

VTO: An Innovative Approach to Sustainable Supply Chains

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Abstract- Today the fashion industry faces a serious sustainability problem regarding the excessive consumption, frequent fast fashion cycles and the use of resources in manufacturing processes, as well as the large amount of textile waste. One of the major causes of this environmental impact is the high volume of product returns from ecommerce, the use of physical inventory and reverse logistics. This abstract discusses the development of Virtual Try-On (VTO) technology as a transformative and innovative solution to an optimized sustainable supply chain in the retail and apparel industry. VTO systems use Augmented Reality (AR) and 3D body scanning to help consumers accurately test fit, drape and shape of garments before buying, on a virtual mannequin. A supply chain point of view, VTO creates sustainability by separating out value from material throughput and dematerializing the traditional retail process. Most importantly, the addition of VTO technologies directly tackles the environmental impacts of online shopping, with the product return rate on average reduced by 20% to 30% and in some cases as much as 64%, aiming to increase fit accuracy and decrease overbuying. VTO's immersive digital technologies also have an impact on minimizing waste beyond the point of sale by helping to reduce the need for physical prototypes in the industry and decreasing unsold inventory. VTO creates a systemic tool for sustainable consumption and production, and not only a marketing gadget, by making physical and virtual operations converge. In conclusion, VTO technologies contribute to a more sustainable, personalized, and efficient fashion industry by drastically cutting down on the carbon footprint, physical transportation, and waste of materials that are traditionally part of today's supply chain.

Keywords: Sustainability, Fashion, Returns, Simulation, Retail, Immersive, Customization, Innovation, Dematerialization

I. INTRODUCTION

Today, the fashion system is facing a global crisis of unprecedented proportions, with fast cycles of consumption, overproduction, and significant

consumption of resources (Cunha, 2025). The traditional supply chains, together with the huge rise in e-commerce, have intensified the environmental impacts of their operation, mainly because of the number of product returns caused by fit issues and the lack of correct product visualization (Vitola, 2024).

Fashion supply chains contribute to massive carbon emissions and produce millions of tons of textile waste every year, thus it is imperative to implement transformative strategies such as incorporating innovative technologies to achieve the best sustainable supply chain management (SSCM) and to enable responsible consumption and production (Ahmed et al., 2024; Cunha, 2025).

Two groundbreaking technologies have come to the fore to address these systemic inefficiencies: Virtual Try-On (VTO) and digital 3D body scanning technologies (Botasheva, 2026). To give consumers a realistic and highly personalised experience, VTO uses Augmented Reality (AR), Virtual Reality (VR) and sophisticated 3D simulation software to let them make a virtual assessment of fit, drape and silhouette of clothes before purchasing them (Botasheva, 2026; Harjati, Masnita, & Kurniawati, 2025).

VTO is not just an experimental consumer engagement or market mechanism but a vital facilitator of sustainability, connecting the dots between digital visualisation and physical production (Mesjar, Cross, Jiang, & Steed, 2023). One of the main reasons for VTO's environmental impact is its capacity to significantly cut down the rate of e-commerce returns (Vitola, 2024). The history of online clothing shopping is marked by high return rates, a significant factor in the carbon footprint of reverse logistics, packaging waste and the way unsold clothing is disposed of (Vitola, 2024).

VTO systems use precise anthropometric information to generate customer avatars, which reduces the subjectivity of virtual shopping, offering more precise and reliable fit details to the customer (Botasheva, 2026; Lee, 2021). The specific return reduction also serves to directly counteract the environmental impact of physical transport, making VTO a key measure towards dematerialising retail activities and reducing material waste (Vitola, 2024).

In addition, there is a deep optimization of the upstream part of the supply chain (Botasheva, 2026), thanks to the use of VTO and 3D scanning. The virtual fitting lets designers and engineers test clothing fit and form in the digital prototyping phase – before a physical sample is sewn – which decreases the need for multiple physical trial iterations, saving fabric, labor and development time (Botasheva, 2026). This technological evolution also enables the move towards Real-Time Fashion Systems (RTFS) and agile supply chains, which are responsive to individualised consumer demand, in real time (Lee, 2021).

In an RTFS context, clothing can be designed and produced to order, eliminating excess stock, or surplus garments that have to be thrown away (Lee, 2021). In conclusion, the fusion of fashion, immersive digital technology and sustainable supply chain management offers a vital and viable direction for the fashion industry to go in the future (Mesjar et al., 2023). VTO technology enables a more personalized, efficient, and eco-friendly operational model, moving beyond the fast fashion trend towards sustainable consumption and production, which marks digital innovation as a key pillar of the future of the fashion supply chain (Botasheva, 2026; Mesjar et al., 2023).

II. REVIEW OF LITERATURE

The world of fashion is being closely watched as it is becoming increasingly aware of the problem of sustainable supply chain management (SSCM) (Mesjar et al., 2023), which deals with the consequences of the high resource consumption and massive waste that the industry generates.

The literature in recent years emphasizes the fact that technology has not only become a secondary driver of sustainability goals, but also a primary one in manufacturing (Ahmed, Al Bashar, Taher, & Rahman, 2024). Of these innovations, Virtual Consumer Engagement (AR/VR/VTO) stands out as one of the most powerful levers to overcome the digital divide between consumer engagement and sustainable production (Mesjar et al., 2023).

One of the major focuses in the literature is VTO's ability to optimise the operations of the downstream supply chain by reducing e-commerce returns. The product-related risks in online apparel shopping include fit, which inevitably result in a high return rate and the associated carbon foot print of reverse logistics (Liu et al., 2020). According to Vitola (2024), virtual fitting rooms represent a digital innovation strategy to reduce this waste.

Through personalised avatars and AR, VTO offers highly realistic garment visualisation, which helps alleviate consumers' concern regarding fit and enhances purchase intent (Liu et al., 2020). The level of "Technology Informativeness" significantly affects consumer adoption of these technologies. Harjati, Masnita, and Kurniawati (2025) concluded that VTO that clearly communicates a product in terms of specifications, information, and details increases perceived usefulness and fun, which in turn directly impacts purchase uncertainty.

Moreover, the immersive VTO experiences create "self-presence" and self-explorative engagement, enabling consumers to meaningfully engage with brands in virtual environments, thereby reinforcing long-term adoption (Lavoye, Sipilä, Mero, & Tarkiainen, 2023).

Apart from the retail interfaces, literature highlights two factors particularly for driving upstream supply chain dematerialization: VTO and 3D simulation.

Botasheva (2026) states that designers can perform accurate tests on the fit and drape of a garment during the digital prototyping process through digital 3D body scanning and digital fittings. The technological shift eliminates the need for multiple physical trial iterations, thus speeding up the product development

process and significantly saving fabric and manpower (Botasheva, 2026).

In an actual implementation of VR technology in digital prototyping, brands that have successfully used this technology see a decrease in physical samples of more than 65%, which translates to significant savings in materials, chemicals, and energy (Jaroenningwattana, 2025). Immersive environments also enable designers to test out their zero-waste patterns and upcycling concepts before any actual production is undertaken, supporting principles of circular economy strongly (Mesjar et al., 2023).

These 3D systems are also accelerating the shift towards Real-Time Fashion Systems (RTFS) (Lee, 2021). RTFS is using digital customization to shift the fashion supply chain from a speculative mass production to sustainable, on-demand production. In this context, the consumers become 'prosumers' and are involved in the design process so that the garments are only produced when there is direct demand (Lee, 2021).

Also, collaborative strategies are also critical to the success of the technological advances. To fully leverage the operational efficiency that digital innovations bring, cloud-based infrastructures and collaborative partnerships that cross organisational lines are vital, as Ahmed et al. (2024) state.

In conclusion, the existing literature provides a solid foundation of evidence that immersive VTO technologies are not just a passing trend in the marketing world but also serve as integral structural enablers of SSCM, contributing to a more sustainable, efficient and consumer-friendly fashion system (Mesjar et al., 2023).

III. OBJECTIVES

- Dematerialization of the Supply Chain: Explore the role of immersive technologies (VTO, AR, VR) that are changing the industry from physical to digital processes to promote sustainability in the value chain.
- Optimize Design & Production: Discuss the use of 3D body scanning and virtual prototyping to

enhance garment fit, optimise production and significantly reduce material waste.

- Decrease E-Commerce Returns: Review how virtual fitting enhances product visualization, helps minimize consumer doubt on fit and ultimately helps to decrease returns in the online space.
- Enable On-Demand Manufacturing: Discuss the possibilities of VTO and AI in an overhauling Real-Time Fashion Systems (RTFS) to shift the industry from speculative mass to Real-Time Fashion systems.
- Analyze Consumer Adoption: Understand the factors that drive consumer adoption—including informativeness of technology, perceived usefulness, and fun – and what they mean for consumer purchase intent for VTO.

IV. RESEARCH METHODOLOGY

The papers that were based on secondary data were those that had literature review methodologies, and did not have primary experiments or surveys. To put it simply, their strategies are:

Systematic Literature Reviews: Academic databases were searched with specific keywords and inclusion and exclusion criteria were set. This has reduced the number of documents to a small selection for thematic and narrative analysis, in some cases by applying guidelines such as PRISMA.

To also include industry reports, news, and trade articles that fall into the "grey literature" category, some reviews intentionally added secondary literature, which is information created outside of the academic research environment.

Other papers applied Analytical and Integrative Reviews that involved summarizing and combining previous academic research with the current practices in the industry, enabling them to analyze the applications, challenges and real-world impacts of the technologies examined.

V. RECOMMENDATION

For Brands and Retailers: Connect the investments in immersive technology to sustainability metrics like

decreases in return volumes, physical samples etc., and adopt clear and transparent data privacy policies that will help consumers trust your brand.

- Technology Developers: Improve the photorealism and fabric simulation of virtual models, make a push towards interoperability between various models, and integrate sustainability analytics directly into 3D design software.
- For Government and Academic Institutions: Provide subsidies and tax relief to companies to make 3D technologies affordable and enhance the digital skills gap in the fashion industry by updating educational programs.
- For Future Research: Focus on empirical research that measure the actual and long-term environmental impact and outcomes of immersive technologies, quantitatively.

VI. CONCLUSION

The use of Virtual Try-On (VTO), 3D body scanning, and immersive technologies (AR/VR) marks a paradigm change in Sustainable Supply Chain Management (SSCM) in the fashion sector. These technologies have grown up from experimental marketing gadgets to become must-have tools for systemic environmental change.

VTO enables the consumer to accurately visualize the fit of the garment, significantly reducing the high percentage of e-commerce returns and the substantial carbon footprint of reverse logistics. In addition, 3D virtual prototyping eliminates the "upstream" supply chain, drastically cutting the number of physical samples and reducing textile waste.

While VTO and sustainable fashion systems have great transformative potential, there are a number of challenges that must be overcome for the systems to be successful in implementation.

These include technological constraints relating to realistic fabric rendering, consumer hesitation due to data privacy concerns, the cost of adopting the technology and a noticeable gap in digital skills of current workers.

The way to a sustainable, agile and on-demand fashion supply chain needs a collaborative effort from all stakeholders, developers and policy makers.

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