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Article

Fashion 4.0 and emerging designers: *leveraging data and AI to drive creativity, innovation and compliance in global supply chain regulation*

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Abstract

- This paper presents three interrelated arguments concerning the fashion industry and regulation. First, we propose that Bertola's and Teunissen's concept of *Fashion 4.0* offers a powerful framework for understanding the organization of global fashion today. This model emphasizes the dynamic, decentralized and technology-driven character of the 'smart factories', 'smart networks' and 'smart products' that dominate the global fashion industry. The value of this framework is illustrated with contemporary examples from the UK.
- Second, we argue that increasing regulatory demands impose uncertain and costly compliance obligations on firms across multiple aspects of their operations and supply chain. Our discussion highlights the confluence of challenges related to intellectual property, value chain monitoring and AI regulation. We contend that smaller and medium-sized enterprises, particularly emerging designers, are disproportionately affected by this regulatory burden—a phenomenon we term the 'tragic character' of contemporary compliance.
- Finally, we explore how the challenge of navigating an increasingly complex business and regulatory landscape necessitates the deployment of ever-more sophisticated digital technologies, especially AI. We outline several potential applications of such technologies across the fashion industry.
- In conclusion, we suggest that in the context of *Fashion 4.0*, understanding the interaction between different regulatory schemes, as well as their effects on industry stakeholders, is becoming critical yet increasingly complex and opaque. This raises difficult questions about the limits of law and other regulatory schemes in fostering innovative, sustainable, and socially responsible business practices in the fashion sector.

1. Introduction

Harri, a rising star in London's fashion scene, gained recognition for its avant-garde, inflatable latex garments.[1] Led by Indian designer Harikrishnan, Harri is celebrated for its bold, nonconformist designs that push traditional fashion boundaries.[2] At just 30, the designer has already made a significant mark, being named as one of the British Fashion Council's NEWGEN recipients.[3] His work seamlessly blends modern materials, traditional craftsmanship and cutting-edge technology to create striking, sculpture-like pieces that reshape the fashion landscape.

Despite its innovative vision, Harri's global success in the fashion scene comes with challenges related to protecting the brand's

[1] G Costanzo, 'HARRI: From Inflatable Fantasy to Everyday Edge' (*Le Mile Digital Special*) Available at https://www.lemilemagazine.com/art-archive/harri-interview (accessed 27 September 2024).

[2] J Hahn, 'Harikrishnan's Inflatable Latex Trousers Create "Anatomically Impossible" Proportions' (*Dezeen*, 24 February 2020) Available at https://www.dezeen.com/2020/02/24/harikrishnan-lcf-inflatable-latex-fashion/ (accessed 27 September 2024).

[3] Alex Kessler, 'It Centers Around Form and Texture: Harri on His Sculptural Debut Spring Collection' (*Vogue*, 22 September 2023) Available at https://www.vogue.com/article/it-centers-around-form-and-texture-harri-on-his-sculptural-debut-spring-collection (accessed 27 September 2024.

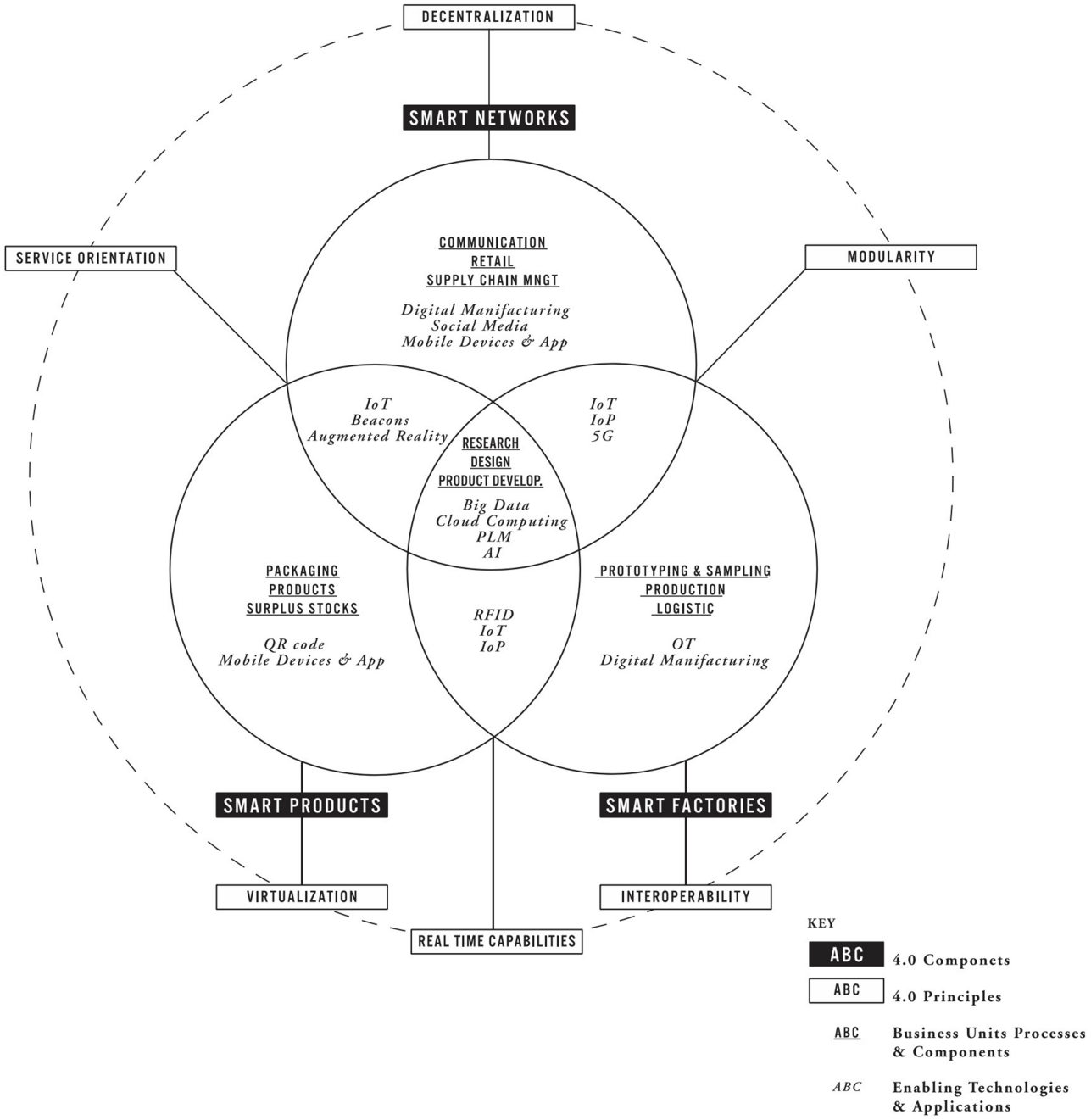

Figure 1. Fashion 4.0.
Bertola & Teunissen (n 8), 357.

intellectual property (IP) and ensuring regulatory compliance. The brand faces significant IP issues, especially concerning the copying of its distinctive inflatable designs. As a small, emerging label with a global supply chain—handcrafted garments with latex from Sri Lanka and the Scottish wool—Harri's unique products are highly vulnerable to imitation, making IP protection both critical and challenging. Additionally, as is typical with emerging designer brands, Harri keeps the design process a closely guarded trade secret.

Harri is not only rethinking fashion design but also reimagining the fashion business model. As a brand grounded in innovative shapes for garments, they would be limited by the traditional fashion calendar and wholesale model. Together with business partner Abhinov Asokan, the pair also runs a blockchain-based digital product passport app, Lyftime.[4] Through collaboration, Harri seeks to explore alternative revenue streams, including licensing imagery, exclusive exhibitions and an emphasis on cultural heritage.[5] This innovative approach to design and business reflects Harri's broader vision: a fashion brand that embraces technology, sustainability and nonconformity while navigating the complexities of a global market and various regulatory challenges.[6]

[4] See Available at https://www.lyftime.app/ (accessed 27 September 2024).
[5] See Available at https://harri.store/blogs/article/harri-x-the-botree (accessed 27 September 2024).
[6] K Gillet, 'Who Is Harri, the Kerala-Born Designer Behind Sam Smith's Brit Awards 2023 Look' (*The National News*, 12 February 2023) Available at https://www.thenational

As Harri's example illustrates, the fashion industry is undergoing rapid transformation, driven by technological developments, shifting consumer behaviors and increasing regulatory scrutiny. Traditionally, the fashion supply chain has been viewed as a linear process encompassing design, manufacturing, distribution and retail.[7] However, this simplified view fails to capture the intricate complexities of the contemporary fashion industry and the business and regulatory challenges that now exist.

In this paper, we introduce three interrelated arguments concerning the fashion industry and regulation. Section 2 argues that the contemporary fashion supply chain is often misrepresented and misunderstood. To understand the complex realities of this emerging transnational economic, cultural and technological formation, we utilize the concept of *Fashion* 4.0 as developed by Bertola and Teunissen.[8] This framework emphasizes the emergence of 'smart factories', 'smart networks' and 'smart products'—reshaping how fashion is created, produced and consumed. By adopting an open, decentralized and circular approach to value creation, *Fashion* 4.0 creates new challenges in navigating the intricacies of modern fashion production and supply chain management.

Section 3 suggests that recent regulatory developments, particularly those aimed at improving corporate accountability and transparency, impose extensive and indeterminate compliance obligations on firms across the entire value chain. Here, we focus on intellectual property, global value chain monitoring and AI regulation to illustrate this more general claim. Smaller and medium-sized firms, such as emerging designers and brands, are particularly heavily hit by the burdens of these shifting regulatory obligations—which we refer to as the tragic character of contemporary compliance. These firms, already struggling to secure financing and establish themselves in a competitive marketplace, now face additional regulatory hurdles threatening their long-term viability.

Drawing on the experience of the London fashion industry—one of the world's most dynamic and diverse fashion hubs—we argue that smaller firms, such as Harri, are especially vulnerable to the burdens imposed by compliance obligations. Unlike large multinational corporations, which can invest in comprehensive legal and compliance frameworks, emerging designers often lack the resources and capacities to meet these demands, placing them at a significant disadvantage.

Section 4 proposes that the path forward, particularly in terms of navigating the growing complexity of business and compliance obligations, lies in the adoption of digital technologies, especially AI. We suggest that integrating AI tools across the fashion value chain might help alleviate some of the regulatory pressures by streamlining operations, improving transparency and enhancing decision-making. However, this raises critical questions about how AI regulation and other regulatory schemes interact and how these areas can be harmonized to foster greater creativity. More generally, such a discussion raises questions about the role, limits and future of law and regulation in fostering innovative, sustainable and socially responsible business models in the fashion sector.

One of the primary aims of this article is to offer a more holistic perspective on the intersection of emerging technologies, innovation and the regulation of the fashion business. The authors seek to address a gap in fashion law literature, which often focuses on isolated cases or specific areas of law, such as copyright, intellectual property rights, trade secrets, and the impact of various business models and technologies on the fashion industry. In this article, the authors take a broader view, examining the diverse forces and factors that shape the fashion business. This is achieved through the introduction of a circular framework for understanding fashion—*Fashion* 4.0—which unravels layers of complexity that go beyond the oversimplified linear approaches that have dominated the existing literature. Additionally, the authors aim to bridge three distinct areas of emerging regulation—intellectual property, global value chains and artificial intelligence—and to highlight how the lack of coordination among these regulatory domains increases the burden on creators.

2. Fashion 4.0

Fashion 4.0 represents a significant shift in how the fashion industry operates, moving away from traditional methods and embracing the potential of digital innovation. Bertola and Teunissen first proposed *Fashion* 4.0 in 2018 as a model for integrating textiles and garments into the Industry 4.0 paradigm.[9] Much like the evolution from Industry 2.0 to Industry 3.0, *Fashion* 4.0 marks the beginning of a new era, one that promises to reshape the entire supply chain.[10] At its core, *Fashion* 4.0 revolves around advanced manufacturing, but its implications extend far beyond. The foundation rests on three interconnected pillars: smart factories, smart networks and smart products, to transform every stage of the fashion process—from design to production to distribution.

Central to these three pillars are developments in digital technology and, increasingly, AI. *Fashion* 4.0 represents a seismic transformation in the fashion industry, a profound shift away from traditional linear disconnected systems.[11] *Fashion* 4.0 is driven by the integration of digital technologies. This concept focuses on harnessing innovations like AI, the Internet of Things and potentially blockchain to transform every stage of the fashion process—from design to production to distribution.[12] The promise of *Fashion* 4.0 is clear: a more efficient and adaptable ecosystem aligned with consumer demands and rapidly changing trends.[13] The fundamental principles of interoperability, interconnectivity, virtualization and decentralization that are central to Industry 4.0 are mirrored in *Fashion* 4.0. *Fashion* 4.0 takes these same principles and applies them to the fashion industry, blending traditional craftsmanship with cutting-edge digital tools in a way that reshapes the entire sector.

news.com/lifestyle/fashion-beauty/2023/02/12/who-is-harri-the-kerala-born-designer-behind-sam-smiths-brit-awards-2023-look/ (accessed 27 September 2024).

[7] D Ellams et al., 'Identifying and Analyzing UK Fashion Micro-Clusters: Building Regional Supply Chains that Foster Sustainable Approaches and Circular Economies' [2023] Available at https://pec.ac.uk/discussion_paper_/identifying-and-analysing-uk-fashion-micro-clusters/ (accessed 27 September 2024), 40.

[8] P Bertola and J Teunissen, 'Fashion 4.0: Innovating Fashion Industry Through Digital Transformation' (2018) 22 *RJTA* 353.

[9] id. 353.

[10] M Braglia et al., 'Managerial and Industry 4.0 Solutions for Fashion Supply Chains' (2023) 25 *JFMM* 184.

[11] A Grieco and others, 'An Industry 4.0 Case Study in Fashion Manufacturing' (2017) 27th International Conference on Flexible Automation and Intelligent Manufacturing, FAIM2017, 27–30 June 2017, Modena, Italy 872.

[12] S Thomassey and X Zeng, 'Introduction: Artificial Intelligence for Fashion Industry in the Big Data Era' in S Thomassey and X Zeng (eds) *Artificial Intelligence for Fashion Industry in the Big Data Era* (Springer Series in Fashion Business, Springer Singapore 2018) 1; for more about the application of blockchain in fashion, see S Yanisky-Ravid and G Monroy, 'The Promised Land: Blockchain and the Fashion Industry' (2022) 87 *Brooklyn Law Rev* 609 Available at https://brooklynworks.brooklaw.edu/blr/vol87/iss2/4 (accessed 28 September 2024).

[13] H Harreis et al., 'Generative AI: Unlocking the Future of Fashion' (8 March 2023) Available at https://www.mckinsey.com/industries/retail/our-insights/generative-ai-unlocking-the-future-of-fashion (accessed 27 September 2024).

Fashion 4.0 provides a contemporary vision that goes beyond the desire to enhance efficiency. *Fashion* 4.0 fosters collaboration across the industry, bringing designers, manufacturers and consumers into closer alignment. It encourages creativity and personalization in fashion, allowing for new levels of engagement and innovation. In essence, *Fashion* 4.0 seeks to redefine how technology and fashion intersect, creating a more dynamic, agile industry that is better equipped to meet the needs of the future.[14]

At the heart of *Fashion* 4.0 are fundamental principles—interoperability, interconnectivity, virtualization and decentralization—that mirror the foundational elements of Industry 4.0.[15] This approach enables smarter factories, networks and products, making the fashion industry more efficient, agile and responsive to shifting consumer demands.[16] Notably, both frameworks also emphasize sustainability and innovation, aiming to not only streamline production but also foster greater collaboration and creativity.[17] In the process, they tackle critical challenges like IP management and environmental responsibility. *Fashion* 4.0, then, is best understood as a focused application of the broader Industry 4.0 revolution, designed to meet the specific needs and complexities of the fashion world.

2.1. Smart factories

In the realm of *Fashion* 4.0, 'smart factories' represent a pivotal shift in how fashion is produced, characterized by highly automated and interconnected manufacturing environments. These factories harness advanced sensors, data and AI-powered tools to link machines, robotic devices and systems, enabling seamless real-time communication and data exchange.[18] This interconnectedness allows for precise monitoring and control of production lines, leading to greater efficiency, reduced waste and faster adjustments to production.[19]

In late 2024, Manchester Metropolitan University is set to open its Robotics Living Lab, where it has developed micro-scale robotics tools for fashion production. This £4 million funded project is focused on building an innovative facility to develop a future-focused, high-value and low-volume UK garment manufacturing industry.[20]

Smart factories also leverage AI to analyse vast amounts of data, making informed decisions that optimize operations and improve performance.[21] They offer a level of customization and flexibility previously unavailable, enabling manufacturers to adapt to shifts in consumer demands and fashion trends. This level of agility primarily supports emerging designers as they are the group most affected by high minimum-order quantities currently associated with traditional fashion manufacturing. The facilitation of smart factories powered with data and AI that can adapt to production demands and do fast switching between designs means they can sample quickly, produce small production runs and have shorter lead times.[22] Robotics and automation streamline routine tasks, freeing human workers to focus on more creative and complex aspects of production. Additionally, the use of blockchain technology could enhance transparency and traceability, ensuring that materials are ethically sourced and produced.[23]

Moreover, AI is increasingly being adopted in smart factories within the fashion industry, largely due to the integration of AI into existing fashion design software tools. One prominent example is CLO 3D, the most widely used fashion design software taught in fashion universities.[24] CLO 3D incorporates two main AI-driven features: a pattern generator and a fabric simulation engine.[25] This AI-driven pattern generator enables the software to analyse existing garments to create new patterns. A pattern is a template that guides how the fabric is cut and assembled to create the garment, to ensure that it matches the original design. The fabric simulation engine allows designers to understand how different fabrics will behave, providing a visualization of the fabric's drape and movement. For instance, silk drapes very differently from leather, and this tool enables designers to see these crucial differences in real time.

Other digital design tools including Lectra[26] and Browzwear[27] also offer AI integrations focused on grading and fitting. Grading is the process of resizing a pattern to create different sizes while maintaining the original design fit and proportions. These tools provide automatic pattern grading, seamlessly converting sizes from sample size, something that was a laborious manual task prior to these digital innovations. With Browzwear, designers can customize patterns based on specific sizing requirements, enhancing precision and efficiency in the design process. By integrating AI into these design tools, smart factories are revolutionizing the fashion industry. They are making the design process more efficient and responsive, allowing for greater customization and better alignment with consumer needs. This technological advancement not only streamlines production but also fosters innovation, illustrating how AI can be a transformative force in fashion.

Sustainability is another key feature of smart factories, as they are designed to optimize resource use and minimize environmental impact. Sustainability becomes even a bigger issue in the context of fast fashion.[28] By integrating these advanced technologies, smart factories play a crucial role in transforming the fashion

[14] N Särmäkari and A Vänskä, '"Just hit a button!" - Fashion 4.0 Designers as Cyborgs, Experimenting and Designing with Generative Algorithms' (2022) 15 *Int J Fash Des Technol Educ* 211, 220.

[15] A Grieco and others, 'An Industry 4.0 Case Study in Fashion Manufacturing' (2017) 27th International Conference on Flexible Automation and Intelligent Manufacturing, FAIM2017, 27–30 June 2017, Modena, Italy 872.

[16] S Black et al., *Accelerating Sustainability in Fashion, Clothing and Textiles* (Taylor and Francis, London, 2024) 204.

[17] Z Wu and others, 'AI Creativity and the Human-AI Co-creation Model' in M Kurosu (ed) *Human-Computer Interaction. Theory, Methods and Tools*, HCII 2021, Lecture Notes in Computer Science, vol. 12762 (Springer, Cham 2021) 172.

[18] S Shirkhani et al., 'Study of AI-Driven Fashion Recommended Systems' (2023) 4 *SN Comput Sci* 521.

[19] L Zeng et al., 'Fashion Innovation Through an Innovation Ecosystem - a Research Agenda' (2024) 17 *Int J Fash Des Technol Educ* 62–75.

[20] Manchester Metropolitan University, 'Robotics Living Lab' (2024) Available at https://www.mmu.ac.uk/about-us/200-years/creative-excellence/robotics-living-lab (accessed 27 September 2024).

[21] K Gohari, 'The Intelligent Factory: How AI and Data Analytics Are Transforming Traditional Manufacturing' (*Canvas Intelligence*, 19 March 2024) Available at https://www.canvasintelligence.com/the-intelligent-factory-how-ai-and-data-analytics-are-transforming-traditional-manufacturing/ (accessed 27 September 2024).

[22] Bertola and Teunissen (n 8) 364.

[23] See eg S Yanisky-Ravid and G Monroy, 'When Blockchain Meets Fashion Design: Can Smart Contracts Cure Intellectual Property Protection Deficiency?' (SSRN, 13 December 2019) Available at https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3488071 (accessed 27 September 2024).

[24] See Available at https://www.clo3d.com/en/ (accessed 27 September 2024.

[25] S Chaudhary et al. 'Maximising Performance of Apparel Manufacturing Industry Through CAD Adoption'(2020) 12 *IJEBM1* 12.

[26] 'Pushing the Boundaries of Innovation with AI' (*Lectra*, no date) Available at https://www.lectra.com/en/about-us/discover-lectra/innovation/Lectra-AI-assisted-image-labeling-model (accessed 27 September 2024).

[27] See Available at https://browzwear.com/ (accessed 27 September 2024).

[28] See eg F Souchet, *Fashion Has a Huge Waste Problem. Here's How It Can Change* (*WEF*, 28 February 2019) Available at https://www.weforum.org/agenda/2019/02/how-the-circular-economy-is-redesigning-fashions-future/ accessed 27 September 2024; K Raustiala and CJ Sprigman, 'Faster Fashion: The Piracy Paradox and its Perils' (2021) 39 *Cardozo Arts & Ent LJ* 535, at 546.

industry into a more agile, responsive and sustainable system.[29] In doing so, they embody the broader goals of Fashion 4.0, fostering innovation and collaboration across the entire fashion value chain.

There are key design tools that not only assist with the creative process but also provide early-stage manufacturing support. Take Optitex,[30] for example, which integrates AI to enhance sustainability by minimizing waste.[31] The tool automatically optimizes pattern layouts to reduce fabric waste, allowing designers to visualize a pattern in a flat lay that is already configured for efficiency. When both the designer and the factory use this tool, they can collaborate far more effectively. The AI integration enables a smoother, more efficient process, aligning design and production with sustainability goals. This is a clear example of how AI can facilitate innovation and efficiency, benefiting both the environment and the industry.

2.2. Smart networks

In the world of *Fashion 4.0*, the concept of a 'smart network' refers to a highly connected system that uses digital technologies to boost communication and collaboration among all key players in the fashion industry.[32] Designers, manufacturers, suppliers and consumers are integrated into a network where real-time data sharing and decision-making become the norm.[33] With tools like generative AI, the Internet of Things (IoT) and blockchain, these networks have the potential to offer access to information, as well as increased transparency and traceability across the entire fashion value chain. AI can enhance smart fashion networks through data to enhance insights, collaboration and supply chain optimization. Enhanced collaboration can be developed as designers, manufacturers and retailers can share insights and updates instantly to facilitate more efficient and informed decision-making.[34] The use of data and AI could provide greater visibility by making it easier to track sourced materials, value-creation processes and products.[35] Moreover, these new smart networks powered by data and AI can be leveraged to advance sustainability and ethical practices.[36]

From the very beginning of the design process, data-driven insights allowed designers to identify consumer preferences and adapt to market demands, which can reduce the risks they are taking with key decisions.[37] The inclusion of data and AI-powered tools takes this even further, optimizing everything from inventory management to production, reducing waste and increasing efficiency.[38] Network optimization can be developed through AI-driven efficiency in logistics and inventory management, which can help to reduce waste and improve the responsiveness of designs.[39] For example, London-based fashion-technology platform *xyz.exchange* is driving this change with its AI-driven design and inventory management software designed to democratize access to the industry.[40]

The smart network also supports product customization, allowing fashion to adapt more readily to consumer preferences and shifting market trends, creating more personalized experiences. Data-driven smart networks enable a new kind of collaboration between human designers and AI, fostering greater creativity and innovation in fashion design. The smart network concept in *Fashion 4.0* signals a move toward a more agile, responsive and sustainable fashion industry, one that emphasizes connectivity and collaboration.[41] This shift is aimed at meeting the evolving needs of consumers while addressing some of the industry's most pressing challenges.

2.3. Smart products

The final pillar of *Fashion 4.0* centres on 'smart products'—fashion items that integrate advanced technologies to enhance both functionality and user experience. These products often incorporate sensors, generate data and utilize Internet of Things (IoT) capabilities, allowing them to connect to consumer devices and the Internet. Smart products represent a significant leap forward in merging style with technology, offering more customizable and interactive fashion solutions. This transformation aims not only to meet the evolving needs of consumers but also to address broader industry challenges like sustainability, innovation and IP protection.

Consider, for example, the use case of a smart jacket embedded with sensors that monitor the wearer's physical metrics or environmental conditions, providing real-time feedback.[42] This technology empowers consumers with valuable insights and enables designers to engage in more responsive, data-driven product development.

Blockchain technology is often integrated into fashion products to ensure authenticity, traceability and enhanced IP protection.[43] Platforms like EONs industry-leading ecosystem exemplify this approach by providing a digital twin for each product, facilitating connectivity from authentication through to resale.[44] Trusted by leading luxury brands and resale providers such as Vinted[45] or Vestiaire Collective,[46] this technology underscores the potential of smart products to reshape the fashion industry.

Finally, smart products may advance sustainability through features like recyclable materials and energy-efficient manufacturing processes. Technologies can help aid in the analysis of sustainable material performance and lifecycle assessments to

[29] FY Tam and JYW Lung, 'Impact of Covid-19 and innovative ideas for a sustainable fashion supply chain in the future' (2023) 25 *Foresight* 225 at 235.
[30] See Available at https://optitex.com/ (accessed 27 September 2024).
[31] MM Babuet and others, 'The Role of Artificial Intelligence in Shaping the Future of Agile Fashion Industry' (2022) 35 *PPC* 2084 at 2087.
[32] Bertola & Teunissen, supra note 8, 352.
[33] WC Kang et al., 'Visually-Aware Fashion Recommendation and Design with Generative Image Models' (arXiv, 2017) arXiv:1711.02231 [cs.CV] Available at https://arxiv.org/abs/1711.02231 (accessed 27 September 2024).
[34] MMM Peeters and others, 'Hybrid Collective Intelligence in a Human–AI Society' (2020) 36 *AI and Society* 214.
[35] See eg 'AI for Supply Chain Optimization: Enhance Visibility' (AIM Consulting, no date) Available at https://aimconsulting.com/insights/ai-enhance-supply-chain-visibility/ (accessed 27 September 2024); 'End-to-End Supply Chain Visibility: How AI and Data Connect the Dots' (*GEP*, 27 November 2023) Available at https://www.gep.com/blog/technology/end-to-end-supply-chain-visibility-how-ai-and-data-connect-the-dots (accessed 27 September 2024).
[36] UNESCO, 'Ethics of Artificial Intelligence: The Recommendation' Available at https://www.unesco.org/en/artificial-intelligence/recommendation-ethics (accessed 27 September 2024).
[37] N Särmäkari and A Vänskä, '"Just hit a button!" - Fashion 4.0 Designers as Cyborgs, Experimenting and Designing with Generative Algorithms' (2022) 15 *Int J Fash Des Technol Educ* 213.
[38] A Khan and A Ahmed, 'Optimizing Retail Operations, Inventory Management and Sales Forecasting with Big Data and AI in China' (2024) 16 *Emerging Trends in Machine Intelligence and Big Data* 21.
[39] S Thomassey and X Zeng (n 12) 1.
[40] 'XYZ Exchange' Available at https://www.xyz.exchange/ (accessed 27 September 2024).
[41] Bertola and Teunissen (n 8) 353.
[42] 'Elevating Luxury Fashion: Prifina and Ichijiku's Sensorized Jackets Redefine Customer Experiences' Available at https://www.prifina.com/blog/20230525jackets (accessed 27 September 2024).
[43] S Yanisky-Ravid and G Monroy (n 16), 609.
[44] 'EON Exchange' Available at https://www.eon.xyz/eon-exchange (accessed 27 September 2024).
[45] 'Vinted' (Vinted, no date) Available at https://www.vinted.co.uk/ (accessed 27 September 2024).
[46] 'Vestiaire Collective' Available at https://us.vestiairecollective.com/ (accessed 27 September 2024).

support brands in making environmentally conscious decisions on key design and manufacturing elements. One example is the Ellen MacArthur Foundation's research, conducted in collaboration with Google, exploring AI and the circular economy.[47]

3. The regulatory burden

One of the objectives of this paper is to illustrate the multidimensional and intricate nature of the fashion value chain and how it collides with laws and other regulation. In this section, we aim to demonstrate how recent developments in a legal context contribute to an increasingly complex mosaic of regulatory obligations facing all firms operating in the fashion space. We present an overview of selected emerging regulations affecting both the fashion supply chain and the governance of emerging AI technologies. For fashion brands—whether well-established or emerging—this regulatory complexity presents a significant challenge to ensure regulatory compliance. As such, an opaque and murky legal risk is added to the business and technological challenges outlined in the previous section describing *Fashion 4.0*.

In particular, how does this complex and evolving regulatory landscape impact leading and innovative creatives like Harri? Emerging designers and small-to-medium fashion enterprises often operate with limited budgets, struggling to cover basic operational costs, so compliance costs hit such creators especially hard.[48] Here, we explore how three distinct legal frameworks—focusing on (a) IP protection, (b) global fashion value chain oversight and (c) rapidly expanding AI regulation—intersect, creating significant new hurdles for such creators. The convergence of these regulatory regimes intensifies the compliance burden, making it increasingly difficult for smaller players to navigate the legal landscape and remain competitive. As is often the case, regulation benefits incumbents and reinforces the status quo power hierarchies.[49]

3.1. IP regulation

The integration of AI technologies into the *Fashion 4.0* value chain raises numerous IP challenges, creating a significant regulatory burden for designers, manufacturers and other stakeholders.[50] Here, we aim to briefly highlight several key IP and AI-related issues across smart factories, smart networks and smart products, each of which requires careful consideration to ensure the protection of creative rights and the fair distribution of ownership within the fashion industry. Our intention is to indicate the scale and diversity of the challenges and not to offer a comprehensive or deep review.

In the context of smart factories, one major IP challenge revolves around *data sharing and permissions* on a global scale. As factories increasingly employ AI systems across their operations, the question of what data can be accessed and shared becomes critical. Designers must know they can trust supply chain factories not to infringe on their IP by copying or misusing designs, a process that requires expensive due diligence. For example, if a factory has access to design patterns and production techniques, how are permissions managed to ensure that proprietary information is safeguarded? Without clear regulations and contracts, there is a risk that design IP could be exploited without the designer's knowledge or consent.

Another issue arises when *factories make edits to garment patterns using AI tools*. AI-driven alterations aimed at improving efficiency or reducing waste, often for sustainability purposes, may result in significant design changes. The challenge here is how these changes are communicated to the designer for approval. This raises questions about the relationship between human creativity and machine input. If the AI's contribution to the design process leads to significant modifications, who owns the resulting design? Furthermore, how do designers maintain creative control when AI plays an active role in modifying their work?

A related concern involves *robotics in manufacturing*, specifically the ownership and control of the knowledge used to train robots. Robots in smart factories are often trained using specialized skills that may be proprietary to specific brands, which is something being explored by the research team at Manchester Metropolitan University as part of their Robotics Living Lab development. They are seeking industry insight to support the training of robots in fashion production. In such cases, questions arise about who owns the training data and the resulting expertise embedded in the robots. Is it the company that provided the training or the manufacturer that operates the robots? This issue touches on both IP ownership and the transfer of specialized knowledge in automated environments.

Smart networks, which enable real-time collaboration between designers and AI systems, also raise important IP questions. One significant issue is the *ownership of AI-driven collaborative output*. When designers work with AI to create fashion designs or patterns, it can be difficult to determine who holds the rights to the resulting products. If AI contributes significantly to the creative process, should the ownership be shared between the designer and the AI system's creator? Establishing clear guidelines for ownership in these collaborative contexts is crucial for protecting both human creativity and the technological innovations that support it.

Additionally, the use of AI for *data-driven trend analysis* introduces the potential risk of homogenizing fashion design. If AI systems are widely used to predict and respond to trends based on shared data, there is a danger that the fashion industry may lose its creative diversity. When all designers respond to the same AI-generated trends, the uniqueness of individual designs could be diminished. This raises the question of whether such reliance on data-driven trends might stifle creativity, as designers become increasingly dependent on AI systems to shape their work.

Smart products, particularly those that incorporate sustainable technologies, present unique IP challenges, particularly around *patents for sustainability innovations*. As the fashion industry moves toward more sustainable practices, it is crucial to balance the need for collaboration with the protection of proprietary innovations. A notable example is the sustainable dye technology developed by SAGES London,[51] which holds a patent for its environmentally friendly garment dyeing process. While such innovations are essential for advancing sustainability in

[47] See Ellen MacArthur Foundation, 'Artificial Intelligence and the Circular Economy: AI as a Tool to Accelerate the Transition' (2019) Available at https://www.ellenmacarthurfoundation.org/artificial-intelligence-and-the-circular-economy (accessed 27 September 2024), and also 'Artificial Intelligence and the Circular Economy: AI as a Tool to Accelerate the Transition' (*McKinsey*, 23 January 2019) Available at https://www.mckinsey.com/capabilities/sustainability/our-insights/artificial-intelligence-and-the-circular-economy-ai-as-a-tool-to-accelerate-the-transition (accessed 27 September 2024).

[48] S Black et al., *Accelerating Sustainability in Fashion, Clothing and Textiles* (Taylor and Francis, London, 2024) 129.

[49] M Fenwick et al., 'Data Portability Revisited: Toward the Human-Centric, AI-Driven Data Ecosystems of Tomorrow' (2025) *Vand J Ent & Tech L (forthcoming)*.

[50] N Saardchom, 'Risk of Intellectual Property Among Fashion Designs' (2017) 20 *JLERI* 1. Available at https://www.abacademies.org/abstract/risk-of-intellectual-property-among-fashion-designs-6816.html (accessed 18 November 2024).

[51] 'Sages London' Available at https://www.sageslondon.com/ (accessed 27 September 2024).

fashion, they also raise questions about how to protect the value of these innovations while encouraging broader industry adoption.

The issue of *licensing and sharing sustainable innovations* is central to this debate. Fashion brands and designers may want to collaborate on developing new eco-friendly technologies, but without clear licensing agreements, there is a risk of undermining the proprietary value of these innovations. Striking a balance between collaboration for the greater good and protecting the IP rights of individual innovators is crucial to fostering both sustainability and creativity in fashion.

In summary, the *Fashion 4.0* value chain introduces a range of IP challenges related to the use of AI in smart factories, networks and products. From data-sharing permissions and AI-driven design edits in factories to questions of ownership in AI collaborations and sustainable patents, these issues highlight the need for updated regulatory frameworks that protect creativity while supporting innovation. As the fashion industry continues to evolve, addressing these challenges will be essential for ensuring the fair and equitable distribution of IP rights across the value chain.

3.2. Global value chain regulation

A second central pillar of the contemporary regulatory framework impacting *Fashion 4.0* is global value chain regulation. Regulators have reacted to several key developments: scandals involving major brands, a rising global call for justice from civil society and the exposed shortcomings of extant national legal and policy approaches.[52]

In response to these developments, regulators have introduced measures extending legal liabilities for actors across the value chain. This response has also been driven by a growing international consensus that solely relying on existing soft mechanisms, especially those of a voluntary nature, is insufficient for ensuring responsible business practices. Consequently, this realization has spurred the creation of mandatory human rights due diligence laws in various jurisdictions.

These measures collectively aim to effectively foster adherence to human rights standards in the private sector. The genesis of this legislative trend was marked by the inception of mandatory disclosure-focused regulations, exemplified by the 2010 *California Transparency in Supply Chain Act*[53] or the 2015 UK *Modern Slavery Act*,[54] and in an EU context, there was the *Non-Financial Reporting Directive* (2014).[55] A significant shift occurred, however, with France's *Loi au devoir de Vigilance* (2017),[56] which introduced more stringent legal consequences for non-compliance with legal obligations and established itself as a seminal model. Contrasting with the prevalent disclosure-centric approaches, which only indirectly impact corporate conduct, the French legislation mandates a more direct method, compelling companies to reform their operational activities.[57]

The ongoing expansion of legally enforceable corporate due diligence obligations is witnessing significant advancements at both domestic and regional levels, particularly within several European Member States and the broader EU context. The EU corporate sustainability due diligence directive[58] is the most far-reaching. It will oblige firms to mitigate their adverse impacts on human rights and the environment, such as child labour, slavery, labour exploitation, pollution, deforestation, excessive water consumption or environmental damage. They will have to integrate due diligence into their policies and risk-management systems, including descriptions of their approach, processes and code of conduct, and civil liability will be imposed.

These new forms of public regulatory intervention are multifaceted and fragmented, and a number of general features should be noted. First, when thinking about what is happening here, Gralf-Peter Callies and Peer Zumbansen's concept of 'rough consensus' is instructive.[59] This concept points to the fact that much contemporary transnational business regulation is primarily marked by a general agreement on the desirability of regulatory measures, such as regulating the GVC and imposing due diligence obligations. However, this consensus is invariably 'rough', resulting in minor yet significant differences among different regulatory interventions.

These differences bear significant implications regarding legal risk for all stakeholders. Mandatory due diligence obligations now form a central pillar within the liability mix, which is constituted by a rich cocktail of international, national, public, private, binding and voluntary measures. Given that value chains often span various legal forms, geographical boundaries and multiple layers of applicable law, legally mapping the global value chain presents intricate challenges for fundamental questions and positive legal analysis.

A second helpful concept for understanding legal developments in this context is that of hybridization.[60] The new law of the GVC involves a multitude of regulatory arrangements that combine elements from several legal orders. A number of central dichotomies of modern law are deconstructed: national vs. transnational law, international vs. transnational law, convergence vs. divergence, soft law vs. hard law, territorial vs. non-territorial, 'top-down' vs. 'bottom-up' globalization and national vs. global.[61]

Finally, over the last few decades, the theory and practice of regulation have focused on improving the ability of regulators to respond to changing industry practices and on improving relationships between regulators and regulated entities across

[52] For instance, in the early 1990s, Nike faced severe backlash when investigative journalists and labour activists exposed horrific practices in its factories in Indonesia. The scandal revealed child labour exploitation, hazardous working conditions and sexual harassment. See e.g., Kodiak Hub, 'A Look Through History's Most Disastrous Supply Chain Disruptions' (no date) Available at https://www.kodiakhub.com/blog/a-look-through-historys-most-disastrous-supply-chain-disruptions (accessed 27 September 2024).

[53] California Civil Code § 1714.43. See also A Prokopets, 'Trafficking in Information: Evaluating the Efficacy of the California Transparency in Supply Chains Act of 2010' (2014) 37 *Hastings Int'l & Comp L Rev* 351; BT Greer, 'Opaque Transparency: Why California's Supply Chain Transparency Act is Unenforceable' (2018) 8 *Oñati socio-leg ser* 32–49.

[54] Modern Slavery Act 2015 (c. 30). See also G LeBaron and A Rühmkorf, 'The Domestic Politics of Corporate Accountability Legislation: Struggles over the 2015 UK Modern Slavery Act' (2019) 17 *SER* 709.

[55] Directive 2014/95/EU of the European Parliament and of the Council of 22 October 2014 amending Directive 2013/34/EU as regards disclosure of non-financial and diversity information by certain large undertakings and groups [2014] OJ L330/1, 1–9.

[56] LOI n° 2017–399 du 27 mars 2017 relative au devoir de vigilance des sociétés mères et des entreprises donneuses d'ordre (Law relating to the duty of vigilance of parent companies and ordering companies), Available at https://www.legifrance.gouv.fr/jorf/article_jo/JORFARTI000034290627 (accessed 27 September 2024).

[57] ibid.

[58] Directive (EU) 2024/1760 of the European Parliament and of the Council of 13 June 2024 on corporate sustainability due diligence and amending Directive (EU) 2019/1937 and Regulation (EU) 2023/2859 [2024] OJ L202/1 (entered into force 25 July 2024).

[59] GP Calliess and P Zumbansen, *Rough Consensus and Running Code: A Theory of Transnational Private Law* (Hart Monographs in Transnational and International Law Hart 2012).

[60] See e.g. P Jurcys, PF Kjaer and R Yatsunami (eds), *Regulatory Hybridization in the Transnational Sphere* (Brill Publishing, Leiden, 2013).

[61] Recent work on these issues has drawn on insights of Niklas Luhaman, see for example, Anna Beckers, 'The Invisible Networks of Global Production: Re-Imagining the Global Value Chain in Legal Research' (2020) 16 *Eur Rev Contract Law* 95–117; R Condon, *Network Responsibility, European Tort Law and the Society of Networks* (Cambridge University Press, Cambridge, 2022).

the value chain. In this context, so-called dynamic or smart regulation responds to changing industry practices through feedback effects and enhanced information for developing regulatory forms.[62]

Fashion brands and emerging designers are expected to navigate these complex new legal demands despite limited resources, highlighting the impracticality of the current regulatory approach. The obligation placed upon them—and companies in general—is so expansive that compliance becomes an unattainable goal, underscoring the need for a more feasible and 'smart' compliance framework.

3.3. AI regulation

Given the centrality of digital technologies in Fashion 4.0, a third pillar of the regulatory framework that is particularly relevant is the emerging field of AI regulation. The global landscape of AI regulation is on the verge of a dramatic shift. Currently, there may be around 10 AI regulations in effect, one of the most prominent examples being the EU AI Act.[63] However, this is set to change rapidly: recent estimates show that approximately 752 proposed AI regulations are being considered worldwide. In the next 12 to 18 months, over 750 bills on AI are expected to be introduced across various countries.[64]

This raises a critical question: if all these regulations come into force, what will it mean for industry players? The complexity of navigating this fragmented and fast-evolving regulatory environment is immense. Companies like Harri and other fashion brands will face significant challenges in compliance, innovation and strategic planning as they adapt to this new reality.

However, these regulations should not be viewed as targeting individual companies in isolation. Rather, they represent a broader network of shared responsibilities. This perspective aligns with Sustainable Development Goals (SDGs)[65] related to smart networks, emphasizing that when we discuss governance and regulation, we must account for the network of stakeholders who are affected. This shifts the focus from individual accountability to a more systemic approach—one that recognizes the interconnected nature of modern industries.

Recent discussions have highlighted how the handful of existing AI laws are already shaping how we think about data use and the integration of AI tools. As this regulatory landscape expands, it becomes clear that a networked approach to responsibility is essential.[66] Businesses, regulators and stakeholders must work within this complex web of relationships, ensuring that innovation can flourish while accountability remains strong.

3.4. Interim observations

The most important observation is that the three critical domains of regulation—IP, those governing global value chain management and AI technologies—have mainly evolved independent of each other. At a high level, it is often difficult to discern the relationship between these three pillars of contemporary regulation. Despite their potential intersections, these regulatory domains frequently develop autonomously, without cohesive strategies to address how they interact or overlap.

Second, fashion is one of the industries most likely to be affected by emerging global supply chain regulations. In the following sections, we will focus on the specific impact of value chain regulations on emerging fashion designers. We aim to demonstrate that while new technologies present social, legal and ethical challenges, they could also offer a way forward for the industry. However, every company in the fashion sector, particularly small enterprises like Harri, faces the immense challenge of navigating these distinct regulatory frameworks. The burden of compliance, including adhering to disparate regulations, disproportionately impacts smaller players.

Finally, *Fashion 4.0* paints a stark picture of the growing compliance burden. Companies are now expected to monitor their value chains in real-time, dynamically and reflexively, to ensure that IP laws, human rights and environmental laws are upheld. This creates a harsh burden, particularly on smaller enterprises, which lack the resources of larger corporations. IP-related challenges are just one aspect of this intense monitoring requirement. The fashion industry, especially in countries like France, is poised to be among the most affected by these evolving regulations, as it struggles to balance innovation with increasingly stringent compliance demands.

4. Applied AI in Fashion 4.0

The current discourse surrounding the use of AI in the fashion industry tends to focus on concept creation and product marketing, particularly in the realm of social media and digital marketing. While these applications are undoubtedly significant, this narrow perspective overlooks the broader, transformative potential of AI across the entire fashion value chain. By limiting the discussion to just a few stages of the process, we risk missing the full scope of opportunities that AI can unlock—opportunities that could drive innovation, efficiency and sustainability throughout every facet of fashion production and distribution beginning at the design stage.

To address these gaps, the concept of 'value creation', as proposed within the *Fashion 4.0* paradigm, provides a useful lens through which to explore the full range of AI's potential. AI can be strategically integrated into multiple segments of the fashion value chain, from research and development to prototyping, sampling, production, logistics, packaging, surplus management, retail, communications and supply chain management. Taking this holistic approach highlights how AI can enhance not only design and marketing but also the more 'invisible' stages of fashion production, where inefficiencies and information silos—such as the inability to trace the origins of materials like cotton—persist.

In this section, we focus on the neglected 'middle' of the fashion value chain and argue that greater data interoperability and transparency are essential for addressing the industry's current challenges. The *Fashion 4.0* framework encourages us to think about the various domains where information asymmetries should be minimized, especially as it relates to the complex network of actors involved in fashion production.

We will explore the potential for AI tools to empower emerging creators by addressing a key question: where can data and AI be effectively applied at each segment of the fashion supply chain?

[62] H Habuka, 'Governance for Society 5.0' *Governance Matters Magazine*. Available at https://www.chandlerinstitute.org/governancematters/governance-for-society-5-0 (accessed 27 September 2024).

[63] Regulation (EU) 2024/1689 of the European Parliament and of the Council of 13 June 2024 laying down harmonised rules on artificial intelligence and amending Regulations (EC) No 300/2008, (EU) No 167/2013, (EU) No 168/2013, (EU) 2018/858, (EU) 2018/1139 and (EU) 2019/2144 and Directives 2014/90/EU, (EU) 2016/797 and (EU) 2020/1828 (Artificial Intelligence Act) [2024] OJ L1689/1, published 12 July 2024.

[64] S Yavorski and J Kudon, 'The Future of AI Regulation and Legislation: 5 Key Takeaways' (Orrick, 23 September 2024) Available at https://www.orrick.com/en/Insights/2024/09/The-Future-of-AI-Regulation-and-Legislation-5-Key-Takeaways (and the accompanying video recording) (accessed 27 September 2024).

[65] United Nations General Assembly Resolution 70/1, 'Transforming our world: the 2030 Agenda for Sustainable Development' A/RES/70/1 (21 October 2015), specifically SDGoals 9 and 12.

[66] See eg R Condon (n 65).

4.1. Research and product development

In the conceptualization and prototyping phases, designers are increasingly integrating generative AI tools into their creative processes. These tools are becoming embedded in more of the platforms and software that creators rely on, reshaping the landscape of design. It is crucial to emphasize the transformative role data AI plays in research and product development. AI has the potential to be a game-changer, especially in predicting trends. For instance, companies like Trendimensional[67] have harnessed AI to create virtual prototype libraries, offering a new way to anticipate market shifts and streamline the design process. By leveraging AI, designers can move more quickly and accurately from concept to creation, fundamentally altering the way fashion responds to evolving consumer demands. Similarly, AI-powered fashion design software like CLO 3D[68] now has AI-driven pattern generators and fabric simulation engines, which allow designers to create patterns and simulate how different fabrics will behave. Other tools, such as Lectra[69] and Browzwear,[70] offer AI integrations for grading and fitting patterns, automating the shift from one size to another. Optitex[71] is another AI tool that minimizes fabric waste by optimizing pattern layouts, contributing to sustainability.

The lack of legal certainty with regard to inputs and outputs seem to be among the biggest challenges in the fashion industry.[72] First, there is significant uncertainty about how generative AI tools actually work.[73] A key concern for designers is the lack of transparency regarding the data used to train these tools.[74] Are the prompts recorded? What datasets have these AI models been trained on?[75] This raises serious legal challenges, particularly when it comes to the potential unauthorized use of images and data in AI training. The frustration in the market is palpable—designers simply do not know what data is behind the tools they are using.[76] Greater transparency and more robust disclosures would go a long way in addressing these concerns.[77]

Second, there is considerable uncertainty around the legal ownership of AI-generated outputs.[78] Collaboration with AI tools requires significant time and effort, often involving the use of multiple tools to achieve a final design. Yet, the legal framework around ownership of outputs remains murky.[79] Who owns the result when it emerges from a complex interplay between human creativity and AI assistance? As fashion designers increasingly rely on AI to enhance their work, the need for clarity on these issues becomes more urgent. Clear policy direction on data use and ownership is essential to navigate these emerging challenges.

4.2. Prototyping, sampling and production

In terms of prototyping, many brands still rely on traditional methods, sending physical samples back and forth sometimes internationally, which is inefficient. AI tools help by reducing material waste and improving collaboration, but tracking changes remains a challenge. We need to ensure that credit is given where it is due, and AI tools can help with that by logging changes, tracking design iteration contributions at every stage of the process.

At the prototyping, sampling and production stage, the process becomes more collaborative, with multiple creators and stakeholders involved. For instance, designers typically send their work to factories for sampling and production.[80] But it is at this point that such questions as protection of trade secrets (e.g., undisclosed patterns and designs) and sustainability challenges start to surface.[81] Take, for example, a London-based designer working with a factory in Portugal. Samples and products are shipped back and forth multiple times, increasing the potential number of individuals in the network who may have access to initial designs as well as adding carbon footprint of the production process. The complexity only grows when 3D samples and models are introduced, further complicating logistics.

With the use of generative AI, designers can push the boundaries of creativity, producing innovative, trend-responsive designs that speak directly to evolving consumer demands. AI tools can create personalized experiences, adapting to user preferences and behaviors based on data analysis. GENERA LAB's new 3D customization engine for clothing utilizes AI-powered tools for digital clothing customization.[82] AI tools allow for product customization based on individual consumer preferences, providing consumers with a personalized experience, something that digital fashion house, The Fabricant, have been leading on since the launch of their first AI-designed collection, DEEP, in 2017.[83] These AI-powered design tools are also useful for early-stage manufacturing. When both designers and factories use these AI-integrated tools, it leads to a more efficient and collaborative process.

Consider a scenario where a designer has already developed a clear concept—knowing precisely the type of garment and the specific item to be created. The designer sends a digital template

[67] 'Trendimensional' Available at https://www.trendimensional.com (accessed 27 September 2024).

[68] 'CLO 3D' (CLO 3D, no date) Available at https://www.clo3d.com/en/ (accessed 27 September 2024).

[69] 'Pushing the boundaries of innovation with AI' (*Lectra*, no date) Available at https://www.lectra.com/en/about-us/discover-lectra/innovation/Lectra-AI-assisted-image-labeling-model (accessed 27 September 2024).

[70] 'Browzwear' Available at https://browzwear.com (accessed 27 September 2024).

[71] See Available at https://optitex.com/ (accessed 27 September 2024).

[72] See eg H Härkönen, 'The Impact of Artificial Intelligence on the Fashion Sector: A Moral Rights' Perspective' forthcoming in E Rosati and I Calboli (eds) *The Handbook of Fashion Law* (OUP 2025), Available at https://papers.ssrn.com/sol3/papers.cfm?abstract_id=4573087 (accessed 12 November 2024).

[73] See eg H Härkönen (n 76 above); M Fenwick and P Jurcys, 'Originality and the Future of Copyright in an Age of Generative AI' (2023) 51 *CLSR* 105892.

[74] See eg The Fashion Law, *Uniqlo is Suing Shein in Japan Over 'Copyright' Bag Design* (*The Fashion Law*, 16 January 2024) Available at https://www.thefashionlaw.com/uniqlo-is-suing-shein-in-japan-over-copycat-bag-design (accessed 12 November 2024); A Greenwald, 'Artificial Intelligence and Copyright: Commercial Interior Designer Perspectives on the Use of AI for Contracted Work' Available at https://www.regulations.gov/comment/COLC-2023-0006-9104 (accessed 27 September 2024) 5.

[75] See eg C Geiger, 'Elaborating a Human Rights-Friendly Copyright Framework for Generative AI' [2024] IIC; Andrés Guadamuz, 'A Scanner Darkly: Copyright Liability and Exceptions in Artificial Intelligence Inputs and Outputs' (2024) 73 *GRUR Int* 111; T Margoni, 'Artificial Intelligence, Machine Learning and EU Copyright Law: Who Owns AI?' Available at https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3299523 (accessed 12 November 2024).

[76] P Jurcys, 'Who Owns AI-Generated Output? — Insights from "Crafting the Future: AI, Creativity & Rights" Workshop' (Medium, 31 October 2024), Available at https://medium.com/@pjurcys/who-owns-ai-generated-output-a4eb310fc643 (accessed 18 November 2024).

[77] See eg H Härkönen, 'The Impact of Artificial Intelligence on the Fashion Sector: A Moral Rights' Perspective' forthcoming in E Rosati and I Calboli (eds) *The Handbook of Fashion Law* (OUP 2025), Available at https://papers.ssrn.com/sol3/papers.cfm?abstract_id=4573087 (accessed 12 November 2024).

[78] See eg E Rosait, 'Infringing AI: Liability for AI-generated Outputs under International, EU, and UK copyright law' (2024) *Eur J Risk Reg* 1; P Jurcys (n 80).

[79] See e.g., M Lemley, 'How Generative AI Turns Copyright Upside Down' (2024) 25 *Colum Sci & Tech L Rev* 190. This discussion is not new, see P Samuelson, 'Allocating Ownership Rights in Computer-Generated Works' (1985) 47 U Pitt L Rev 1185.

[80] K Ross, 'Artificial Intelligence in Fashion Manufacturing: From Factory Operation to Advisory Role' in Y-A Lee (ed) *Leading Edge Technologies in Fashion Innovation: Product Design and Development Process from Materials to End Products to Consumers* (Springer Switzerland 2022) 95–116.

[81] CA Hardy, 'Fast Secrets: Trade Secrets in Fashion' forthcoming in E Rosati and I Calboli (eds) *The Handbook of Fashion Law* (OUP 2025), Available at https://papers.ssrn.com/sol3/papers.cfm?abstract_id=4636520 (accessed 12 November 2024).

[82] 'Genera Labs' Available at https://www.generalabs.app/ (accessed 27 September 2024).

[83] 'The Fabricant' Available at https://www.thefabricant.com/collection/deep (accessed 27 September 2024).

from London to a factory in Portugal. Even during this early prototyping stage, the process may involve several iterations, with the factory sending the prototype back to the designer multiple times. From the designer's perspective, a key concern emerges: who has access to this digital file? Who can see this prototype? Without adequate protection, these early-stage designs are vulnerable, particularly in an industry where competition is fierce. Protecting creative ideas at such a formative stage is not merely important—it is essential to safeguarding the IP that underpins the designer's work.

Many smart factories have already integrated data-driven and AI-powered tools to streamline production. For instance, the UK factory Fashion Enter[84] has partnered with Style3D, a platform that combines advanced AI and simulation technology for designers and enterprises alike.[85] Yet, these technological advancements bring their own set of challenges. Designers increasingly worry about the security of their creative concepts during the digital design phase. As digital designs are shared across multiple platforms, concerns about IP protection emerge long before physical samples are produced. The risk of unauthorized access or misuse of design data is significant, highlighting the urgent need for stronger safeguards as the fashion industry embraces more tech-driven processes.

From the legal perspective, the issues surrounding ownership, collaboration and sharing work with those outside of one's brand or design studio are becoming increasingly complex. Designers face a tangled web of contracts when working with factories, many of which are overly complicated and unnecessary. This is especially true when production involves multiple countries, making the process even more challenging. One potential solution is the adoption of smart contracts, which could simplify and streamline these interactions.

As it stands, there is a noticeable lack of standardization across the fashion industry.[86] Each interaction between designers, factories and other participants tends to be unique, which often leads to delays, friction and frustration. The absence of uniformity not only slows down the process but also creates opportunities for misunderstandings and inefficiencies. To address these challenges, smarter technologies—like data-driven automation, standardization and smart contracts—offer a way forward. These tools could help create more predictable, efficient workflows, reducing friction and paving the way for smoother international collaboration. As a policy recommendation, focusing on the integration of these technologies could be a critical step toward overcoming the current hurdles in the fashion supply chain.

4.3. Logistics, packaging, retail and surplus management

Although logistics may seem like an unexciting stage in the fashion value chain, the fundamental—and fascinating—issue in the fashion industry is how to effectively connect the dots between the various actors in a global network. Currently, participants in the fashion value chain suffer from significant disconnects and a troubling lack of transparency. In many cases, actors within the fashion supply chain simply do not know where materials originate. For example, factories often have no knowledge of where their cotton comes from—did they purchase it through a middleman? This uncertainty raises pressing questions about the intermediaries in fashion and how they extract fees for various services. Ultimately, factories are unaware of the true sources of their cotton and fabrics.

From a legal standpoint, implementing better systems to enhance transparency is essential, regardless of whether they involve blockchain technology. More specifically, blockchain technology could help increase transparency and traceability in both logistics and packaging, which is essential for sustainability and meeting regulatory requirements. Such improvements would not only shed light on the supply chain but also address the broader challenges of accountability and ethical sourcing within the industry.

When it comes to packaging, retail and surplus management, a few considerations become paramount: greener packaging, sustainability interoperability and interconnected systems. Brands work on a global scale even if they are emerging designers or early stage, demonstrating that interconnected systems are integral to success. To support growth, brands must ensure that their inventory management systems are effective and accurate to enhance their retail services and offer to the consumer. A lack of proper technological coordination can lead to inefficiencies and frustrations, highlighting a significant gap in operational effectiveness that exists now even within high-end retail environments.

The situation becomes even more complex when multiple players across the fashion value chain must coordinate. In these multi-player scenarios, the need for greater interoperability between software programs becomes critical. Add to those local factors—such as environmental conditions or seasonal shifts in consumer behaviour—and the challenge intensifies. This is where big data and predictive technologies come into play. Big data analytics can reveal nuanced market trends across different regions, helping companies make informed decisions. Predictive tools can be particularly valuable in managing surplus, allowing businesses to localize deliveries based on anticipated demand. For example, summer clothing in San Francisco might be stocked differently than in other regions, thanks to predictive technologies that align supply with local conditions and consumer behaviour. By leveraging these tools, the fashion industry can improve efficiency, reduce waste and better meet localized demand.

5. Paths forward?

This paper has highlighted the increasing complexity and multidimensional nature of the fashion value chain, particularly as it intersects with global supply chain regulations and AI regulation. Our observations emphasize the need to move beyond simplistic notions of networks, recognizing that the fashion industry functions as an interconnected web of stakeholders, regulatory bodies and evolving technologies and processes. These overlapping networks complicate compliance and create unique challenges for both large fashion brands but especially emerging designers.

As such, the concept of 'network' as it pertains to the fashion value chain is more intricate than traditionally understood. There are multiple layers of networks at play, from stakeholders and regulators to AI-powered technology-driven ecosystems. These networks operate in an interdependent manner, with each entity's success often relying on the contributions of others. Yet, current regulatory frameworks fail to adequately address this complexity, treating fashion brands as isolated entities rather than recognizing the interconnectedness that defines *Fashion 4.0*. This necessitates a rethinking of how regulation should approach such multidimensional relationships, potentially introducing a new concept that captures the dynamic interactions within the value chain.

[84] See Available at https://www.fashioncapital.co.uk/tag/ai-tools/ (accessed 27 September 2024).

[85] 'Linctex' Available at https://www.linctex.com/ (accessed 27 September 2024).

[86] S Black et al., *Accelerating Sustainability in Fashion, Clothing and Textiles* (Taylor and Francis, London, 2024) 56.

One of the critical takeaways from this paper is the need for a more integrated, systemic approach to compliance. By leveraging the principles of *Fashion 4.0*—through smart products, smart factories and smart networks—brands can reduce inefficiencies and distribute compliance burdens more equitably across the value chain. Current regulations often place undue pressure on individual brands, particularly smaller entities, to manage compliance independently. However, the adoption of AI technologies offers a way to redistribute these responsibilities and manage regulatory demands more effectively.

This raises critical questions about how AI regulation and other regulatory schemes interact and how these areas can be harmonized to foster greater creativity. More abstractly, such a discussion raises difficult questions about the role, limits and future of law and regulation in fostering innovative, sustainable and socially responsible business models in the fashion sector.

For this vision to become a reality, however, the regulatory landscape must evolve alongside technological advancements. Emerging designers and small businesses, in particular, require support in navigating these challenges if they are to thrive in this new environment. By embracing AI and other digital tools, the fashion industry has the potential not only to meet its compliance obligations but also to foster a more creative, sustainable and inclusive future.

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