحفزات للصناعة. تولدت الموضة السريعة لتلبية «نزوات» المستهلكين الذين يرغبون في البقاء أنيقين وعصريين في جميع الأوقات. وتصل موضة جديدة في المتوسط كل موسم ؛ لذلك، يجب أن تقدم هذه الصناعة ما يتوقعه عملاؤها في الوقت المحدد. الموضة السريعة هي استراتيجية عمل لإنتاج منتجات عصرية وتلبية طلبات المستهلكين من خلال سلسلة توريد متسارعة وفعالة. تميز العديد من الميزات صناعة الأزياء السريعة، بما في ذلك استراتيجية leagile supply chain واستخدام التقنيات (RFID، والذكاء الاصطناعي، augmented reality، و blockchain، internet of things). بالإضافة إلى عملياتها السريعة، فإن هذه الصناعات ضارة بالبيئة. مع المتطلبات البيئية للمستهلكين، يواجهون ويضطرون إلى التغيير للحد من تأثيرهم البيئي. يسلط هذا العمل الضوء على السلوكات المواكبة والتحديات التي تواجه صناعة الأزياء السريعة من خلال ركائز الاستدامة.

كلمات مفتاحية : الموضة السريعة ؛ supply chain ؛ التكنولوجيا ؛ الاستدامة ؛ السلوكات المواكبة والتحديات.

Abstract

Innovation and need are usually the catalysts for industry. Fast fashion (FF) was born to meet the "whims" of consumers who want to stay trendy, stylish, and fashionable at all times. A new fashion arrives on average every season; hence, this industry has to deliver what its customers expect on time. Fast fashion is a business strategy that aims to produce fashionable products and meet consumer demand through an accelerated and efficient supply chain. Several characteristics distinguish the FF industry, including a leagile supply chain strategy (lean and agile), a fast mode approach, and the use of technologies (RFID, artificial intelligence, augmented reality, blockchain, contactless shopping, internet of things) to identify demand data for FF supply chains. Fast-mode products require supply chain strategies that address their complexity. Besides their rapid activities, these industries harm the environment. With the Green requirements of consumers, the FF industries are confronted and forced to change so that their environmental impact is reduced. This work highlights current fashion trends and the challenges of the fast fashion production industry through the pillars of sustainability.

Keywords: Fast fashion; supply chain; technology; sustainability; Trends and challenges.

Résumé

Les besoins sont habituellement les catalyseurs de l’industrie. La mode rapide est née pour répondre aux "caprices" des consommateurs qui veulent rester élégant et à la mode à tout moment. Une nouvelle mode arrive en moyenne chaque saison ; par conséquent, cette industrie doit livrer ce que ses clients attendent à temps. La mode rapide est une stratégie commerciale qui vise à produire des produits à la mode et à répondre à la demande des consommateurs grâce à une chaîne logistique accélérée et efficace. Plusieurs caractéristiques distinguent l’industrie de la mode rapide, dont une stratégie de chaîne d’approvisionnement leagile (lean et agile), une approche de mode rapide, et l’utilisation des technologies (RFID, intelligence artificielle, réalité augmentée, blockchain, achats sans contact, internet des objets). Outre leurs activités rapides, ces industries nuisent à l’environnement. Avec les exigences écologiques des consommateurs, elles sont confrontées et forcées de changer pour réduire leur impact environnemental. Ce travail met en évidence les tendances actuelles de la mode et les défis de l’industrie de la production de la mode rapide à travers les piliers de la durabilité.

Mots clés : Mode rapide ; chaîne d’approvisionnement ; technologie ; durabilité ; tendances et défis.