

## From rapid production to responsible practices: Fast fashion trends, systemic challenges, and technological pathways to sustainability

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### ABSTRACT

This article provides a detailed analysis of the fast fashion (FF) supply chain, focusing on emerging trends and significant challenges. It aims to define fast fashion, identify current supply chain trends, and clarify sustainability issues across environmental, social, and economic areas. Using a systematic literature review, the study examines relevant research published from 2020 to 2025, drawing from various electronic sources. The findings highlight key trends, including increased transparency and traceability enabled by technologies such as blockchain and RFID, sustainable sourcing practices, and greater digitalization and collaboration among stakeholders. However, it also underscores urgent environmental issues, such as water contamination and carbon emissions, as well as social concerns, like worker exploitation, and economic issues, such as overproduction. Technological challenges, such as infrastructure upgrades and resistance to change, are also addressed. The paper recommends that future research explore innovative business models, such as ultra-fast fashion, to better align with consumer preferences and address overproduction. While offering extensive insights into fast-fashion trends and sustainability issues, the study acknowledges some limitations in the scope of innovative business ideas. Practical implications underscore the importance of advanced technologies to improve supply chain transparency and reduce environmental impacts, advocating strategic shifts toward sustainable sourcing and circular-economy principles. Overall, this systematic review consolidates key data on the fast-fashion industry's supply chain, providing valuable insights for stakeholders seeking to adopt more sustainable and fairer practices.

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## 1. Introduction

The fast fashion industry emerged to meet consumer demand for contemporary, stylish clothing by quickly introducing new fashion items, often with a fresh style each season (Camargo et al., 2020). This industry operates as a business strategy focused on producing fashionable products and meeting consumer needs through an expedited, efficient supply chain. Key characteristics of the fast fashion industry include a leagile supply chain strategy (combining lean and agile approaches), a rapid operational method, and the strategic use of technologies such as RFID, artificial intelligence (AI), augmented reality (AR), blockchain, contactless shopping, and the Internet of Things (IoT) to gather demand data for its supply chains (Hussain et al., 2025).

Historically, the fashion industry has undergone significant change, especially during the Industrial Revolution, shifting from bespoke creation to mass production through mechanisation and automation (Jin & Shin, 2021). The third industrial revolution enhanced process efficiency and leveraged information and communication technology, leading to the emergence of fast fashion, which offers innovative products at lower prices and trend-driven designs more frequently than traditional models (Peters et al., 2021; Backs et al., 2021). Digital growth accelerated with the fourth industrial revolution, during which technologies such as IoT, 3D printing, and virtual and augmented reality have helped refine the fast-fashion business model, tackling issues of overstock and misaligned demand (Casciani et al., 2022). The production process in fast fashion involves managing a complex supply chain characterised by fluctuating demand, maintaining medium-to-low inventory levels, and operating with short lead times, typically ranging from two to four weeks (Fraser & Van der Ven, 2022).

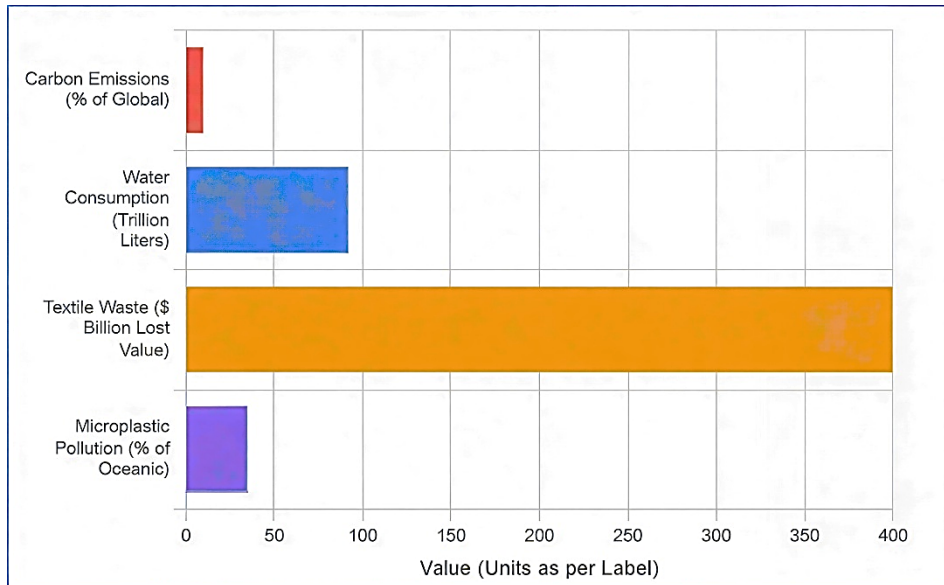
The fast fashion industry has fundamentally reshaped modern consumer culture, driven by its capacity for rapid production and the widespread availability of affordable, trend-driven apparel. This sector continues to expand its global footprint, with

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market value projected to increase from USD 150.82 billion to USD 214.24 billion by 2029 (McKinsey & Company, 2025), reflecting a robust 7% Compound Annual Growth Rate (CAGR).

This rapid expansion, however, is inextricably linked to substantial environmental and social costs. The fashion industry is a significant contributor to global environmental burdens, the second-largest consumer of water, and is responsible for approximately 10% of global carbon emissions (see Fig. 1). Annually, an estimated 1.2 billion tons of greenhouse gases are produced, and the industry's water consumption could meet the needs of five million people. The sheer volume of production is staggering: over 150 billion garments are manufactured globally each year, resulting in significant textile waste. For instance, Europe alone discards 2 million tons of textiles annually, contributing to a global waste of approximately \$400 billion worth of clothing.



**Fig. 1.** Major Environmental Footprint Areas of Fast Fashion Production

The industry also faces significant social issues, including labour exploitation affecting over 60 million workers, primarily in developing nations with lax labour regulations, where 97% of fast-fashion apparel is produced (Fashion United, 2025). Violations may include excessive workloads, inadequate pay, poor working conditions, and instances of forced or child labour. Additionally, the industry struggles with overproduction, with only around 60% of stock being sold, resulting in significant waste being sent to landfills (Akram et al., 2022).

The fast-fashion industry is increasingly challenged and must adapt to "Green requirements" from consumers and stakeholders. This has driven the adoption of more sustainable and transparent practices. There is a growing demand for solutions such as circular-economy principles, sustainable sourcing, and greater transparency. The prevailing linear "take-make-dispose" model of fast fashion production is increasingly recognised as unsustainable, prompting urgent calls for a fundamental shift towards more responsible, circular production and consumption. This imperative is amplified by escalating consumer awareness and demand for ethical and environmentally sound products, particularly among younger demographics such as Gen Z and millennials, who prioritise quality, durability, and ethical sourcing over fleeting trends (Wang et al., 2020; Farahani et al., 2021; Ly, 2021; Hussain et al., 2025)

Innovative use of technologies, such as artificial intelligence and trend forecasting software, is being employed to enhance efficiency, productivity, and the ability to quickly reproduce designs at minimal cost, thereby staying aligned with trends. Additionally, technologies such as Blockchain, IoT, and AR are being integrated into supply chains to achieve sustainability goals, meet client expectations, and remain competitive (Das et al., 2025; Sovtić et al., 2025; Rockett et al., 2025).

Given the complex dynamics of rapidly changing trends, global economic effects, significant environmental and social impacts, and the increasing demand for sustainable practices, a comprehensive review of the current state of the fast fashion industry is necessary. A systematic review synthesising emerging trends and key challenges within the fast-fashion supply chain, particularly from the perspectives of environmental, social, and economic sustainability, and considering the role and potential of technological innovations, is essential for a better understanding and for guiding future strategies.

This systematic literature review addresses important research gaps by providing a comprehensive and synthesised understanding of the fast fashion industry, which many individual studies (as outlined in Table 1) fail to offer due to their limited

scope or specific constraints. While studies such as Farahani et al. (2021) and Wang et al. (2020) focus on specific aspects, such as general trends or blockchain technology, this review provides a broader analysis of how various technological innovations affect the entire value chain, addressing sustainability challenges from environmental, social, and economic perspectives. Unlike studies with limited sample sizes or a geographical focus, e.g., Camargo et al. (2020) and Jin & Shin (2021). This review employs a systematic methodology that includes a broader range of recent and highly cited articles. The review also synthesises findings from multiple sources to overcome data limitations and real-world validation issues highlighted in studies such as Santos et al. (2021) and Wren (2022). It critically assesses the effectiveness of current sustainability models, particularly "circular fashion," addressing issues such as flawed economic assumptions, overproduction, greenwashing, labour concerns, and the influence of dominant brands on sustainability discourse. This critique builds on findings from studies such as Hussain et al. (2025), which question the validity of value-recovery claims.

In summary, although individual studies offer valuable insights, this review stands out by providing a comprehensive overview of the current state of the fast-fashion industry, synthesising emerging trends and sustainability-related challenges, and examining the role of technological innovations. This integrated and critical approach enhances understanding and acts as a holistic guide for future strategies. This paper is organised as follows: Section 2 describes the methodology used for this systematic literature review. Section 3 presents the findings, including a detailed analysis of prevailing trends and challenges in the fast-fashion supply chain, categorised by economic, environmental, social, and technological factors. Finally, Section 4 offers the discussion and conclusion, providing insights into the industry's future.

## 2. Methodology

This article employs a systematic literature review method, defined as "a research method and process for identifying and critically appraising relevant research, as well as for collecting and analysing data from said research" (Snyder, 2019).

**Research questions:** The main objective of this review is to analyse the new trends and challenges of fast fashion throughout the supply chain, from which these relevant questions arise:

- What are the latest trends in the fast fashion supply chain?
- What challenges are these industries facing?
- How can the fashion industry transition to more sustainable and equitable practices?

**Keywords:** the primary search terms and expressions included: "Fast fashion"; "Fast fashion supply chain"; "Trends; Challenges"; "Sustainability"; "Circular economy"; "Technology".

Furthermore, we examined articles that included the terms "apparel", "textile", "fashion", and "garment industry" because they are similar to fast fashion in their operations and raw materials. Many of these articles also use these terms interchangeably and often cite fast-fashion brands such as ZARA and H&M to represent the fashion or apparel industry.

**Sources:** We researched major electronic libraries, including Google Scholar, ScienceDirect, IEEE Xplore, Springer, Wiley Online Library, and Taylor & Francis.

**Inclusion and Exclusion Criteria:** A primary consideration in selecting sources was the recency of publication dates and citation counts, with a focus on including all relevant journal articles, book chapters, and other sources to ensure comprehensive results. Additionally, 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 optimisation. Empirical studies on fast-fashion companies were also among our selection criteria. We limited our collection to papers published in English between 2020 and 2025.

By incorporating these inclusion and exclusion criteria, we aimed to ensure our research remained relevant and up to date while providing a comprehensive understanding of the fast-fashion industry and its impact on society and the environment.

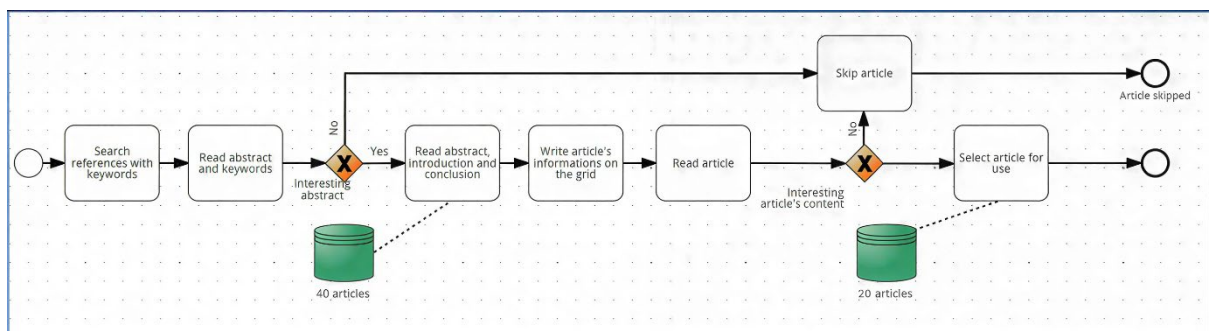


Fig. 2. The process of selecting articles

**The process** involved collecting 40 articles and 10 blog posts to select the most relevant. We summarised the contributions and limitations of each in Table 1. By applying the process shown in Fig. 2 and using the established inclusion and exclusion criteria, a total of 20 articles were identified as meeting the pre-established selection criteria and have been incorporated into our study. Furthermore, to enhance our investigation, we extracted statistical and trend data from published reports on the websites of fast fashion organisations and foundations.

**Table 1**  
Overview of selected articles

Article	Contributions	Limitations
(Camargo et al., 2020)	This article contrasts fast fashion and ultra-fast fashion, emphasising their different approaches to supply chain methods, inventory lead times, manufacturing sites, and forecasting models.	<ul style="list-style-type: none"> <li>The use of a limited sample.</li> <li>Underutilisation of technological capabilities.</li> <li>Technology is seen as a tool rather than a capability that may create a competitive advantage.</li> </ul>
(Wang et al., 2020)	The study proposes a blockchain-based system architecture for fast-fashion circular supply chain management, highlighting the interconnectedness among BCT, fast fashion, and CSCM.	The application of blockchain technology in the circular economy is still in its infancy. It requires further refinement for smaller pilot projects before it can be integrated into large, fast-fashion supply chains. Deploying blockchain-based systems is challenging due to the need for stakeholder input and the participation of multiple organisations.
(Bacs et al., 2021)	The research proposes an agent-based model of the clothing market that considers relevant parties, activities, and interactions. It explores the benefits of a fast-fashion supply chain compared to a traditional one.	The application to a specific fashion industry cannot yield managerial conclusions, and the consumer component could be expanded to address additional research-related issues.
(Farahani et al., 2021)	The paper employs qualitative research methods, including econometric analysis, optimisation models, and game-theoretic approaches, to facilitate collaboration between fast fashion companies and charities, thereby maximising revenue and expanding their capacity in the reverse supply chain. It discusses general trends in the fast-fashion market, textile waste collection, the second-hand clothing market, and online shopping.	Lacks a thorough analysis of the impact of the circular business models used by fast fashion companies and charitable organisations on the environment, society, and the economy.
(Jin & Shin, 2021)	This article examines how Industry 4.0 technologies can address challenges in the fast fashion industry, including hyper-personalisation, environmental sustainability, and productivity.	The study's sample is limited to Western nations.
(Ly, 2021)	The study indicates that apparel multinationals can utilise circular economy principles in their operations and product development to gain a competitive advantage and create value, thereby steering their corporate strategy towards sustainability.	<ul style="list-style-type: none"> <li>A small-scale case analysis was employed</li> <li>Analyse secondary data using qualitative methods.</li> </ul>
(Santos et al., 2021)	The article supports a digital twin strategy for fast-fashion businesses to support decision-making by mirroring the entire production process and delivering real-time data analysis, enabling companies to optimise manufacturing and respond swiftly to evolving consumer demands.	The proposed digital twin approach in fast fashion may not be practical for all companies due to substantial financial and technological investments, as well as limited testing and implementation.
(Soundararajan et al., 2021)	The article advocates for a humanised approach to supply chain management to improve working conditions and identifies four sustainable characteristics that may be harmful if the social component is included.	The article, dubbed the humanising research program, focuses solely on how to conduct respectable research on sustainable supply chain management.
(Akram et al., 2022)	This article addresses challenges in the fashion industry, including trend forecasting, environmental considerations, and health predictions, utilising IoT, AI, blockchain, and AR/VR technologies. It also examines how Industry 4.0 can help achieve the UN's Sustainable Development Goals.	The article examines the potential of digital technology advancements in the fashion industry, with a focus on research into applications for healthy clothing.
(Casciani et al., 2022)	This article provides a comprehensive analysis of digital transformation in the fashion industry, focusing on its impact on sustainability and the supply chain, and examining data on digitalisation across various stages.	A shortage of dimensional, virtual, and digital technologies has environmental effects on the entire fashion supply chain compared to the traditional one.
(Dragomir & Dumitru, 2022)	The study examined the sustainability reports of six major fast-fashion companies, H&M, Inditex, PVH, OVS, Gap Inc., and VF Corp., using a global circular value chain model. It also evaluated their involvement in sustainability and their role in advancing circularity trends.	<ul style="list-style-type: none"> <li>A single data source served as the study's foundation.</li> <li>Despite the use of standards, there is still a risk of subjective evaluation</li> </ul>
(Fraser & Van der Ven, 2022)	This study presents an initial analysis of transparency applications in fast fashion, encompassing domestic laws, norms, and organisational values. It highlights that private governance is insufficient to address the industry's significant sustainability issues.	The article lacks transparency statistics for a specific period and relies on limited data and measurement techniques. Future research should utilise expanded longitudinal data on transparency to better understand shifts in brand transparency.
(Sellitto et al., 2022)	The article examines the strategies and requirements of both slow and fast fashion, offering recommendations for businesses to manage them effectively simultaneously.	The research strategy is restricted to the six biggest retail businesses in Brazil that operate both. Therefore, only large companies that use both strategies in emerging markets can draw applicable conclusions.
(Wren, 2022)	This study addresses the knowledge gap in sustainable supply chain management (SSCM) within fast-fashion supply chains, providing essential steps to enhance strategies that support long-term sustainable infrastructure investments and the renewal of clothing fibre supplies.	This paper utilised annual sustainability reports to estimate waste and greenhouse gas emissions from the supply chains of leading fast-fashion companies, which have over 800 suppliers across multiple countries, as relying solely on these reports was deemed impractical.
(Chen, 2023)	The article examines the impact of blockchain technology on the fashion industry's business practices and sustainability, highlighting challenges in its adoption and analysing the Greater Bay Area apparel industry through case studies.	The study focuses on the fashion industry of the Greater Bay Area, excluding works from other databases, and utilises articles indexed in the Science Citation Index.
(Matuszak-Flejszman et al., 2024)	The study evaluates transport-related emissions, assesses disclosure levels among leading companies, determines the proportion of emissions attributable to transport, evaluates mitigation efforts, and recommends improved environmental reporting with transport-related indicators.	Notes data comparability issues due to varying business sizes and Scope 3 calculation methods; identifies discrepancies in Inditex data; highlights lack of specific transport mode data; points out generalised action plans and absence of specific transport targets.
(Das et al., 2025)	The study highlights economic challenges in waste engagement, including product condition, fabric composition, and design issues; inefficient disposal, collection, and reprocessing infrastructure; and a lack of data-based economic benefit analysis.	The study highlights economic challenges in waste engagement, including product condition, fabric composition, and design issues; inefficient disposal, collection, and reprocessing infrastructure; and a lack of data-based economic benefit analysis.
(Hussain et al., 2025)	Criticises circular fashion proposals, reveals \$460 billion miscalculation, argues concepts are disconnected from academic theory, and advocates for new, validated sustainable fashion ideas.	The paper critiques existing models of CF, focusing on "grey literature" rather than peer-reviewed studies, despite its primary limitation: it does not propose new models.
(Rockett et al., 2025)	Fashion 4.0 proposes a global framework for fashion organisations, focusing on smart factories, networks, and products. It highlights the impact of IP, value chain monitoring, and AI regulation on smaller firms and emerging designers.	The report highlights regulatory inconsistencies, uncertainty about the functionality of generative AI tools, and a lack of legal certainty regarding inputs and outputs in AI-driven creative processes, all of which affect creators.
(Sovtić et al., 2025)	The study examines the potential of blockchain to enhance traceability, authenticity, and transparency in the fashion supply chain, proposes an innovative model, assesses customer readiness, and makes theoretical and managerial contributions.	The study acknowledges target-group bias, challenges in real-world validation, technical adaptation, and the limited scope of validation, primarily focusing on young, digitally literate, highly educated female students.

### 3. Findings

This section examines trends and challenges in fast-fashion supply chains, focusing on economic, environmental, social, and technological factors. It highlights emerging trends that are transforming the garment design, manufacturing, and distribution landscape.

#### 3.1 Emerging Trends in Fast Fashion Production

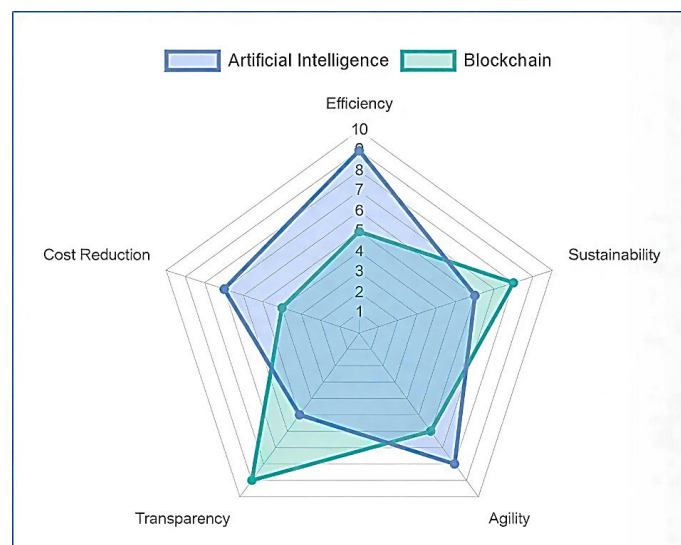
This subsection highlights key emerging trends transforming the fast-fashion production industry, driven by pressures to innovate and pursue sustainability. Notable trends include enhanced transparency and traceability through technologies such as blockchain and RFID, a commitment to sustainable sourcing (e.g., recycled materials and organic cotton), increased digitalisation to streamline the value chain, and greater collaboration among stakeholders. The adoption of advanced digital technologies, including IoT, AI, blockchain, AR, and VR, is crucial for modernising infrastructure and achieving sustainability objectives.

#### a. Technological Integration and Industry 4.0

To align with the United Nations Sustainable Development Goals (SDGs), particularly the ninth goal, the fast fashion (FF) industry must modernise its infrastructure by integrating advanced digital technologies such as the Internet of Things (IoT), AI, blockchain, Augmented Reality (AR), and Virtual Reality (VR). This modernisation will enable clothing to become "smart," allowing individuals to express their personality and monitor health through IoT and AI integration. AI can enhance trend forecasting, which is crucial for FF's complex demand forecasting (Akram et al., 2022).

The integration of advanced technologies central to Industry 4.0 significantly influences fast fashion production, including the adoption of AI and blockchain (See Fig. 3). AI transforms production stages, from design to inventory management, by analysing large datasets to forecast fashion trends, thereby reducing overproduction and waste accurately. Generative AI tools assist designers by creating innovative designs, shortening timelines, and minimizing the need for physical samples. AI-driven automation boosts efficiency and sustainability in manufacturing by optimising material use and decreasing fabric waste. It also streamlines supply chains through real-time tracking and demand forecasting, preventing overstocking and stockouts. Smart textiles are evolving to adapt to environmental conditions and user preferences. Blockchain technology enhances transparency and traceability in the fashion supply chain, addressing issues such as counterfeiting and unethical labour practices (Wang et al., 2020). The combination of IoT and blockchain improves real-time tracking and supports a circular economy, while AI further optimises inventory forecasting and risk management.

Fashion 4.0, similar to Industry 4.0, features intelligent factories, networks, and products that emphasise interoperability, interconnectivity, virtualisation, and decentralisation. This framework combines traditional craftsmanship with digital tools to create a flexible ecosystem that is responsive to changing trends. Technologies such as 3D modelling and virtual prototyping are crucial for brands like Nike and Adidas, allowing for virtual samples that reduce physical sample requirements and material waste (Santos et al., 2021). This digital shift is vital for enhancing competitive advantage and overall performance in the clothing industry, with AR optimising size and colour choices remotely and VR enhancing product development and retail experiences.



**Fig. 3.** Integration benefits of two cutting-edge technologies in fast fashion supply chains

## b. Circular Economy and Sustainability Initiatives

The drive for sustainability is prompting notable shifts towards circular economy (CE) models in fast fashion production (see Fig. 4). These models focus on the principles of “reduce, reuse, and recycle” to extend product lifespans, turn waste into valuable resources, and reduce environmental impact. Sustainable sourcing in the fast fashion industry involves obtaining raw materials and manufacturing new garments in ways that reduce negative environmental and social impacts, while ensuring the long-term availability and sustainability of the resources used. This includes sourcing materials from suppliers who prioritise sustainability, uphold ethical labour standards, and maintain diligent environmental management throughout their supply chains (Chen, 2023). Some brands incorporate recycled fibres into their garments, such as recycled cotton, ecologically grown cotton, recycled polyamide, and recycled polyester fillings (e.g., ZARA) (Gheorghe & Matefi, 2021). Others rely entirely on recycled materials; for example, H&M uses 100% fibre from organic cotton farming (Dragomir & Dumitru, 2022). Additionally, brand owners increasingly favour domestic sourcing for convenience and risk mitigation; Everlane (2025) even publishes its suppliers on its website to promote transparency about their raw material sources (Wren, 2022). Moreover, blockchain technology can verify the origins of fabric sellers, dyeing processors, and certified garment manufacturers, supporting the implementation of sustainable practices (Chen, 2023).

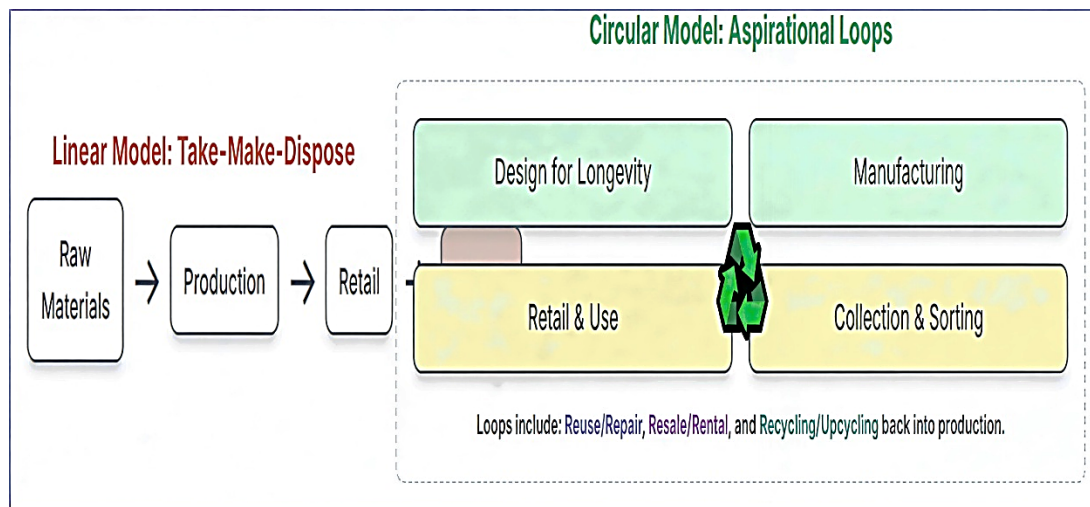


Fig. 4. Linear Model versus Circular Model

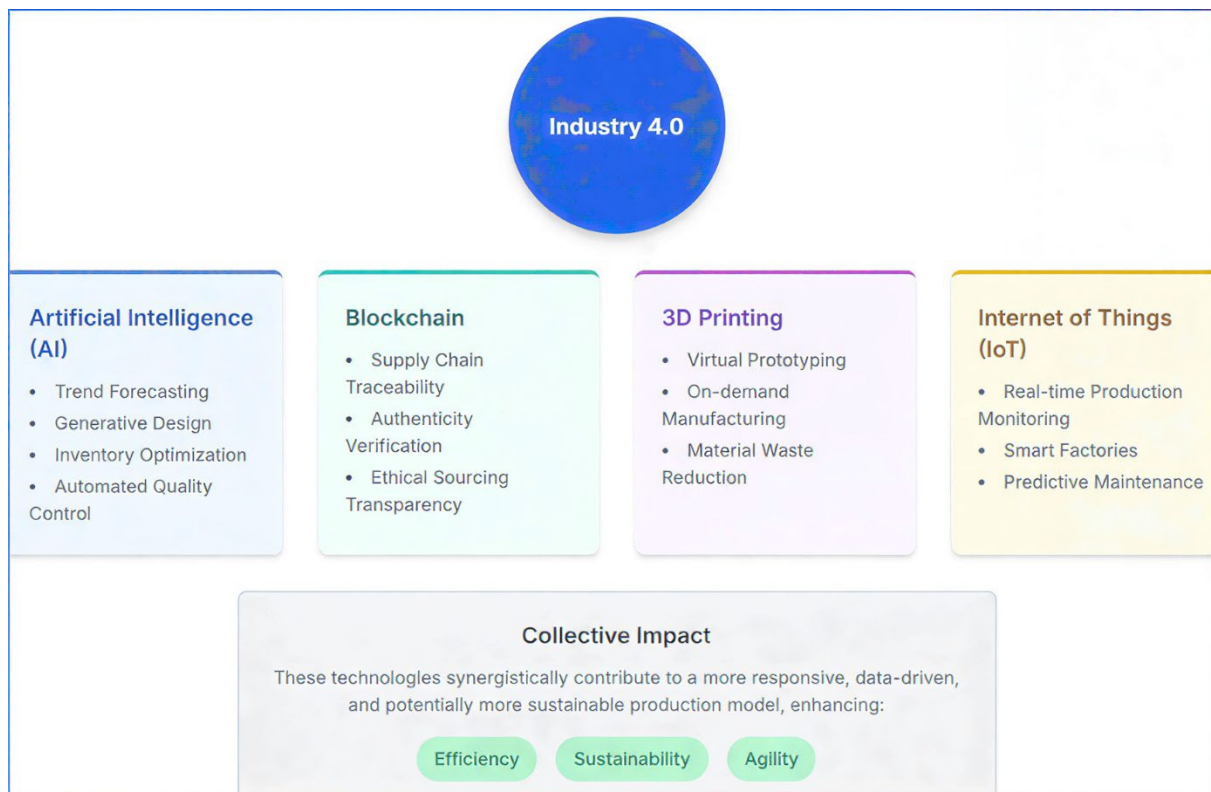
Blockchain technology plays a crucial role in attaining sustainability goals within supply chain practices by reducing product recalls and material waste, enhancing product lifecycle transparency, tracking carbon emissions, and supporting recycling efforts. Research is ongoing to develop new natural resources from plastic fibres, substitute synthetic colours with natural alternatives, and reduce water consumption. The aim is to shift from a “buy-and-throw-away” mindset to a more conscious “buy-less-and-these-are-needed” approach. Companies are investigating various waste management strategies, particularly recycling methods applicable at different stages of textile manufacturing, including converting waste into recycled yarn, regenerated fibres, biofilms, and biodegradable composites. Initiatives like Zara's 'Closing the Loop' programme aim to collect used clothing for sorting and recycling, encouraging closed-loop systems.

The integration of Circular Economy (CE) principles into the textile industry aligns with the UN's Sustainable Development Goals (SDGs), emphasising the reduction of water, resource, and energy use while promoting responsible consumption and production. The economic benefits of CE, alongside environmental advantages, are increasingly supported by data-driven evidence. Additionally, digital innovations such as AI-driven route optimisation and blockchain for supply chain traceability are helping companies.

## c. Supply Chain Agility and Resilience

In response to global trade upheaval, supply chain uncertainty, and shifting consumer preferences, fast fashion (FF) companies are prioritising agility and resilience in their production networks. This involves strategic adjustments to sourcing, manufacturing, and distribution. Diversifying suppliers is a key strategy to mitigate risks associated with geopolitical uncertainties and tariffs. Companies are accelerating efforts to diversify their supply chains in countries such as Vietnam, India, and Mexico to lessen their reliance on a single region, particularly China, after a 6-percentage-point decline in U.S. apparel and textile imports from 2019 to 2023. While nearshoring is being considered, procurement and production networks are expected to continue leaning heavily on Asia. The FF industry is characterised by a supply chain encompassing various processes, from raw material processing to the distribution of finished products (Camargo et al., 2020). Main challenges faced by FF companies include the need to closely match supply and demand, manage a complex and volatile supply

chain (Fraser & Van der Ven, 2022), and minimise the negative environmental and social impacts of their production. The supply chain's efficiency is the backbone of FF operations, requiring ongoing management, monitoring, and optimisation to sustain high performance. The adoption of just-in-time manufacturing and investment in real-time tracking systems are proving crucial for maintaining agility. Technology, especially advanced analytics and AI-driven forecasting, plays a vital role in optimising operations, more accurately predicting trends, and reducing excess inventory while avoiding shortages. Automation and AI-driven production are also employed to enhance efficiency and cut labour costs in nearshoring facilities. The ability to swiftly respond to rapid changes in fashion trends, exemplified by Zara's two-week design-to-distribution cycle, highlights the industry's need for ultra-responsive supply chains. FF companies can utilise an IoT-based traceability architecture (Akram et al., 2022), incorporating technologies such as RFID (Nayak et al., 2015), sensors, and other digital solutions to manage supply chains effectively. This architecture includes six stages: generate, read, communicate, aggregate, consult/trace, and analyse. Textile products are created and fitted with sensors and tags to enable tracking during production. During the read stage, data from sensors and tags, such as geographical location and environmental details, is collected. The tracked information is then communicated to relevant authorities, enhancing control and visibility across the supply chain and enabling more efficient management and potential cost savings (Akram et al., 2022). Blockchain technology has the potential to revolutionise supply chain management in the fast-fashion sector by enabling secure, transparent transactions without intermediaries (Wang et al., 2020).



**Fig. 5. Technological Adoption in Fast Fashion Production**

**Fig. 5** illustrates the interconnectedness of advanced technologies within the fast-fashion production ecosystem.

#### d. Collaboration and Partnerships

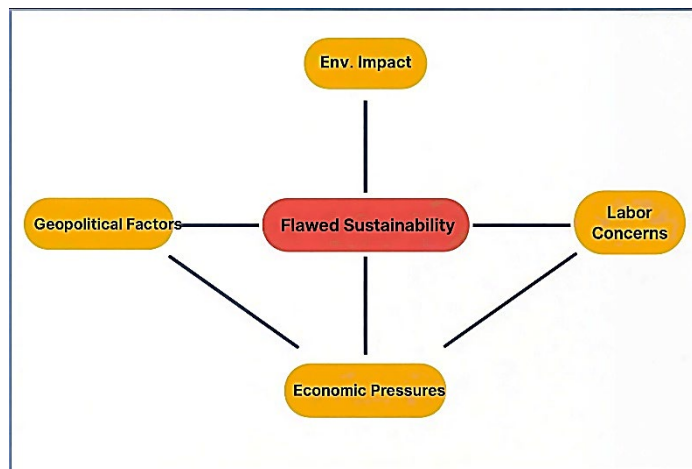
The fast-fashion industry has shown growing concern for the environment, fostering a shared vision among stakeholders both within and outside the sector. This emerging trend presents opportunities for strategic collaborations and partnerships to achieve mutual sustainability goals. As indicated by previous research (Dragomir & Dumitru, 2022), adopting sustainable practices in fast fashion requires a collective effort and shared responsibility from various actors along the supply chain. Collaboration combines strengths to reduce weaknesses. For instance, the Foundation Ellen MacArthur (2025) exemplifies this. Other collaborations involve organisations outside the sector, such as citizens interested in recycling (Ly, 2021), universities, and startups offering innovative solutions to enhance processes and reduce environmental impact. (Table 2) summarises notable examples of collaboration. Successful partnerships depend on aligning each party's objectives and involve interventions across the supply chain. To measure the success of these links, companies such as H&M and Inditex use quantitative indicators of clothing collection and reuse initiatives to evaluate their partners (Dragomir & Dumitru, 2022).

**Table 2**  
The Collaboration and Partnerships of Some Fast Fashion Companies

<i>Collaboration and partnership</i>	<i>Companies are committed to collaboration.</i>	<i>Targets of collaboration</i>
<i>Make Fashion Circular by MacArthur )</i>	INDITEX H&M GAP PVH	The initiative aims to promote a circular fashion economy by fostering collaboration among industry stakeholders, policymakers, and consumers and by advancing renewable, safe business models.
<i>Sustainable Apparel Coalition</i>	VFC OVS	The organisation promotes sustainable practices in the fashion industry by selecting eco-friendly materials, developing the Higg Index, providing guidance and resources to companies, advocating for policies and regulations, and working with consumers.
<i>Accelerating Circularity Project</i>	INDITEX VFC GAP	The goal is to promote circularity by conducting research, mapping, managing, and reporting on the development and performance of circular supply chains.
<i>University of Catalonia</i>	INDITEX	The project aims to create filters for domestic washing machines to combat microfiber pollution.
<i>Fabrics Startup</i>	H&M	The goal is to create a negative-carbon polyester to reduce carbon emissions.
<i>Aquafil company</i>	OVS	Develop a closed-loop process that converts nylon waste, such as fishing nets, into new nylon yarn, a type of recycled polyamide.
<i>Moda Re</i>	INDITEX	The fashion industry should prioritise recycled materials and circular production processes to minimise waste and reduce environmental impact.
<i>The Renewal Workshop startup</i>	H&M	The fashion industry can transition to a circular economy by minimising waste, extending the lifespan of apparel and textiles, and promoting sustainability and responsibility throughout the supply chain.

3.2 Challenges in Fast Fashion Production

The fast-fashion production industry faces significant challenges despite technological and sustainability advancements. Key issues include severe environmental impacts, such as water pollution, excessive waste, and high carbon emissions, as well as social concerns, including the exploitation of workers in developing countries. Economic challenges arise from overproduction and landfill waste, while technological hurdles involve updating infrastructure, protecting intellectual property, and enhancing the efficiency and transparency of supply chain management (see Fig. 6).



**Fig. 6.** Interconnected Challenges in Fast Fashion Supply Chain Management

**a. Environmental Impact**

The environmental footprint of fast fashion remains a critical concern, characterised by extensive resource depletion, pollution, and waste generation. The industry's reliance on synthetic fabrics, such as polyester, which account for approximately 60% of global clothing production, contributes to high carbon emissions during manufacturing and exacerbates the pervasive problem of microplastic shedding during laundering. Fast fashion contributes 35% of microplastic pollution and generates over 92 million tons of textile waste annually (Akram et al., 2022). These microfibers pollute waterways and oceans, eventually entering food chains. Fast fashion uses 79 trillion litres of water annually, with 11,000 litres needed to produce only one pair of jeans. The industry is the second-largest consumer of water globally, with processes such as cotton cultivation and textile dyeing requiring vast quantities of water, often resulting in water pollution from untreated dyes and chemicals. Most indigo is synthetic, and dyeing often releases toxins into waterways and lakes (Gheorghe & Matefi, 2021). Furthermore, since cotton is farmed with irrigation on arid land, producing fibre may account for over 88% of the overall water scarcity effects of typical clothing throughout its entire life cycle, making the distribution of water scarcity impacts even more extreme (Peters et al., 2021).

The sheer volume of production, driven by over 52 “micro-seasons” annually, results in massive textile waste, with millions of tons ending up in landfills. This discarded clothing occupies valuable space and, depending on material composition, releases greenhouse gases as it decomposes. Fast fashion accounts for about half of the textiles industry's CO<sub>2</sub> emissions, with these retailers' GHG emissions estimated at 2.1 billion metric tons in 2018. If this sector continues to produce at this rate, GHG emissions could reach 2.7 billion metric tons by 2030, exacerbating the environmental crisis (Wren, 2022). The increasing prevalence of blended materials further complicates recycling efforts, as current technologies struggle to separate and reprocess these mixed fibres, resulting in a higher proportion ending up in landfills or being incinerated.

To reduce waste, companies can modify product composition and produce each product type with a single garment type, thereby increasing recycling capacity. Some companies are modifying their strategies regarding the raw materials used in their products, beginning with the design phase. For instance, some leaders use 100% fibre from organic cotton farming (H&M), while others buy their cotton from the Better Cotton Initiative (BCI) (OVS, Gap). Methods such as partially adapting acetate fibres derived from plastic debris (H&M), natural yarns made from low-value agricultural residues (H&M), and techniques for transforming cellulose-rich materials into fully circular, biodegradable materials (PVH) are among the scenarios being explored (Dragomir & Dumitru, 2022).

To increase the recycled content of cardboard boxes used to transport clothing from suppliers, Inditex introduced its "Green to Pack" program. H&M and PVH have joined Canopy's Pack4Good initiative to source wood-based packaging sustainably, with H&M committing to remove single-use plastics or replace them with FSC-certified paper. Inditex developed a single hanger for transporting clothing from vendors to retailers. At the same time, Gap deployed a hanger recycling system at over 100 locations, and OVS established a closed system for reusing hangers and sending them to producers for recycling when they malfunctioned (Dragomir & Dumitru, 2022).

## **b. Ethical and Labour Concerns**

The fast-fashion industry is characterised by rapidly evolving trends and frequent new-collection introductions (Sizer, 2025), necessitating constant restocking and ongoing efforts to maintain consumer satisfaction. However, this approach often compromises ethical labour practices, resulting in significant labour violations and exploitation, including overwork, underpayment, poor working conditions, and forced and child labour (Soundararajan et al., 2021). The industry often relies on low-cost labour in developing countries with weak labour laws and limited human rights protections, where 97% of fast-fashion garments are manufactured. Reports have revealed issues such as low wages and unsafe working conditions in parts of the fast-fashion supply chain, sparking public concern and regulatory probes, as exemplified by brands like Boohoo. In 2024, a Skechers supplier was accused of utilising forced labour from the Xinjiang Uyghur Autonomous Region (XUAR) and was subsequently added to the U.S. Department of Homeland Security's list of companies suspected of modern slavery. This event highlights the increasing scrutiny over labour practices and the rising demand for companies to enhance transparency and traceability within their supply chains. Regulations such as the EU's Corporate Sustainability Due Diligence Directive and the U.S. Uyghur Forced Labour Prevention Act (UFLPA) are compelling brands to address human rights and environmental issues throughout their operations, with vigorous enforcement expected in 2025. To tackle these social issues, adopting a more sustainable and ethical sourcing framework that emphasises transparency, traceability, and fair labour practices (Fashion Revolution, 2025) is crucial. Moving towards a sourcing approach that is flexible, rapid, sustainable, digitally enabled, and consumer-centred is vital. The utilisation of blockchain technology has been proposed as a means of gathering and evaluating information on working conditions in the fashion sector. By leveraging blockchain to collect and analyse data (Chen, 2023), companies can gain deeper insights into the conditions within their supply chains and environmental impacts, enabling them to take corrective measures where needed and pinpoint opportunities for enhancement (Wang et al., 2020).

## **c. Economic and Geopolitical Pressures**

The fast-fashion industry operates in a volatile global economic and geopolitical environment, facing numerous external pressures. Economic uncertainty and high inflation are prompting consumers to seek more affordable options, even as sustainability demands intensify. Fashion leaders surveyed in late 2024 expressed pessimism, with a substantial percentage expecting worsening industry conditions in 2025. Geopolitical factors, particularly tariffs and changes in trade policy, pose significant risks to sourcing costs, inflation, and consumer spending. The potential for new tariffs, especially during a second U.S. presidential term, remains a significant concern. Changes to the "de minimis" rule, which allows imports valued under \$800 to enter the U.S. duty-free (a provision leveraged by fast fashion giants like Shein and Temu to keep prices low), could result in higher prices and longer shipping times if the rule is altered. This complex landscape creates obstacles for brands seeking growth.

Furthermore, fashion retailers often face overproduction issues. To meet all customer demands, they produce more garments than they sell; it is estimated that only 60% of inventory is sold, with the unsold items often sent to landfill (Wren, 2022). To tackle this problem, the four R's, "recycling, rental, repair, and resale", are increasingly being adopted by leading brands (Wren, 2022). For example, H&M utilises its extensive network of stores to collect used clothing for recycling. Companies

such as "Banana Republic's Style Passport," "Rent the Runway," and "Style Lend" offer rental options, enabling customers to utilise garments temporarily. The third "R" involves repair services, exemplified by Patagonia. There is also considerable potential for resale through startups like Depop, which specialise in online resale and secondhand clothing. Charitable organisations can benefit by collecting unwanted garments and selling useful ones (Farahani et al., 2021).

Supply chain disruptions, caused by natural disasters, political instability, or transportation problems, pose significant threats to the availability and cost of materials, affecting brands' ability to deliver products. Companies like Zara, with complex global supply chains, are especially vulnerable to such disruptions. Moreover, garment factories can benefit from aligning market demand with upstream fabric supply by adopting blockchain technologies in fashion supply chains, thereby reducing overproduction. This creates a centralised platform for order production coordination that links all ERP modules across various supply chain members.

#### e. Limitations of Current Sustainability Models

A recent study has questioned the effectiveness of sustainability strategies, particularly those that are rapid and circular (Das et al., 2025). The study found that current circular fashion solutions, such as resale and rental, are based on flawed economic assumptions, resulting in lower profit margins than those from new product sales. This contradicts claims of sustained economic expansion. The study also revealed a \$460 billion error in commonly referenced assertions about value recovery through circularity, challenging the belief that circular fashion automatically offers growth potential. Overproduction is often overlooked in circular fashion literature, which tends to focus on customer behaviour rather than the industry's habitual disposal of unsold inventory. Concerns about greenwashing remain, as sustainability reporting faces criticism for the disparity between discourse and genuine action. Labour issues are frequently neglected in the shift to lower-margin circular models, potentially worsening insecure employment. The debate on sustainability is often driven by business interests, with consulting firms and global leadership groups shaping policies without thorough scrutiny. This suggests that the current implementation of circular fashion may reinforce image-centric, high-frequency purchasing patterns rather than offering meaningful solutions.

## 4. Discussion and Conclusion

The fast fashion production sector is at a pivotal moment, characterised by significant technological advances, evolving sustainability demands, and ongoing structural issues. The review highlights a clear trend towards increased digitalisation, driven by the integration of technologies such as Artificial Intelligence (AI), blockchain, and Industry 4.0 principles. These tools aim to enhance efficiency, optimise supply chains, and strengthen traceability across the value chain. The industry is also progressively adopting circular economy principles, focusing on waste reduction and extending product lifespans through improved recycling and the use of sustainable materials. This shift emphasizes supply chain agility and resilience, which are crucial for navigating an unpredictable global economic and geopolitical environment. Despite these positive signals, the study's findings indicate that deeper, unresolved issues often overshadow such advances. The fast-fashion sector has a substantial environmental footprint, driven mainly by overproduction, resource-intensive manufacturing, and significant challenges related to textile waste and microplastic pollution. Ethical concerns, particularly labour abuses and transparency deficiencies, pose serious risks, which are further complicated by the complexity of global supply chains and geopolitical tensions. Recent research points to the limitations of current circular fashion models. While promising, these models are often criticised for their weak economic foundations, neglect of overproduction issues, and susceptibility to 'greenwashing.' This suggests that although technological solutions can improve current practices, they may not fundamentally change the industry's unsustainable business model.

The fast fashion supply chain is undergoing significant changes to address its challenges. The adoption of technologies such as AI, Blockchain, IoT, and AR/VR helps minimise overproduction and waste and enhances transparency and traceability. AI is revolutionising demand forecasting, reducing waste, and aligning collections with customer preferences. Blockchain creates an unalterable record that enhances transparency and traceability by tracking products from design to delivery. IoT systems enable real-time monitoring of fashion activities, supporting a circular economy. AI also enhances supply chain efficiency and flexibility through real-time tracking, demand forecasting, and intelligent reorder points. The circular economy and sustainability initiatives aim to reduce environmental impact by utilising recycled fibres and organic cotton, and by addressing overproduction.

The findings have several practical implications for industry stakeholders and policymakers, including the adoption of quantitative indicators and the formulation of specific recommendations. We present below relevant KPIs for the fast fashion industry:

- **Environmental Performance Metrics:**
  - **Water Usage:** The yearly water consumption of the fast fashion industry (e.g., 79 trillion litres) and for specific items (e.g., 11,000 litres for a single pair of jeans).

- Water Scarcity Impacts: The proportion of total water scarcity caused by fibre production (e.g., over 88% from cotton farming).
- Microplastic pollution: The contribution of the fast fashion industry to microplastic pollution (e.g., 35%).
- Textile Waste Generation: The annual amount of textile waste produced (e.g., >92 million tons).
- Carbon Emissions (Greenhouse Gas Emissions): The CO<sub>2</sub> emissions attributable to the fast fashion sector (e.g., estimated 2.1 billion metric tons in 2018, projected to reach 2.7 billion by 2030 if current rates persist). The capacity to track carbon emissions is also recognised.
- Use of Sustainable Materials: The proportion of materials made from organic cotton farming (e.g., H&M uses 100% fibre from organic cotton farming) or recycled content (e.g., recycled cotton, polyamide, polyester filling, acetate fibres from plastic debris, natural yarns from agricultural residue, biodegradable foams).
- Renewable Energy Use: The proportion of renewable energy utilised in company operations (e.g., Everlane uses 100% renewable energy internally).
- **Social Performance Metrics:**
  - Labour Exploitation Data: Information on workers impacted by labour exploitation (e.g., over 60 million workers).
  - Production Location: The percentage of garments made in developing countries with weaker labour laws (e.g., 97%).
  - Working Conditions Data: Environmental data such as light, humidity, and temperature, along with worker state and working hours, can be collected and assessed to monitor working conditions.
  - Transparency and Traceability: Although often qualitative, the sources mention providing information about manufacturing processes, certifications, and reports on raw material origin and extraction. Quantitative measures might include the number of multi-stakeholder sustainability networks (MSSN) partnerships or the amount of supply chain information publicly disclosed.
- **Economic/Operational Performance Metrics:**
  - Inventory Sold vs. Unsold: The proportion of inventory sold compared to what is sent to landfill (e.g., only 60% of the inventory is sold).
  - Clothing Collection and Reuse Initiatives: Quantitative indicators employed by companies like H&M and Inditex to assess their partners in these programmes.
  - Circularity Trends Contribution: Metrics to evaluate how much companies support circularity trends. This includes measuring progress in recycling, material reduction, reuse, transformation, and resale initiatives.
  - Overproduction Reduction: The effect of strategies like the "four R's" (recycling, rental, repair, resale) on minimising unsold stock. Blockchain technology can also help synchronise market demand and fabric availability to prevent over-ordering.
  - Process Optimisation: Digitalisation results in benefits such as dematerialisation of resources, streamlining operational processes, and reducing lead times. Although not explicitly stated as KPIs, these areas suggest measurable enhancements.

Such metrics are often collected from annual sustainability reports, and new technologies, such as blockchain, are proposed to improve data flow, track events in real time, and enhance transparency for these metrics, especially in sustainable sourcing, production, and circular-economy practices.

To promote a genuinely sustainable and ethical fast fashion industry, a comprehensive approach is essential.

For industry stakeholders, the focus must shift towards systemic change rather than merely optimising existing practices. Brands are encouraged to fundamentally transform their business models to address the core issues of overproduction and overconsumption. This transformation involves moving from volume-driven strategies to value-driven approaches that emphasise durability, quality, and product longevity. Additionally, investing in circular infrastructure is crucial, as it requires collaboration across the value chain to develop effective textile collection, sorting, and recycling technologies. Enhanced supply chain transparency and accountability are also essential, utilising technologies such as blockchain for genuine traceability and ethical compliance. Rigorous auditing and public disclosure can help build consumer trust. Lastly, the ethical and responsible use of AI is vital; it should focus on optimising resource use and minimising waste rather than exacerbating overconsumption.

Policymakers and regulators play a critical role in shaping a sustainable fast-fashion industry through robust, coordinated regulations. They need to develop comprehensive legislation that mandates environmental and social due diligence throughout the supply chain, establishing clear standards for emissions, water usage, and labour conditions. Incentives for sustainable innovation should be created to encourage brands to adopt practices that promote durability and recyclability while disincentivising overproduction. Furthermore, addressing the influence of "grey literature" is necessary to ensure that industry claims are rigorously scrutinised, preventing greenwashing and grounding policy decisions in validated research. Finally, harmonising global regulations will facilitate international cooperation, standardise ethical and environmental

standards, and reduce compliance burdens on smaller firms, thereby promoting a more equitable and sustainable industry landscape.

Future research should focus on the empirical validation of circular models, longitudinal studies on digital transformation, and changes in consumer behaviour towards sustainable products. Longitudinal studies should monitor the long-term effects of AI and blockchain adoption on efficiency, sustainability, and labour dynamics in fast fashion supply chains. Interdisciplinary approaches ought to be encouraged to develop comprehensive solutions for the complex challenges faced by fast fashion. The future of the industry depends on its capacity to move beyond incremental changes and adopt a transformative agenda. The actual impact of technological advancements will rely on their strategic deployment within a framework that emphasises environmental integrity, social equity, and economic sustainability.

### Conflicts of Interest

The author(s) declare no conflicts of interest related to the research, authorship, or publication of this article. No financial, personal, or professional relationships exist that could be seen as influencing the work presented.

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