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RESEARCH ARTICLE

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Sustainable value in the fashion industry: A case study of value construction/destruction using digital twins

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Abstract

New technologies—especially the emergence of digital fashion and a growing interest in creating digital twins (DTs)—are expected to alter existing value chains in the fashion industry as DT technology triggers a redesign of value creation processes. This qualitative case study demonstrates how and to what extent the development of DTs in the fashion industry addresses the sustainability needs of various stakeholders in both real-world and virtual-reality settings. The article examines the possibilities, benefits, and challenges of creating sustainable value in two distinct ways: traditionally, through physical processes, and through digital transformation by employing virtual processes via DTs. The main implication for further research is to examine the distribution of value facilitated by DT among heterogeneous stakeholders.

KEYWORDS
digital twin, fashion, sustainability, sustainable value, value creation

1 | INTRODUCTION

The growing significance of immersive technologies, such as augmented reality, virtual reality, and the technologies comprising extended reality, presents challenges to academics, business practitioners, and, most importantly, society (Awan et al., 2021). These technologies may enable the development of new applications that transform various sectors and markets as interconnected humans engage with the world through interactive skills (Nurhas et al., 2022). However, the contribution of these developments to solving pressing contemporary problems (e.g., by reducing carbon emissions and improving working conditions and consumption habits) needs to be carefully monitored and controlled (Hellemans et al., 2022). Bohnsack et al. (2022) p. 601, argue that ours is a "rapidly changing society with myriad consequences for sustainability that need to be better understood." The concept of the extended self (Belk, 1988)—which embraces humans' bodies, ideas, experiences, others, places, and the things to which people are emotionally attached—is relevant in contemporary markets, particularly the fashion industry, in which consumers use key goods (such as garments) to broaden and strengthen their identities and sense of self.

Digital twin (DT) technology is based on the logic of mirroring people's appearances, choices, and characteristics. A DT is a computer-generated representation of a physical entity or system and is perceived as a key enabler of digital transformation (Kritzinger et al., 2018). The DT is represented as a software object or model that encapsulates a distinct physical object, process, organization, person, or other abstraction (Singh et al., 2021). Data from multiple DTs could be combined to create a composite view of a variety of real-world entities and processes, such as a power plant, city, or virtual model of a human. **DTs are a tool fostering sustainable development because this technology enables operational optimization (Carvalho & Rodrigues da Silva, 2021). Designers adopt DT to virtually test their new fashion collection without using raw materials by simulating the use of eco-friendly materials, cutting down on work hours, and only producing physical fashion items when the simulation yields an accurate assessment of a new product. DTs and product design are**

primarily connected in two ways: (I) DTs are virtual representations of physical products that are augmented with real-time feedback data describing design changes. These data enable an understanding of actual behaviors and facilitate necessary adaptations. (II) Testing the virtual items using DTs becomes more affordable and simpler than developing new physical prototypes.

Customers today expect diverse types of value based on advanced customization and personalization as well as near-instant access to products and services that are tailored to their needs. This, combined with the concept of the DT, has resulted in entirely new business models. Furthermore, the increased popularity of digital fashion and a growing awareness of overproduction in the garment industry have introduced an entirely new field of investigation focused on value and value propositions (Upward & Jones, 2016) as well as sustainable value (Evans et al., 2017; Patala et al., 2015). Recent research has considered how a digital platform facilitates knowledge sharing, emotional support, and the (re-) confirmation of opinions and suggestions (Hellemans et al., 2022), employing the platform to enable the transition toward sustainable societies meeting the United Nations' Sustainable Development Goals (Bonina et al., 2021). Complementing that research, this study highlights the operational processes (and their consequences) facilitated by DT technology on a digital platform. Tan and Zhan (2017) and, more recently, Di Maria et al. (2022) p. 622, highlight the need to investigate how "technologies might support deeper interaction and integration within the firm and across different functions, for example, in critical activities, such as the development of new products." Consequently, the research question of this case study asks: How can the creative design process in the fashion industry be supported by DT technology, and what are the contributions to the transition toward **sustainable** production?

Industry 4.0's development of new cutting-edge technologies can help to enhance sustainability by giving new prospects for closing production cycles, maximizing the use of already applied resources, and thereby reducing raw material extraction (Dantas et al., 2021). Reuter (2022) notes that **sustainable** business models are not limited to reuse or recycling but also embrace resource efficiency enabled by loss/waste avoidance and lifelong repair. DT technology promises to reduce the use of physical resources by integrating functions in the creative design process and allowing deeper interactions in collaboration. This study addresses the potential of digital innovation and transformation through extended reality by means of DT technology, aiming to identify how value creation processes focused on meeting various organizational stakeholders' needs are designed or redesigned to be more sustainable. We demonstrate how and to what extent DTs in the fashion industry assist in meeting the sustainability needs of various stakeholders in both real-world and virtual-reality settings.

Recent studies on extended reality technologies and convergent technologies (Wagner & Cozmiuc, 2022) indicate that these are an upcoming and innovative research domain that by now is limited by empirical evidence shedding light on processes and consequences of industrial implementations. Grasping the challenge, this study adds to both theory building and practice—we use a single case study to illustrate a theory-grounded explanation. In the implementation context we examine the various stages of digital versus physical garment creation and value creation. The ethnographic research design builds upon the triangularization of evidence from multiple data sources (i.e., interviews, process results published in virtual environments, company reports and their press releases/webpages). **This article is conceptual in nature. The qualitative data from the interview serves as an illustration and proof-of-concept. The specificity of the DT concept itself is strongly established in the industry in the context of supply chains or forecasting environmental changes (Nativi & Craglia, 2020) based on quantitative data. This study takes the perspective of value enabled by DT technology in the fashion industry. It considers the social context, and also relates to creativity and art. In doing so the mainly technical discussion of DT technology is complemented.** This study contributes to management theory by connecting the concept of sustainable value (SV) to technological advancements, such as DTs, in the process of SV creation, delivery, capture, and destruction. The study's empirical contribution is the identification of an enterprise's real process of establishing and deploying a DT to create a SV proposition, deliver it, and collect some of that value. The research approach (an interview with representatives of the technological start-up) enabled a thorough analysis of the benefits and drawbacks of developing a DT in the industry.

The article comprises two main sections. The first examines the theoretical underpinnings of value creation and sustainability. Because of its multidimensionality, the concept of value is fundamental in areas such as the creative industries, art, and fashion. The second section presents the case study findings to illustrate the practical use of DTs in a fashion company. It is concluded with implications for further research.

2 | RELATED RESEARCH

2.1 | Sustainability and value creation: Categories and complexities

Value can be defined as a human actor's perception that a fundamental need is satisfied; it may be assessed in various ways, including by monetary, utilitarian, psychological physiological, or esthetic criteria (Upward & Jones, 2016). Value has two major components: perceived use value and exchange value (Bowman & Ambrosini, 2002). The former indicates that the value is subjective while the latter describes potential value that is not captured in the existing business model (Reuter, 2022; Yang et al., 2017). A value portfolio is constructed by combining various forms of value along the triple bottom line of economic, social, and environmental dimensions, such as dividends, customer solutions, and decreased environmental impact (Ludeke-Freund et al., 2020). Drawing upon Laszlo (2008), we use two descriptors to outline four scenarios of value creation or destruction: (1) value recipient (shareholders, stakeholders) and (2) value process (value creation, value destruction) (Figure 1).

Value destruction occurs when the user perceives a loss in utility, resulting in a negative consequence (Canhoto & Clear, 2020). Notably, stakeholders may not agree on whether a project's outcome is beneficial or undesirable or even on which criteria should assess it. Recognizing this enables managers to detect possible concerns and implement preventive or remedial measures. Value destruction might also occur if the parties lack necessary resources. In the management

Value destruction for shareholders and stakeholders	Value destruction for shareholders with value creation for stakeholders
When value is destroyed, both shareholders and stakeholders are put in an unfavorable position.	The transfer of value from shareholders to stakeholders places the organization in financial debt to its shareholders. Thus, activities that create stakeholder value while diminishing shareholder value are incompatible with the company's viability.
Value creation for shareholders and stakeholders	**Value creation for shareholders with value destruction for stakeholders**
This is an example of SV creation and a possible source of hidden business value.	By transferring value from stakeholders to shareholders, stakeholders present a potential risk for the company's future, implying that shareholder value built on the backs of stakeholders is more about value transfer than value creation.

FIGURE 1 Value creation and destruction in stakeholders' and shareholders' perspectives (based on Laszlo, 2008)

literature, value destruction is described as service performance that falls short of customer expectations (Järvi et al., 2018).

A holistic view of SV could be proposed that includes economic, social, and environmental value forms (Evans et al., 2017). Clearly, there has been a substantial shift in managers' responsibility to create value for both shareholders and stakeholders through company performance. An enterprise creates sustainable value when it provides value to its owners and stakeholders (Laszlo, 2008). Capturing long-term value requires a special, positive manager's mentality (an implicit collection of thoughts) that has evolved from a "traditional" shareholder-focused strategy to a more open, stakeholder-oriented approach. Sustainability-related innovation has become a pressing subject (Nasiri et al., 2021), requiring an awareness of how sustainability might lead to value creation (Yang et al., 2017; Zulauf & Wagner, 2021). Continuous value creation suggests that economic prosperity should be founded on value creation that contributes to wealth after taking natural capital and society into consideration.

2.1.1 | Toward (more) sustainable value

A significant development in management strategy is linked to sustainability, which should be addressed in terms of economic, social, and environmental considerations. SV may be generated when physical production components (structural resources), such as processes, infrastructure, business models, and goods and services, are linked to notions of sustainability effect and values (cultural resources) (Brennan & Tennant, 2018).

SV creation is defined as the promise of economic, social, and environmental benefits provided by a company's offering (Patala et al., 2015) or stakeholder impacts (Freudenreich et al., 2020). A triprofitable organization could create adequate financial rewards, social benefits, and environmental regeneration as assessed by stakeholders with governance rights (power). When developing an SV proposition, value deterioration, missing (or uncaptured) value, and new value creation opportunities should all be addressed (Bocken et al., 2013).

Finally, SV creation necessitates a dedicated, systems-based, stakeholder-responsive (broader, more inclusive) understanding of value that accounts for collaboration and relational progress. Total value creation measures must account for both stakeholder power relationships and value capture patterns (Yang et al., 2017).

Assigning ideological worth to objects is feasible taking the perspective of sustainable development, but this implies that items are evaluated in an entirely different way which depends on environmental values (Niinimäki, 2015). The fashion industry is being progressively altered because sustainability is emerging as a "megatrend." Sustainable fashion is a component of the long-term fashion movement because it dismantles barriers between the organization and its stakeholders, and emphasizes worker empowerment by providing a choice that facilitates change. It does not embody the fast fashion paradigm (Clark, 2008). As a result, sustainable fashion is becoming more and more popular (Henninger et al., 2016).

2.1.2 | Challenges addressed by sustainable fashion

Fashion is one of the most important cultural and economic industries (Brydges & Pugh, 2021). Supply chains that are detrimental to the environment (Niinimäki et al., 2020) and waste has been created through excessive material consumption. This has contributed to the catastrophic climate change–resource depletion, waste, and pollution (Fletcher, 2022). Notably, the evolving dynamics between the fashion industry and the environment encompass both social advancement and environmental deterioration (Brooks et al., 2017). The future is shaped by both technological advancement and social transformation, including various social realities and a revolutionary restructuring of the relationships between fashion, consumption, technology, and the environment. Because human systems are interdependent with all other systems, a change in the fashion processes has far reaching consequences and is difficult. Human decisions and the manufacture of specific goods, frequently done without much thought for or comprehension of the whole system, have a cumulative, layered, holistic impact on entire systems (Fletcher & Tham, 2019).

The increase in synthetic fiber usage constituted a significant transformation in the interaction between fashion, people, and the environment from the perspective of global environmental change and an unsustainable global clothing business (Brooks et al., 2017). The rise of

fast fashion, a business model based on delivering consumers regular novelty in the form of inexpensive, trend-driven products causes dramatically increased textile production and fashion consumption (Niinimäki et al., 2020). People maintain and use clothing for a shorter period of time as a result of a shorter phase of possession and a faster rate of fashion consumption (Brooks et al., 2017). The price of clothing has fallen dramatically as a result of increased efficiency in fashion production and increased consumer demand (Niinimäki et al., 2020).

The environment is at risk due to the increased consumption of garments. Adopting new materials and business strategies to reduce the effects of garment production and consumption is currently the topic of discussion in fashion communities (Brooks et al., 2017). Sustainable change requires many different ways of information exchange, cooperation, and completely new organizational and governing structures (Fletcher, 2022). The industry must be held responsible for its environmental effects, including water, energy and chemical consumption, CO_2 emissions, and waste creation, from fiber manufacturing to retail. However, minimizing and reducing these effects calls for change, which corporations frequently resist mainly because of economic factors. By reducing waste and avoiding excess production, innovative business models based on proactive design help stabilize the business environment (Niinimäki et al., 2020).

The traditional way the fashion industry uses fabric to make clothes is wasteful and ineffective. DT technology provides an opportunity to overcome obsolete structures and create new ones. New systems are being created for the design, manufacture, and consumption of fashion. These initiatives are not only more environmentally friendly but have also led to some of the most promising new advances in the textile industry in recent years. Although the manufacturer may be content with the total fabric usage from an economic standpoint, there are typically fabric off-cuts left after garments have been cut. This fabric waste even occurs during the design phase (Rissanen, 2013). The forms of pattern components and how they might affect fabric width are not factors in traditional fashion design of a garment. The main goal of traditional pattern cutting is to help bring a fashion idea to life. The majority of waste is produced after the garment has been developed during manufacture. Production frequently occurs in a different geographical location and thus the fashion designer and pattern cutter are typically not aware of the quantity of waste produced (ibidem). The solution proposed in this study is to investigate various fabric options digitally.

A promising technology for the traditional textile industry and smart clothing is DT (Alkhammash et al., 2022). Unified computing environments and digital supply chain management present significantly more efficient movement of resources and information that optimizes the costs and quality of the product. Moreover, this technology allows for the creation of fresh styles and designs that may be tailored to each individual customer's preferences.

2.2 | Digital twins: Impacts and transformations in the fashion industry

Michael Grieves is credited with introducing the DT concept in a draft version of NASA's technological roadmap created with John Vickers in 2010 (Haag & Anderl, 2018; Jones et al., 2020). The term describes a virtual copy or model of any physical entity (physical twin), with both entities interconnected via real-time data exchange (Singh et al., 2021). Digital twin originally described a product, but modern technology allows processes (manufacturing, electricity generation, etc.) to be topics of virtual space reproduction ("twinning") to reap the same benefits (Kritzinger et al., 2018). A DT replicates the physical twin's condition in real time and vice versa, so a DT is an integrated, probabilistic simulation of an item or process(es) that mimics its twin by employing the best physical models, sensor updates, entity history, and other attributes (Shafto et al., 2010). In the physical world, the DT represents a fairly accurate picture of the current state of a process and actions connected to the environment (Rosen et al., 2015). It is considered the virtual equivalent of actual things, with virtual representations and communication capabilities forming smart objects that operate as intelligent nodes in the Internet of Things and in services (Schluse & Rossmann, 2016).

A DT connects physical and digital objects and subjects in a precise, real-time manner (Liu et al., 2021). With the emergence of Industry 4.0, the emphasis has switched to manufacturing and smart goods (Dantas et al., 2021). In this context, DTs can contribute to information continuity throughout the product lifecycle, to the virtual commissioning of (manufacturing) systems, and to decision-support and system-behavior predictions based on computer-aided simulations during product development and subsequent lifecycle phases (Haag & Anderl, 2018). In processes or organizations, DT technology is expected to eliminate silos that operate in isolation within departments and divisions in traditional industrial systems (Singh et al., 2021). Among the industries researching DTs are aerospace (Mandolla et al., 2019), agriculture (Angin et al., 2020), civil engineering (Jiang et al., 2021), and healthcare (Corral-Acero et al., 2020), and the significance of DTs is increasingly recognized in the fashion business. For example, Cheng and Kuzmichev (2019) employed DT to generate "a range of human models" (p. 5) and test men's underwear designs on virtual bodies to achieve the best fit and pressure distribution, testing their results in the factory.

Durão et al. (2021) investigated the role of DTs in enhancing operational decision-making of a fast fashion manufacturer in the context of Industry 4.0. They state that the nimble, flexible decision-making required by fashion firms allow companies to flourish in a high-variability environment of items and demand. Riedelsheimera et al. (2020) proposed a user-centered development of a digital clothing twin (DCT) with the goal of enabling sustainability in a product's mid-life and end-of-life phases. **DT improves several aspects of garment sustainability by providing technical information such as details on the product's history, the materials used, and its resource use and emissions, textile maintenance or repair which in turn results in less energy and detergent use.** Their DCT approach meets the following requirements:

- carries pertinent social and environmental information about a product's lifecycle and makes it always available to all stakeholders
- gives instructions on how to fix and clean the garment

- identifies and suggests end-of-life solutions, such as recycling or resale.

In 2020, the Joint Research Centre of the European Union published its report titled "Destination Earth–Use Case Analysis" (Nativi & Craglia, 2020). It presents cutting-edge research on the needs for the design and production of DT. It also provides an essential technical framework and the first mapping of existing developments in the field of DTs in Europe. However, it omits research on the function of DT in the fashion industry, which means that this study is legitimate and necessary.

We argue that, beyond several benefits to the fashion industry (particularly fast fashion), DT could and should substantially contribute to sustainability in this economic sector. The benefits of increased flexibility and shorter manufacturing times should be complemented by decreased waste, physical prototypes, and transportation of clothing between value-chain entities (Fearne et al., 2012). Thus, we examine the feasibility of employing DTs to achieve better sustainability, particularly in the context of creating SV.

This article demonstrates that DT enhances sustainability, which is supported by the research of other authors. DTs could be utilized as a source of information on environmental, social, and economic issues throughout the fashion life cycle and provide support by minimizing the environmental and social impact of the product. Grain (2021) argues that the goal of 3D digital design systems and tools is to supplement existing methods rather than completely replace them. Less pre-consumer fabric waste in the production phase and faster lead times are two advantages. These technologies also give the opportunity to assess and predict the fit of garments at the pre-manufacturing stage and to make judgments regarding the accuracy of drafted pattern pieces.

Digital technologies, such as body scanning, should be incorporated into design methodologies. Data indicate that body shape is a significant moderating factor in ensuring garment fit, and the information gives merchants a knowledge of female body types that can help them improve their advertising methods (Chrimes et al., 2021). Furthermore, mobile 3D body scanning applications give potential buyers a simple, contactless way to take their own digital measurements at home. Buyers also receive fit recommendations based on their measurements and body shape information, as well as a fit visualization on customized models (Idrees et al., 2021). By improving sales and reducing the expenses and waste associated with online returns, virtual body scanners encourage sustainable retail practices (Mitchell, 2021).

The DT technology is not without flaws and criticisms; it is a continually evolving technology that is expensive both throughout the creation process and once it is put into use. The rapid expansion of the use of digital technology is said to accelerate the depletion of natural resources. It is also claimed that the production and use of digital technologies consumes more resources and energy and generates more waste. Furthermore, digitized manufacturing is said to be more energy intensive, leading to increased electricity demands to support data centers and their supporting network (Chen et al., 2020). One of the top-priority streams for waste management now involves garbage from ICT hardware and devices. According to the calculations, keeping dark data could result in an annual global carbon footprint of 5.26 million tons, 41.65 gigaliters of water and 59.45 square kilometers of land, respectively (Al Kez et al., 2022). Implementing DT technology is expensive; therefore, people who want to use them must have access to resources which are frequently unavailable in underdeveloped nations (Botín-Sanabria et al., 2022). DT is also criticized for limiting and marginalizing relationships and interactions between people (such as in the context of doctor-patient relations). The criticism also addresses the accountability and reliability of the data, and the models built utilizing it (Mittelstadt, 2021).

2.3 | Interaction in the creation and buying processes

Collaboration between fashion designers and tech companies appears to be creating a major new textile trend. A primary motivator for this cooperation may be the rising interest in and significance of sustainability and the environmental effect of fashion (Friedrich, 2021). The contemporary fashion business requires processes combining traditional, physical procedures with digital activities,[1] so DT technologies could provide economic, social, and environmental benefits (Riedelsheimera et al., 2020). We expect that developing DTs in this sector will contribute to meeting the sustainability demands of many stakeholders in both real-world and virtual-reality settings and that DTs would be especially valuable to the following entities working toward fashion sustainability:

a. **Fashion companies and designers**, saving them time and money (resources) by minimizing the resources spent on multiple physical prototypes, thus producing economic value
b. **Fashion buyers (customers)**, who gain access to items perfectly suited to their bodies thanks to DTs and digital personas; customers may also post their outfits on social media without purchasing the real item (creating economic, social, and environmental value)
c. **Fashion subcontractors (materials suppliers and manufacturers)**, for whom DTs would save the time and cost of shipping samples between sites as well as reducing business meetings (the shortened supply chain results in economic and environmental value).

Based on the literature review, we propose a framework (Figure 2) that allows us to address the four SV-based concerns proposed by Ludeke-Freund et al. (2020) and to integrate two perspectives (value-creation processes conducted traditionally and via digital fashion).

The physical-to-virtual and virtual-to-physical twinning processes represent the general logic of mutual relatedness, here understood as two ways (approaches) to facilitating SV creation. The former represents the means by which the physical entity's state is transferred to and realized in the virtual environment (that is, the establishment of virtual parameters to reflect the values of physical ones). The linkage

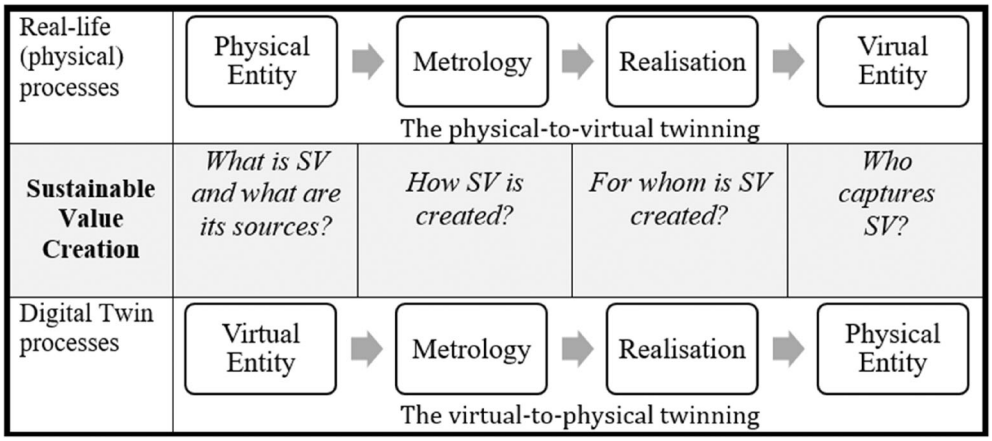

FIGURE 2 Sustainable value creation framework: Real-life and DT-based processes (adapted from Jones et al., 2020, p. 41). DT, digital twin

comprises two phases: metrology (capturing the physical entity's state) and realization (determining the difference between the physical and digital entities and updating the virtual entity accordingly). Virtual processes and metrology methods determine and measure the best possible set of values within a physical entity or environment, and realization methods determine the delta between new values and the existing state, updating the state of the physical entity correspondingly. This derives from Grieves's (2011) definition of the virtual-to-physical connection as the flow of information and processes from the virtual to the physical; that is, the DT provides the possibility of realizing a change in the physical state (Jones et al., 2020).

3 | RESEARCH METHOD AND DATA COLLECTION PROCESS

The research approach was a single-case study. A case study may be theoretically defined as an empirical investigation that addresses *How?* and *Why?* questions about the examined phenomenon (Yin, 2002). This research approach improves understanding of the dynamics in a specific environment (Eisenhardt, 1989). In case studies, common data collection methods include archives, interviews, questionnaires, and observations. Case studies may accomplish a range of objectives, such as giving descriptions and creating and testing theories. **It is argued that, while quantitative research only discusses the statistical significance of the findings (not their practical application), qualitative research carefully evaluates the quality and theoretical status of each datum (Krippendorff, 2009). The qualitative approach can be useful in preliminary research to discover new relationships, as well as in impressionistic procedures for making observations about content characteristics.**

The review and exploratory nature of the study necessitated the use of widely accessible internet materials to discuss the selected example. The first step—desk research—took place in December 2021 and January 2022. We examined the websites of technology companies involved in DT implementation, giving special consideration to companies that create DTs in the fashion industry. We selected one of the pioneering clothing firm that created their whole collection of popular products (puffer jackets) using DT, and later presented the collection to wider audience during one of the prestigious fashion shows, that is, Milan Fashion Week. We conducted a comprehensive, exploratory case study on it, illustrating the work pathway of two entities (a new technology company and a company from the traditional industry, fashion) in developing a DT. The ample information on the websites related to this project provided another motivator for selecting this case.

We demonstrate how a DT could help a fashion company establish a (more) SV proposition by emphasizing the economic, social, and environmental advantages for the many stakeholders involved. In February 2022, two representatives of the chosen tech company (the Italian tech start-up TwinOne) were questioned about their experience of working on the creation of a DT. This semi-structured interview was the second step of the research. Based on the information acquired in the first stage of the research, the interview questionnaire included seven primary questions. The following concerns were addressed in the questions:

1. *What are your main expectations on the impact of new technologies on the fashion industry?*
2. *What role does the digital twin play now and could play in the fashion industry?*
3. *Will customers place higher value on digital fashion in the next few years?*
4. *What is your experience of using DT while working on the collection? What was the most difficult challenge you faced and what pleasantly surprised you?*
5. *Do you believe that technological change will be the primary driver of fashion sustainability, or do you suspect that other phenomena or changes will have a greater impact?*
6. *Do you agree that the creation of virtual collections and the use of DT would diminish the value of real-life fashion experiences, the specific atmosphere of "traditional" fashion shows, and the creativity of the design process while working in an atelier?*
7. *Will you be using DT again in the near future? For what purpose(s)?*

The case illustrates a phenomenon important to the fashion industry—the creation of DTs—to show the multidimensional

perception of value, the diversity of stakeholders involved in creating value, and the role of technological development in creating more sustainable fashion. Although we are only beginning to investigate the DT concept in the fashion industry and its role in generating economic, social, and environmental value, we already see that the discussion of the chosen case can be conducted in two distinct ways: from the perspective of either physical processes (traditional) or virtual processes (modern) in the value chain.

4 | RESULTS

Secondary sources (the company's website, promotional materials published on the Internet, articles on websites) and an interview with TwinOne representatives were used to acquire the information presented in this section of the paper.

4.1 | Virtual humans: Digital twins for fashion sustainability

TwinOne focuses on providing fashion-related technological solutions, creating hyperrealistic DTs and presenting lifelike 3D graphics in real time. TwinOne also created a software system based on the Unreal Engine that allows users to create high-quality virtual images that can be edited and interacted with in real-time and at their own pace.[2] "We employ our visual technologies, which are based on video games, to provide real-time digital realism" said Mauro Mastronicola, TwinOne founder.

The cooperation between two Italian companies—Bacon Clothing, founded by Andrea Pilato Barrara, and TwinOne—provides an instructive example of adopting the DT concept in the fashion sector. The Bacon Winter Collection 2021 (Bacon, 2021) was developed in collaboration by the two teams, combining creativity, style, digitalization, and economic and environmental sustainability, helped by production intelligence derived from real-time computer graphics technology. The project, named "Bacon's Version," digitized some of Bacon's trademark puffy jackets. Both firms worked remotely on the project, which was entirely conceived and implemented during the COVID-19 pandemic.[3]

The project was driven by Bacon's desire to work toward sustainable innovation and by its mission to develop as an inventive, creative enterprise. This is reflected throughout its manufacturing process, which uses certified fiber made from recycled plastic collected from land and sea. As part of this dedication to sustainability and responsible production, biodegradable labels and water print methods are employed, and the packaging is made entirely of recycled materials.

When it was decided to pursue a fully digitalized, sustainable project in Bacon's Version, the working techniques of Bacon's creative director, Roberto Lonoce, were employed, and he was actively urged to employ more advanced digital tools in the creative (design) process. "The technology developed by TwinOne is an instant creation tool that leverages digital twins and allows (Lonoce) to develop and deliver the collection… It enables the creative director to unleash his imagination at the precise moment when he was thinking and bringing the idea to life," stated TwinOne's founder. This is a revealing example of how the industry is evolving, with intelligent, artificial software and algorithms boosting human capital and design talent.

4.1.1 | Phase 1: From hand-drawn sketches to digital twins

TwinOne focused on human intellectual property in the first stage, collecting Bacon's designer's work in the form of traditional, analog drawings, sketches, photos, and fabric samples. Next, they digitized the prints, patterns, and textiles, creating digital references of them. The objective was to recreate the puffy forms of the jackets as well as the materials' surface. The method was unique in that these elements were either recreated/designed by TwinOne's shader artists or scanned from the original objects.

Shapes digitalization followed, with cuts, curves, proportions, and sizes being digitized, with the purpose of providing higher DT quality. TwinOne used a program called Clo3D to generate paper designs, geometries, and clothing simulations.[4] This resulted in three major down jackets, which were used to create a collection of over 60 virtual stock keeping units (SKUs). To obtain a more accurate representation of diverse material types, two versions of each puffer jacket were developed, described as "soft" (i.e., showing more folds in avatar simulations) and "hard" (giving a firmer impression), complementing a small number of physical prototypes. Bacon's motivation was to expand its value proposition.

Digitizing fabrics was the next step. Bacon provided the fabric samples, which were scanned to create digital duplicates (in AxF format) using Twinbru's solutions.[5] TwinOne used an Unreal Engine shading system, which gave them complete control over the fabrics' properties, colors, patterns, and ornamentation. Daniela Robba, TwinOne's CEO, commented on the DT's impact on the design process: "[A] digital twin allows you to be creative, designing and developing a collection in a fully virtual/digital space that enables virtual fitting too. You can change your initial concept at any time by picking color schemes and textures. When it comes to the delivery of innovative projects, on the other hand, you can perform better with clients. Brands should realize that if 3D is at the heart of their strategy and in each step of the product lifecycle, for all the business functions, they will have a plethora of options."

The final step of the first phase was creating avatars for the virtual models. TwinOne used DAZ3D software (Daz3D, 2021) to create five female avatars and selected a variety of poses. Thus, the DTs of puffer jackets were created.

4.1.2 | Phase 2: Virtual prototyping

The second phase pursued two priorities: the technical optimization of assets (i.e., geometries and scanned materials) and the human-related

goal of enabling instant, endless creativity, defined as the ability to customize (in real time) virtual-to-real garments by mixing, combining, and assembling colors, prints, patterns, and materials (TwinOne, 2021). "Thinking about what we've developed, DT can help people be faster, more efficient, define what they want right away, portray a product in a realistic way, and communicate better with the lab that has to do a physical prototype. We're talking about product intelligence, and the use of a digital twin is a clever technique to speed up a process by improving it," argued Mauro Mastronicola. Bacon's costs, time, and waste were reduced as a result of the virtual prototyping phase, which reduced the use of fabric and physical equipment, which are commonly used in fashion development.

4.1.3 | Phase 3: Virtual content creation and endless replication

CG Technology, which provides solutions to the gaming industry, has enhanced Unreal Engine's tool with real-time products (e.g., private networks, systems, operations, system licensing, hardware, software, and management services). By using TwinOne's virtual shooting technology, Bacon created global, end-to-end communication. The company prepared printed catalogs for its sales campaign, provided visuals, design stills, and video content (both avatars and garments in motion) for marketing purposes, and introduced them on its social media platforms. All the photos in the digital lookbook were first taken on a plain background; TwinOne then created light settings for diverse angles, close-ups, each avatar stance, and other options. Approximately 200 high-resolution photographs were created. Bacon also staged a virtual fashion presentation (Figure 3), showing its collection at Milan Fashion Week in February 2021.

"Because our collaboration with Bacon took place during the COVID-19 pandemic, no one was able to attend the fashion show," noted TwinOne's founder. "It's fantastic to have a digital fashion show to mix things up and capitalize on innovation, because we now have new tools and visions. … You'll still have fantastic fashion shows with fantastic front rows and models, but you'll most likely have a different experience with digital collections."

4.1.4 | Phase 4: Twins in motion

The fashion show was entirely digital, with animated avatars modeling the jackets on the runway in a short iteration of the loop walk-stop-pause-restart. The animations were drawn from the Mixamo[6] library and arranged in Maya Software.[7] One merged animation was used for each jacket simulation. The distance between each vertex was set to 5 mm to achieve a high-quality simulation. Bacon then chose the order of the virtual models. The animations were imported using Unreal Engine 4's (UE4) Alembic format[8]; a different format was used for each jacket/avatar.

Throughout the show, each avatar was given a unique set of dynamic lights to fully present the garment's intricacies. After loading the animation into the engine, a geometry cache was added to the sequencer, creating a single instance with the entire look and setting it on the scene (TwinOne, 2021). On the runway, three distinct rows were created, which the avatars entered at specific times. The same set of camera movements and perspectives was repeated for each avatar, so the best shots could be chosen in post-production. The Movie Render Queue (a UE tool) was used in the final export stage to ensure the highest quality of final photos.

4.2 | Production goals and outcomes from digital twins

"The metaverse and 3D reality turn our preconceptions upside down. Because Gen Z's are digital natives, we'll create and dress avatars. This is a huge playground for the fashion business," argued TwinOne's founder. "Many businesses have digital strategy based on digitized

FIGURE 3 Virtual presentation of the Bacon's version collection. *Source*: TwinOne's website

products, but they require digital twins to reach the next stage of design and development. Another consideration is sustainability, cost-cutting, and waste avoidance. There are a lot more opportunities in the 3D world right now, and you'll definitely see other firms use their digital strategies and digital twins as well." Bacon saved a significant amount of money and time in production, assembly, stitching, and dyeing, and the costs of video and photo shoots, post-production, and logistical services were significantly reduced. Quicker collection design, remote work during COVID-19, and the creation of promotional content represent further benefits. The firm's collaboration and use of TwinOne's pipeline resulted in **a perceived** smaller environmental footprint while achieving maximum production intelligence (Figure 4). In this context, money represents **estimated** economic value, time embraces **appraised** social value through people's engagement (employees, designers, DT creators), and sustainability reflects **expected** environmental value.

TwinOne's pipeline generates high-quality digital content, and the initiative has advanced digital fashion. The use of DTs in conjunction with a high level of human capital yielded a remarkable result (a digital fashion show), showing the potential for future applications. Noticeable savings in resource consumption (time, materials, or environmental impact) could be achieved in the described case of collaboration between a technology company and a clothing company. By introducing DTs, in this project Bacon Clothing saved approximately 2 kg of CO2, 40,000 liters of water, and three trees (by using digital versions rather than paper sketches). "The possibilities of using the DT, which is a sort of a Swiss knife, are endless. Inside the organization, between managers and teams, it's all about the company's digital mindset. You won't be able to face this limitless field of possibilities without it," commented Mauro Mastronicola.

The benefits mentioned by Bacon raise questions regarding additional applications of the DT concept, areas of collaboration with various stakeholders, and the possibility of creating SV. Is the value created in traditional processes of designing and manufacturing clothes (here, jackets) better or worse than in the virtual case with DTs? Is it possible to create value in all three contexts (i.e., economic, environmental, and social)?

4.3 | Enhancing sustainability taking a DT perspective

A DT is a collection of all-digital artifacts assembled throughout product development and connected with all the data generated during product use (Haag & Anderl, 2018). Making DT-based judgments lowers the number of operators in the line, reducing idleness and overall lead time (Durão et al., 2021). This is crucial in fashion, as final designs (garments) result from several redesigns, fits, and fabric and cut choices.

Radical visions of the future are necessary to help launch change, because of the moral imperative to act immediately (Black, 2019). Sustainable fashion is a recurring theme, if not a megatrend, that promises to grow exponentially, and sustainable fashion entrepreneurs are essential to the "unmaking of unsustainability" of the fashion industry and can have an impact on the wider fashion industry's shift toward sustainability (Heinze, 2020). One can no longer ignore troubling data on, among other things, the massive overproduction of clothes and their ultimate destination in landfills, the use of difficult-to-recycle materials, and the often uncertain labor conditions of garment workers in fast fashion manufacturing (Niinimäki et al., 2020). These concerns require both changes in customers' behavior (limiting consumption, i.e., excessive purchasing of fast fashion products) and changes in the industry: production on demand, improved production processes to reduce waste, and, in some cases, digitization of the

Money ($) - economic value **Time** (🕒) - human capital (their engagement, social value)
Sustainability (🍃) - environmental value

TRADITIONAL PIPELINE	*Creatives*			TWINONE PIPELINE
	Prototype define shape	$ $ 🕒 🕒 🍃	$ 🕒 🍃 🍃 **DT for Prototyping** define or replicate shape	
	Collection Development develop & test colors, materials, patterns	$ $ $ 🕒 🕒	$ $ 🕒 🍃 🍃 🍃 **DT for collection development** define colors, materials, patterns	
	Sales campaign replicate prototypes, SKU's for sales campaigns	$ $ $ $ 🕒 🕒	$ $ 🕒 🍃 🍃 🍃 **DT for sales campaign** create next generation images, moving or interactive, to present the whole SKU's offer for sales campaigns	
	Marketing contents produce diversified contents for multiple touch points, Face costs, complexity, and timing of a linear, non-scalable and channel based process	$ $ $ 🕒 🕒 🕒 🍃	$ 🕒 🍃 🍃 🍃 **DT for marketing contents** create instantly unlimited contents, for every channel, tanks to one-single, multiple platform process	
	Clients			

FIGURE 4 Traditional pipeline versus digital twin solution (data retrieved from: https://twinone.eu/TWINone/wp-content/uploads/2021/02/bacon-winter-collection-infografica.jpg (accessed: November 28, 2021)

TABLE 1 Creating SV: Traditional and DT perspectives

		Sustainable value (SV) creation				
		What is SV and what are its sources?	**How is SV created?**	**For whom is SV created?**	**Who captures SV?**	**Identified challenge**
Real-life processes	**Creating puffer jackets**	**Using sustainable resources** The firm uses certified fiber made of recycled plastic collected from land and sea.	**Sustainable processes** Sustainable packaging is created by using biodegradable labels and water print methods (recycled materials).	**The company (Bacon)** **Suppliers** **Customers** **The environment** **Society**	**Stakeholders involved** **The company** and its **suppliers** through monetary value and contributions to more environmentally friendly fashion manufacturing **The customer** by purchasing sustainable products **The environment** in terms of cleaner oceans and land (collected and processed plastic) **Society** by living in a cleaner environment	1. (Continued) overuse of materials in the prototyping phase (in conventional, physical design): paper drawings, material samples, actual jacket prototypes 2. In contrast to the postulates regarding the second cycle of clothing, there is still an over-production of new clothing (although it is sustainable).
DT processes		**Creating a virtual equivalent of a jacket** The company's units collaborated with organizations from the multimedia and technology sectors to digitize both the process of making a puffer jacket and the product itself, which was presented (virtually) at a prestigious fashion event.	**Fully digitized processes** Virtual design, prototyping, manufacturing, and product presentation were possible.	**The company (Bacon)** **Technological companies** **The environment** **Society**	**Stakeholders involved** **The company** through savings associated with product virtualization (saving materials, time, and expenses of recruiting models); the possibility of showing garments at Fashion Week without being physically present and without the expenditure of traveling, making prototypes, etc.; the opportunity to select the finest images during a virtual fashion presentation; the reduced likelihood of mishaps; and	1. It is impossible to physically use (wear) a purely virtual product, although it is applicable in virtual environments. Furthermore, how can one produce and deliver physical items in a timely manner if the consumer would like to have them for real-world use? 2. Inability to feel the fabric's texture or even try on the jacket 3. Oversimplification of the creative process in fashion and design (lack of knowledge of material fabrication, avatars instead of human models) 4. Customer value is difficult to measure and specify (value destruction). 5. Existing suppliers (e.g., of materials)

(Continues)

TABLE 1 (Continued)

	Sustainable value (SV) creation				
	What is SV and what are its sources?	How is SV created?	For whom is SV created?	Who captures SV?	Identified challenge
				the ability to operate remotely during the COVID-19 pandemic **The tech company** by its contribution to an interesting project **The environment** through fully digitizing the design, manufacture, and display of jackets, reducing the carbon impact **Society**, as the reduction in produced clothing contributes to the trend of slow, sustainable fashion and responsible, restricted consumption (e.g., unpurchased clothes do not end up in landfills)	are excluded from the process.

Source: Authors' evaluation.

products (Riedelsheimera et al., 2020). **AI algorithms can be used to assess different types of clothing materials and fabrics, predict how well clothing will perform in terms of comfort, help customers have an efficient online shopping experience by enabling virtual garment try-on based on clothing features and customers' measurements, ensure that customers are happy with the fashion design, and assist in sales forecasting** (Alkhammash et al., 2022).

Developing sustainable fashion is crucial from both a utilitarian and a scientific perspective. Discussions in the fashion business about responsibility and ethics are growing louder although these matters still require research, presenting a research challenge. We sought to understand how value creation processes targeted at addressing stakeholder demands could be more sustainably designed, concentrating on how value creation could become more sustainable in terms of process. Two major perspectives were considered in the study (Table 1).

The first perspective, real-life processes, relates to efforts to produce more SV in a clothing company's previously "conventional" activities, here regarded as a shift in a specific logic of action toward greater sustainability. This may be observed in the use of greener, recycled materials in manufacturing operations (e.g., recycled ocean plastic or recycled packaging). Bacon profited from both sustainable resources and changing its operations to be more sustainable, illustrating some of the behavioral patterns of fashion companies. Value was created and captured for various stakeholders, which also corresponded to the presumptions of creating SV, that is, value from an economic perspective (profit for the company and its suppliers), environmental perspective (including more sustainable materials in clothing production), and social perspective (giving customers the opportunity to buy products made of recycled materials).

According to Ludeke-Freund et al. (2020), definitions of SV creation face many problems, including circular arguments, infinite regress,

and dogmatism. Below, the authors offer four key questions as cornerstones of the theoretical debate on SV creation.

4.3.1 | Question 1: What is value, and what are its sources?

Traditionally, a company's resources and capabilities were seen as its primary sources of value, but a number of elements, such as goods, social interactions, and social infrastructures, may be viewed as satisfying stakeholders' desires. Value is generated on various levels by and for diverse entities (persons, groups, organizations, and ecosystems) and may be defined as the sum of all advantages recognized by all parties involved, resulting in value pluralism (value for customers vs. value for various stakeholders) (Upward & Jones, 2016). Furthermore, the main stakeholders' demands and satisfiers must be identified, and both the satisfiers and the capacity to satisfy them should be considered value sources.

Exploiting new technologies is appropriate both in clothing companies' processes (e.g., the production, distribution, promotion, and sale of clothes) and in consumption, addressing customers' quick boredom with products as well as changing the role of clothes themselves (from the utilitarian purpose of covering the body to a manifestation of personality, views, or values, i.e., a "fashion statement"). As a consequence of societal changes, rapid technological growth, and environmental challenges, clothing firms are seeking to enhance their processes and functions, inspiring this examination of the DT perspective (Riedelsheimera et al., 2020).

4.3.2 | Question 2: How is value created?

Value may be assessed from the perspective of a larger, relational paradigm, which enables a greater emphasis on stakeholder relationships and business networks. Since new value is generated through a variety of stakeholder connections and related exchange processes, it is critical to comprehend the many value creation processes and methodologies. Furthermore, the element of value co-creation in a partnership enables acknowledging various stakeholders' roles.

Our case underlines the importance of fitting the value proposition and the means to develop it. Bacon created a virtual garment, digitizing both the process of making a puffer jacket and the product itself, which was presented (virtually) in several forms at a fashion show. Design, prototyping, production, and product presentation were fully digitized.

Bacon saved money through product virtualization (savings on materials, time, and costs associated with finding models) and presented its garments without being physically present, saving the costs of traveling, producing prototypes, and so on. The collaborating companies were able to select the finest photos for promotional purposes, reducing the risk of unforeseen disasters. Furthermore, during the COVID-19 outbreak, virtualization enabled operating remotely, allowing all parties to participate simultaneously. Fully digitizing the jackets' design, manufacture, and display benefitted the environment by shrinking the carbon footprint. The societal benefit was evident in the reduced amount of manufactured apparel, which promotes slow, sustainable fashion and responsible, restricted consumption trends.

4.3.3 | Question 3: For whom is value created?

In comparison to prior strategies, SV creation demands a broader approach, as the requirements of more stakeholders must be identified and satisfied. It is important to know the limits (value recipients) between systems and stakeholder networks; various levels, specialized features, and temporal elements must all be considered. There will be trade-offs and conflicts among value recipients.

The customer—who buys and wears a product while recognizing its benefits—is the obvious and ultimate beneficiary of the value created by fashion designers and companies. Unique design and high-quality craftsmanship are highly regarded elements of the industry's value proposition for a reason, but there is considerable uncertainty about whether value is provided to the customer through developing a virtual product; there is no such uncertainty in the case of a fashion firm, technology company making DTs, or related suppliers. According to Bacon and TwinOne's statement, Bacon saved money on materials while also lowering the CO_2 emissions and water consumption associated with traditional jacket manufacturing. Because there is no way to physically use a virtual product, however, shoppers are hindered from getting a sense of the material's feel and texture and from simply trying on the jacket.

4.3.4 | Question 4: Who captures value?

In examining SV capture, scholars are well-advised to reconsider each stakeholder's perspective must be altered, necessitating the development of alternative total value generation measures. Value capture patterns, or the distribution of value across stakeholders, are influenced by power dynamics, which are closely intertwined with patterns of value capture and thus merit research. The relationships between various stakeholders should be investigated using total value production measures.

In response to the research question, "How can the creative design process in the fashion industry be supported by DT technology, and what are the consequences in contributions to the transition toward **sustainable** production?" we believe that, to make their processes more sustainable, clothing companies can create and capture SV both in traditional, physical garment manufacturing and in DT implementation, for example, through the processes used or even (as in the Bacon example) by full digitization of the product. The examined case of a manufacturer (Bacon) developing a DT with a tech firm (TwinOne) and subsequently using virtual models to exhibit a collection is highly intriguing and demonstrates a number of important shifts in the fashion industry. Companies could produce and capture value for themselves (economic value) and their stakeholders and

society (social value) as well as generate environmental value by leveraging DT. This observation on collaborative value creation and capture complements Belk's (1988) concept of self-extension, which happens through control and mastery of an object, creation of an object, knowledge of an item, and by osmosis resulting from closeness and habituation to an object. As a result, the extended self-functions not only on an individual level but also on a collective one that includes familial, group, subcultural, and national identities.

However, the study revealed that, in the DT case under consideration, the value for the customer changes dramatically, and value destruction may even occur. It should be stressed, however, that Bacon has not stopped making conventional, physical jackets that customers may actually purchase and wear. We argue that value created in a "traditional" manner differs in nature from that created through DTs; it enables different characteristics and components and has different impacts on the stakeholders involved. Yet the two kinds of value (traditional and sustainable one) can be compared but not appraised. DTs are an excellent instrument for advertising a brand in this market—they allowed Bacon to participate in Fashion Week during the COVID-19 pandemic—and one cannot deny the creation of value for the firm, its business partners, society, and the environment (because the product exists only virtually, its creation has little impact on the natural environment). DT emerges here as a tool/technology that enhances garment firms' operations, saving them substantial time, labor, and money, but it does not appear possible to utterly forsake the conventional value provided to consumers by a physical object.

5 | CONCLUSIONS

The perception of a fundamental need being satisfied by a human (or non-human) actor is described as *value*, which may be quantified in various ways, including monetary, utilitarian, psychological, physiological, or esthetic criteria. In the scenario in question, we recognized that creating SV through technological transformation necessitates a shift in managers' perspectives. This supports Laszlo's (2008) claim that long-term value capture demands a distinct, positive managerial mindset that has evolved from a "traditional" shareholder-focused strategy to a more open, stakeholder-oriented approach. As a result, we devised a paradigm that both addresses the four SV-based problems identified by Ludeke-Freund et al. (2020) and combines two perspectives: value-creation processes conducted traditionally and by digital fashion. We illustrated how developing DTs in the fashion industry may contribute to meeting the sustainability demands of diverse stakeholders in both real-world and virtual-reality environments.

Notably, the traditional features of a product, such as design, quality, originality, and visual and practical elements, are and will remain important in the fashion industry. We conclude, however, that DTs represent a very promising concept for the future of fashion and the emergence of digital fashion. Fashion companies can evolve their business model to become tri-profitable organizations by addressing criticism from a variety of social groups as well as customers. Controversy about the industry's negative environmental impact and unethical treatment of workers has prompted it to adopt to greater sustainability, resulting in the creation of more SV. Given the concept's assumptions, its economic value is just as significant as its social and environmental values.

This research, undertaken as a case study with the Bacon company in two dimensions (i.e., in its real-life and digital-twin activities), enabled us to describe the nature of SV, where it emerges, what actions are taken in its development, to whom it is provided, and the important players in its capture. Bacon's managers tackled the challenge with a positive mentality (Fearne et al., 2012). Nevertheless, we identified particular difficulties. In conventional, physical design processes, there is an unnecessary use of materials during the prototyping phase (paper drawings, material samples, physical jacket prototypes). Furthermore, the overproduction of new clothing items (despite their being sustainable) thwarts the advantages of the second clothing lifecycle. Also, it was not possible to identify any method to physically use an item that exists only digitally beyond presenting it online on social media platforms. Based on our analysis of the case study, we conclude that DT technology has so far benefited shareholders (Bacon, TwinOne) more than stakeholders (for example, only three trees were saved by digitizing the design process).

The research demonstrated the advantages of the fashion and design creative process in the DT dimension (the lack of the experience of material textures; employing avatars instead of human models), and the virtual models developed for virtual fashion shows answer Cheng and Kuzmichev's (2019) call to use DT to develop "a variety of human models." However, consumer value is difficult to establish and quantify (we see this as the value destruction). Established suppliers (e.g., of materials and additives) are likewise unable to participate in the creative process.

The case study discussed is one pioneering example utilizing DT to create value for a variety of stakeholders in the fashion industry. The study provides a documentation in one of the first attempts to implement DT technology in the transition toward a sustainable fashion businesses. It was impossible to investigate all research topics. **Thus, it is worth mentioning other interesting problems that have not been addressed in this study, which can be explored through quantitative data. Future studies can explore (1) how the DT process resulted in a smaller environmental footprint, (2) accurately measured how much material, water, and dye treatments were saved, and (3) how it compares to the additional carbon footprint associated with digital technologies in general, such as energy to run equipment, cloud storage, and so forth.** Other important and interesting research challenges meriting further exploration include:

1. *Research on the benefits of and barriers to creating, delivering, and capturing SV*. The main focus for further research is examining the distribution of the value facilitated by DT among heterogeneous stakeholders. The research described in this paper involved a single example of collaboration between two companies implementing a prototype project employing DT. As a result, it captures only a fragment of reality, thus meriting in-depth research on similar projects in the fashion industry, with a particular emphasis on clothing

manufacturers of diverse sizes and scales (from start-ups to well-known companies), specific economic conditions in the countries where the companies operate, and the benefits seen by clothing companies related to the creation of DTs. There is also a need to develop a generic roadmap of actions and activities connected to the creation and implementation of DTs (Hribernik et al., 2021), which could serve as a starting point for apparel firms making important decisions about using DTs. Such a roadmap would outline the processes, iterations, and activities involved in developing and implementing DTs across the company.

2. *The heterogeneity of SV itself in the economic, environmental, and social dimensions*. The social perspective should certainly be examined more broadly, for example, in the context of the relevance of DT for people with disabilities (e.g., in facilitating clothing purchases) or the integration of processes done physically by people (e.g., clothing design, material and fabric selection, creating prototypes of clothes, hand sewing) and their DT counterparts. A more general matter for study is the function of technology in fashion in the 21st century; what is and will be a human's position in the industry? Will DTs take the positions of creative directors and fashion designers, and will garments be presented on "virtual humans" or avatars rather than models?
3. *The evolution of the DT function in fashion firms producing sustainable and/or virtual garment collections*. It is likely that the DT will become the new industry standard. Perhaps, as with sustainability, recognizing the significance of new technologies and the creation and development of DTs represents a new success factor in the fashion industry.
4. *The perception of virtual products (virtual fashion, virtual garments) and their use, investigated from the perspective of diverse customer groups*. This element of virtual fashion trends is highly interesting, especially considering Belk's (1988, p. 160) statement that "our accumulation of possessions provides a sense of the past and tells us who we are, where we have come from, and perhaps where we are going."

In this paper, sustainability is reduced to efficiency (economic and environmental value)–while social sustainability is neglected in the DT discussion and this constitutes an important limitation of the study. Without a doubt, the questions discussed in the paper are merely a subset of a much wider research area concerned with balancing technological progress and sustainability in traditional sectors, including the fashion industry. This establishes the potential for future research not only in the field of management sciences but also by scientists in other disciplines.

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ENDNOTES

[1] The importance of social media and fashion companies' collaboration with influencers (who can be considered opinion leaders) in creating value in the fashion industry cannot be overestimated (Casaló et al., 2020, 2021).

[2] Unreal Engine is an advanced, real-time 3D creation tool for photorealistic visuals and immersive experiences (Unreal Engine, 2021).

[3] A change to online activities was quickly implemented as luxury fashion brands streamed fashion shows on the internet in 2020 because of the global pandemic (Black, 2020). It was far more difficult to change new paradigms, new ways of both making and consuming fashion, and revaluing an often disparaged but economically and culturally significant fashion sector as a result of COVID-19.

[4] Clo3D is a 3D fashion design software (for garment visualization, etc.) (Clo3D, 2021).

[5] AxF is a standardized format for exchanging material appearance data. An AxF file is created with an authoring suite that includes real-world material measurements from which it generates various textures and model properties (Unity, 2021).

[6] Mixamo is a 3D computer graphics company that offers web-based services for 3D character animation (Mixamo, 2021).

[7] Maya is Autodesk's 3D computer graphics app used in creating assets for interactive 3D applications, films, and visual effects (Autodesk, 2021).

[8] Alembic is an open computer graphics interchange framework (Alembic, 2021).

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