



**CONNECTIVITY**  
and **CREATIVITY**  
in times of **CONFLICT**

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**Preface**

Connectivity and Creativity in times of Conflict - conference proceedings VI  
 Cumulus president's message - Design for Adaptation in Times of Complexity IX

**Track 1**

**Nature positive/design for transformation**

**Editorial** 2  
**Design methodology**  
 Scenario-building through a systemic lens: a new perspective on tools and methods to design for sustainability transitions 4  
 Intimacy/integrity: a framework for thinking about epistemological styles in design activity 9  
 Democratizing design: the development of a 'Design for Do-It-Yourself' framework 15  
 The power of imagination: immersive and experiential counterfactuals to engage with sustainability 20  
 Applying human-centered system design to the development of a tool for service innovation 25  
 Pulse approach: integral design project management to empower transformative processes 30  
 Research on design sketch from different disciplines: overview and directions 35  
 Researching the invisible: troubling qualitative research design through information architecture 41

**Design education**

T+ designers: a case for transdisciplinarity in design higher education by way of a South African case study 46  
 Materiality, commons, and design education 51  
 Representing and shaping regenerative futures: a context-specific approach to art and design education. 58  
 Creative strategies for the learning spaces of the future 62  
 Implementing SDGs in a product design curriculum, or: the value of tap water 67

**Design materialization**

Yutaka: how do we prototype the transformative change towards nature positive designs with soil 72  
 Material experience: the future of material selection for product design 77  
 Discerning modes of design in ecological restoration 82  
 From visual to multisensory: how does intangible cultural heritage of traditional costume self-remodel in digital interactive environment? 87  
 Designing sustainable furniture: guidelines to promote furniture life cycle design 94

**Biophilic approaches in design**

Biophilic design for remote studying environments: analysis of case studies involving a collaboration between ergonomics and environmental psychology 98

Bioreceptive interfaces for biophilic urban resilience 103  
 Artificial nature: possibilities for mycelial composite material design 109  
 Botanical design: exploring the application of parametric plants in furniture 113

**Eco-social transitions**

Systemic Design Oriented Leadership (SDOL) – a co-created play for eco-social leadership development with the methods of Systems Thinking 118  
 Design for transformation: unlock competencies for coping complexity 122  
 Change agents: designers interpreting 'the social' and 'social' interpretations of design 127  
 The changing role of designers in transition processes 132

**Fashion innovations**

Fashion design matter: the role of design in guiding a sustainable transformation in Europe 137  
 Convincing fashion consumers to go green: a brand communication problem? 142  
 Prototype dialogues; re-balancing design thinking through negotiations with fabrics, form and future 148  
 Future fashion: new and ancient systems at the intersection of anthropology, ecology and innovation. 152

**Urban design & citizen inclusion**

Design fiction localised 158  
 Transit Oriented Development used to formulate design guidelines for an improved bus network in Malaysia 163  
 Exploring sustainable ecosystems in the "15-minute" urban living circle—take Shanghai Urban Space Season 2021 as an example 169  
 The Unified Citizen Engagement Approach: a design-oriented framework for involving citizens in the energy transition 174

**Design & digitisation**

Designing for Viral Infection Awareness through PLAYMUTATION 179  
 Gamifying the low impact customer solution design 183  
 Connecting to the future; using serious games and scenario development for responsible design 189  
 About utopias, apocalypses, respawning and zombies and how understanding images of space and time may inform design for sustainable behaviour 194

**Track 2**

**Digital futures/hybrid reality**

**Editorial** 200  
**New crafts and craftspeople**  
 Fashion Craftsmanship 4.0. Learning experience about Industry 4.0 technologies for hybrid digital fashion-tech products, processes, and business model design 202  
 Crafting hybrid workflows for the design of augmented textile artefacts 210

Distance: digital immersive technologies and craft engagement	214	Fantastical reality: designing virtual urban space through extended reality	333
Notions of hybrid craft production: conversations and small-scale experiments in digital fabrication	219	The Metapolis – cities between a ripple and a blur	338
<b>Research through design in the cyber-physical era</b>		Towards data activation and engagement within a smart city	345
Digital synesthesia in product design. Building a vocabulary of physical interactions for a sensible quantified self	223	<b>Technology driven design education</b>	
Digital content that offers experience of listening to crystallized music	228	Teaching design of technologies for collaborative interaction - an emerging pedagogical framework	349
The body can not be thought: the 'disabled body' as a catalyst to develop new paradigms for human-computer integration.	232	A mixed-method approach: virtual reality to co-create future higher education workspaces in a post COVID-19 academic environment	357
Metaphysical Instruments: prototypes for hybrid and live music-making	236	An attempt to integrate AI-based techniques into first year design representation course	363
<b>Redefining the role of design(ers)</b>		<b>Digital fashion</b>	
Virtual skin: co-creating 3D materials with synesthetic artificial intelligence	241	The emperor is naked: deconstructed materiality in fashion NFTs	368
Cabinets of curiosities for the postcolony II: tokens: collections I-V	245	Dematerializing fashion- improving design-led sustainable and hybrid retail experiences via digital twins	372
Speculating futures in an age of nostalgia	250	Fashion archive as a meta medium: unfolding design knowledge through media technologies	379
Computational thinking in design and fabrication for augmented and accessible museums.	254	Fashion and the metaverse: from omni-channel to direct-to-avatar	384
<b>Usability and performance of innovations</b>		<b>Track 3</b>	
Usability and UX evaluation of an online interactive virtual learning environment: a case study of Wales' Virtual Hospital	260	<b>Handle with care/inclusivity</b>	389
Design perspectives for the future of work in Industry 5.0 environment: the digital and physical space in Augmented Reality uses	266	<b>Editorial</b>	390
Assessing the impact of immersive versus desktop virtual reality shopping experiences in the fashion industry metaverse	271	<b>Design for/as communication</b>	
A pilot study with the Shaper Origin to determine the learning curve of augmented fabrication	276	Encouraging humanitarian assistance in conflict zones through animated public service announcements	392
<b>Design for and with extended reality</b>		The design of an engaging focus group discussion toolkit involving school-aged children following urotherapy	397
Introducing the material experience concept in the metaverse and in virtual environments	280	Inclusive Transformation of age-friendly communities based on digital technology support	402
Balancing authenticity and creativity: A VR system design for assisting in ceramic creation.	287	Taking care of the elderly through the tools of the animated communication design: a useful and ethical imperative	408
What is the furniture in the Metaverse for?	292	Pee poo period. Exploring the intersection between shame, bodily fluids, and sustainable design	413
<b>Design for and with digital fabrication</b>		<b>Design for diverse users</b>	
Craft in the age of robots	299	Feminist value sensitive design of self-tracking technology based on female body data	419
Light it up: designing electronic textile with a light as a design material	304	Spatial "mutual altruism" as a relationship of care for homeless people. How design impacts social re-integration	425
Strategy for knowledge transfer in AM as a hybrid process chain towards a transition from prototyping to commercialisation	309	I'll be there for you: exploring a sense of belonging to enhance student engagement	429
Speculative tinkering on circular design materials through 3D printing	317	Inclusive design in the context of performative gender through product form	433
Flaws as features, new perspectives for developing an additive manufacturing design language	322	Landing the internship: the role of gender in finding ID internships	438
<b>The digital on urban scale</b>		Object as the tool of recovery - Examining material culture of young refugees in Hungary for trauma processing	443
Designing smart product-service systems for smart cities with 5G technology: the Polaris case study	328	The food delivery industry and its lack of care in gender equality: the speculative case of 'GiGi'	448
		Winning at more than a game! A storytelling board game concept to raise awareness about refugees' language barriers	455

**Care(ful) spaces**

Cities for all: co-design interventions on urban features using inclusive technology	461
Separating Covid from non-covid: spatial adaptations in existing hospital buildings	466
Wayfinding is caring	471
Explore vacant public spaces regeneration to facilitate minor's activities and education under inclusive design principles	475
Human-space relationships as narrative processes for inclusivity	480
Urban darkness: human experience of atmosphere and fear	485
Daily social interactions of hawkers as a catalyst to actuating bottom-up spatial justice: experience from Hong Kong	489
The city of care through walkability and proximity. Researching on and with Generation Alpha on urban walkability assessment	494
Hinges, passages and comfort	499
Renewal of urban ecological transportation network based on inclusivity design — Take Sydney's "Livable Green Network" plan as an example	504
How to take care of the Antwerp modernist social housing of Alfons Francken? And how do this housing blocks take care of its changing population?	510
Inclusive innovation: a study of creative furniture design for urban community public space	515

**Co-creating care(ful) design**

Health, care and prosthetics: co-design methodologies in the case of autofabricantes	519
See the unseen: a co-creation design process for children with incarcerated parents	524
The power of photovoice: AI support provides voicing opportunities for children in sex education	529
Co-design for the common good: a holistic approach to workspace projects	533
Co-designing neighbourhood identities. How to share memories and experiences towards a common sense of belonging	538

**Design(ers) & learning**

Universal design for learning as an inclusive teaching methodology for an African art and culture course in Ghana	544
Material-led thinking as a practice of care: a strategy from art and design education	550
Artful care for self and others in daily design practice	555
Material metaphors: method for physicalising relations and experiences	560

**Design ethos**

A South African approach towards a caring design practice	565
Weighing the tensions of nostalgia, necessity, and care in contemplating the future of the Nigerian design-scape	570
Food as a form of care: designing social innovative processes and practices	575

Designing with posthuman kinship: from posthuman theory to human-non human collaborative design approaches	580
Beyond empathy: how curiosity leads to greater care	585

**Inclusive approaches to intangible cultural heritage**

Convention versus contemporaneity: the affordances of design-led mediation towards sustaining an ancestral cycle of linen making in Castelões, Portugal	590
Combining care for planet, people and culture towards circularity	594
Media art creation process using digitized archetype of Korean traditional dance movement	600
Envisioning design strategies for intangible cultural heritage activation	604

**Sustaining traditional crafts and techniques**

Craft for care, design for life. Heritage contemporary enhancement and communication design tools as a resource for social changes, fostering diversity and inclusion	610
Embroidered heritage: a design-led visual ethnography of traditional Palestinian motifs	615

**Adaptation of the built environment**

Design for Ukraine's heritage: engaging international students during times of war through design activism	619
The technical compatibility of vertical greening with built heritage	624
New design models for proximity retail and senior inclusion	628
Investigating spatial patterns of green infrastructure at built heritage sites in Antwerp, Belgium	632
From architecture to community: adaptive reuse as social practice	636

**Participation and role of communities**

Methodology and evaluation of digital assets reconstruction of cultural heritage with visitor participation in museum	642
Community heritage: an immersive approach to disaster resilience	646
Caring for human diversity and built heritage through design: a multiple case study enquiry	651

**Poster abstracts**

Adding value to the future through design and entrepreneurship: PLACE	657
A video game for emotion regulation of medical students	658
Video game design for ecological impacts	659
Dwell and move, change ensues	660
Transposing timelines	661
Artificial intelligence-aided type design for Chinese script	662
Design and reconstruction of the new interest youth community in china in the post-epidemic era	663
Sound E-scape: an interactive, digital application for music therapy and soundscape generation	664
Development of existing biophilic interior design definition	665

Design-driven approaches to human augmentation. An exploratory study	666	Human augmentation: the role of design in the design of on-body interfaces for cognitive-sensorial wellbeing	718
Designing with people: creating a multi-level interdisciplinary design education environment for more inclusion	667	A conception toward design narratives for innovation	721
Material connotations: meta-structure research of practice based projects with invasive species plant waste	668	Home away from home – The role of design methods in processing trauma of forced migration and loss of place	725
From collecting natural objects to presenting the future anthropocene: exhibition design for the anthropocene theme in museums	669	Decoloniality and healing: confronting inter-generational trauma/ideologies through architectural preservation and education	728
Catacombs: refuge on the border of the virtual and the real	670	The ephemerality of an organic material and its implications: a context specific study with invasive exotic species (Japanese knotweed) waste in Genk, Belgium	731
Hybrid specimens: Phygital artefacts at the intersection of analogue + digital crafts	671	Visual communication bridging intercultural barriers	734
Content management system in mapping movable objects	672	Feeling the future car: designing for driving pleasure in the era of co-driving	737
FlavourGame: interaction design in hybrid games	673	Mediterranean landscapes in emergency: nature and culture	739
Bibliometrics in circular design visual representation	674	Key Performance Indicators for measuring and evaluating users' sensory perceptions and behaviors in learning spaces in higher design education	742
Inclusivity as a hype phenomenon in advertising	675	Textile handcraft making and women creators' psychological well-being: a narrative review	746
Inclusion in recruiting	676	Cross-case analysis on the integration of extended reality (XR) with the design and planning of the built environment	750
Values, design and educational project: contemporary projections	677	Ecosystem services: an interpretive paradigm of urban and territorial heritage. Strategies, guidelines, and vision for sustainable cities	754
Project Hope : the creative revolution mural, a human singularity approach	678	Characteristic analysis of future-oriented design based on cognitive context theory	757
More-than-human ways of thinking through felting wool	679	Digital wellbeing and design	760
"Care strategies to strengthen heritage structures as a community asset during the pandemic: the case of Bahay Nakpil-Bautista"	680	Appropriation and appreciation of Austrian and Indonesian puppetry	763
A novel offloading insole system designed for healthcare	681	Reinventing the gastronomic experience: using interactive digital environments to raise awareness of food-related cultural heritage	766
Towards an embodied expression of pandemic nodes & networks in the age of social distancing	682	Developing cultural heritage sustainability from the perspective of participatory sentimental souvenir design	770
<b>Cumulus Phd network</b>	683	How does design intervention promote sustainable rural transition: an analytical framework based on the multi-level perspective model	774
Evolution of 'Mashrabiya' in the Middle East & North Africa - traditional wood carving technique revival	684	Designing future hybrid creative space using digital tools in educational institutions and organizations	777
Exploring the potential of material innovation to revitalize traditional crafts in Egypt	687		
An overview of design suggestions for contemporary theatrical VR productions	690	<b>Reviewers</b>	781
Polymath interpolation in transdisciplinary open-ended design – design for conservation	693		
Implementation of design culture as a strategic innovation through design-oriented industrial conversion and product diversification	696		
Sustainable transformation of age-friendly community centres based on transition design	700		
Parametric Joinery. Development of a system of configurable joints	704		
Designing a ward inventory for a sustainable healthcare. Framework for healthcare providers of configurations among disposable medical devices, clinical procedures, and medical equipment in the neonatology department.	707		
A safe space of creativity-designing with vulnerable female communities	711		
The direction of wayfinding. From the identification of a place to the expression of its meaning.	715		



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# Track 2

Digital futures/  
hybrid reality

# Dematerializing fashion. Improving design-led sustainable and hybrid retail experiences via digital twins

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## Abstract

Digitization has changed the way individuals build relationships, work, and consume. Such changes have affected the fashion industry in significant ways, revealing a whole series of new practices, not only regarding the design and manufacturing processes but also modifying how products are displayed, distributed, and consumed.

In the age of connectivity and technological innovation, a dematerialized economy is being shaped based on rethought consumption patterns and solutions to reduce energy demand. New concepts come together aiming at the possibility of economic development supported by sustainable social and environmental practices. Regarding this, the fashion industry has relatively recently embraced the dematerialization of fashion products, exploring different paths and opportunities that multiply the possibilities of relationships with the consumer and on the other promotes more sustainable and valuable processes.

Since the outbreak of the covid-19 pandemic, luxury brands and large retailers invested in the incorporation of new technologies, especially regarding the digitization of clothing, where multi-million partnerships between fashion brands and the games industry in the development of skins for electronic games proved to be a promising investment. In addition, for many companies, the adoption of 3D design and computer graphics software for the creation, modelling and prototyping processes represents an optimization in the workflow, increasing productivity, efficiency and reducing the environmental impact. The boundaries between the physical and the digital seem to be progressively being blurred, offering new experiences to users. In these circumstances, the Digital Twins technology, already adopted by other industries, is now starting to find its place in the fashion system, showing a potentially disruptive impact on traditional retail and communication channels that pass from omnichannel to phygital up to a new hybrid reality.

Considering the range of applications and usability opened by the digitalization of fashion, the emergence of new technologies (AI, VR, MX, Digital Twins) and the complexity of new challenges and impositions faced by the design field, the present paper aims to define innovative trajectories within the fashion retail sector, impacting both business models (in order

to make it more sustainable and valuable) and consumer experiences. In addition, this paper intends to discuss how design could contribute to creating new sustainable experiences, supporting the transition between physical and digital spaces, as well as adapting operational practices to make the phygital process positive and viable.

## Author keywords

Fashion Dematerialization; Retail; Digital Twins; User Experience; Design for Sustainability.

## Introduction

The entrance of new players - mostly from Information and Communications Technology areas - into the fashion competitive landscapes, the pandemic crisis that has further required a quick digital transformation (Bertola, 2021), and the emergence of contemporary technologies, such as metaverse, 3D printing, the Internet of Things, VR, AR, AI and Digital Twins, made the fashion industry recognize the importance of integrating digital fashion into its operation portfolio (Baek et al., 2022). Such digitalization process relates to the concept of dematerialization of fashion, which allows the unfolding of new trends into the contemporary design scene, aimed at the development of digital products using advanced technologies (Azambuja et al., 2021). Even if recent, the process of digitalization of fashion may expand the field of action of fashion design by bringing new ways of relating to fashion processes itself, beyond the challenge of bringing together the physical and digital worlds (Giuriatti & Pinheiro, 2022). Furthermore, one of the opportunities created by the digitalization of fashion regards the dematerialization of the supply chain, capable of "improve resource efficiency and compressing, eliminating, and shortening various business activities, as well as reorganizing the operating model toward a more collaborative approach in different stages of the process" (Casciani et al., p.790, 2022).

Within this context, this paper presents a conceptual framework (regarding the impact of advanced technologies on fashion consumer experience and how Digital Twins are reshaping the fashion value chain), followed by an interpretative framework, composed by three different operation models (Digital Twin-empowered hyper-real visual campaigns; Digital





Twin-empowered tailored and sustainable buying and retail dynamics and Digital Twin-empowered phygital and immersive retail experiences), intending to investigate the impacts of Digital Twins technology within the fashion value chain, focusing on distribution and communication processes.

## Conceptual framework

### The impact of advanced technologies on fashion consumer experience

Since the Covid-19 pandemic outbreak, the global fashion industry faces exceptionally challenging conditions, and due to the various restrictions imposed - mainly during 2020 and 2021 - digitalization processes have been accelerated. However, to date, few brands or retailers have embraced technology with a truly competitive mindset to fuel positive and valuable innovations (Bertola, 2021). Now, fashion and technology work together to enable companies to expand into new markets, win deeper levels of customer loyalty, and establish data driven strategies and decision making (Bof & McKinsey, 2022).

Emerging technologies such as blockchain and non-fungible tokens (NFTs) along with impactful technologies such as Digital Twins (DT), artificial intelligence (AI), machine learning (ML), and virtual reality (VR) (Joy et al., 2022), are placing the fashion industry under a historic transformation, entering the new global competition market by augmenting those phases in which design, creativity, sustainability, and technological transformation are the principal axes while simultaneously re-inventing its business models (Iannilli & Linfante, 2022).

Besides the high investments from fashion brands into the Metaverse (Burberry - B Bounce Game, 2019; Gucci - Tennis Clash game, 2020; Balenciaga -Fortnite game, 2021; Ralph Lauren - Zapeto, 2021; Zara - Lime Glam Meta collection, 2022; Adidas - Digital Ozworld Experience, 2022), the use of other technologies are also arising, such as IoT (Burberry, 2012; LDN Adidas, 2019); Mixed Reality (Hipanda, 2019; Lego & Snapchat, 2019; Gucci, 2022); AI (Chanel+Farfetch, 2019; Burberry, 2018) and Digital Twins (Yooxmirror, 2018; Bacon's version, 2021). Apart from increasing process efficiency and quality in the production process, reduce costs and improve logistics, these technologies can strategically create a unique relationship with consumers, especially those belonging to generation Z. In fact, such technological commitment coming from fashion companies is somehow directly linked to the demands of this new generation of consumers, which will define the future of consumption with \$4.4 trillion in estimated discretionary spending power (Snap Inc., 2022). In addition to being considered digital natives, along with Millennials, Gen-z generation base their relationships with companies by evaluation how they treat the environment, protect personal data, and position themselves on social and political issues (Deloitte, 2022).

### How Digital Twins are reshaping the fashion value chain

Digital Twins are expected to become a business imperative, covering the entire life cycle of an asset or process, and forming the foundation for connected products and services (Hartmann & Auweraer, 2020). Coined in 2010 by John Vickers of NASA (Hazrathosseini & Afrapoli, 2023) the term "Digital Twin" stands for an encapsulated software object or model that mirrors a unique physical object, process, organi-

zation, person, or other abstraction (Gartner Glossary, 2023), and according to Kamble et al (2022. p.1) "it is a method of developing sustainable, intelligent manufacturing systems for attaining robust quality, reducing time, and customized products using real-time information throughout the product life cycle".

Listed as one of the top 10 strategic technology trends in 2018 and expected to cross the chasm in 2026 to reach \$183 billion in revenue by 2031 (Gartner, 2018/2022), Digital Twins are being explored in multiple fields (Guo & Lv, 2021), where the most successful ones, according to IBM, are those of engineering (systems), automobile manufacturing, aircraft production, railcar design and building construction manufacturing. The fashion field, however, found itself forced to accelerate its digital processes due to the pandemic (BoF & McKinsey, 2020/2021), and now recognizes Digital Twin technology as a possible valuable and sustainable addition into the field.

A first and rather extensive literature review (Nobile et al., 2021; Noris et al., 2021) has shown a growing interest of the scientific community in the topic, which the proliferation of experiences and explorations of leading fashion brands and emerging digital companies has accompanied. In particular, the authors investigated the field of Digital Fashion (within which Digital Twins represent a particular typology with peculiar features and potentialities) according to three categories: Communication & Marketing - also related to the transformation of the Customer Experience in the retail environment; Design & Production; and Culture & Society. Not surprisingly, the area of Communication & Marketing includes the most studies and applications.

Fashion brands have been experimenting the application of Digital Twins from buying campaigns (SUNNEI) and visual campaigns (Puma Flash Retail Film; Chase the light - Timberland; Kendall for the TB Summer Monogram campaign by Burberry) to animated fashion shows (Bacon's Version by Bacon; GCDS Out of this world SS 2021) and retail distribution (I.T Hong Kong x The Fabricant). Within the gaming industry, widely explored by fashion companies over the last few years, the specific use of Digital Twins is still diffident (Ralph Lauren redesign of polo logo for first time in new digital collection with Fortnite; Moncler limited-run of physical apparel inspired by the fashion house's far-reaching archives with Fortnite; Balenciaga and Fortnite on a series of in-game outfits and a limited-run physical apparel collection). From the creative and production processes to the retail and communication operations, Digital Twins, according to Riedelsheimer et al (2020, p.664) "could be used as an information basis on environmental, social and economic aspects along the whole lifecycle and provide assistance by optimizing the product's environmental and social impact."

## Interpretative framework

### Reframed fashion retail & communication operating models through Digital Twins implementation

Within a context of progressive and pervasive dematerialization of fashion, large and small fashion companies have recognized the great potential of digitization both to make their omnichannel distribution system smoother and more efficient (Jocovski, 2020; Palmié et al., 2022) and to improve and enhance the consumer experience (Alexander & Kent, 2020; Bonetti et al., 2019). According to this critical scenario, this paper proposes an interpretative framework to understand

and analyze the impacts of the adoption of Digital Twins within the fashion value chain, with a specific focus on those distribution and communication processes that typically result downstream of the design and product development phases. Starting from the analysis of exemplary case studies, this research proposes three different operating models that, in one hand, shows the most recent strategies and operational paradigms in the fashion field and on the other hand, identify potential and significant trajectories of development and innovation in the sector.

The three different operating models reflects the many transformations of the "traditional" supply chain (Figure 1) with impacts acting at the level of: business models, user experience, and sustainable processes.

The first operating model refers to the adoption of Digital Twins in a complementary approach to the traditional design and prototyping process of the physical garment, with significant impacts on the collections' display and communication formats and, consequently, on the experiential models proposed to the consumer. The second operating model regards the adoption of Digital Twins by transforming the traditional supply chain from the early stages of fashion product design, opening the possibility of experimenting and redefining key and particularly "unsustainable" processes such as sales campaigns and online distribution channels' management. Finally, the third operating model proposes a still partially unexplored and highly alternative model to the traditional supply chain translating into a properly phygital solution the relationship with the consumer and integrating in a valuable way the digital and physical dimensions of the purchasing experience.



**Figure 1.** Illustrative diagram of the traditional Fashion Supply-Chain (simplified elaboration from the Miroglio Group Supply-Chain diagram presented at the company visit, July 2022).

## Digital Twin-empowered hyper-real visual campaigns

The rise of digital transformation, and its acceleration due to the COVID-19 pandemic, has significantly impacted the fashion industry. One of the most visible and impressive consequences was how visual content and fashion shows are produced. Many fashion events and fashion weeks have been postponed or cancelled due to the pandemic, and those that have taken place have often been held virtually or with strict safety measures. One of the significant impacts of the pandemic on fashion shows has been the shift towards virtual events (de Carvalho Godim & Cunha, 2023; Linfante & Pompa, 2021). Many fashion brands and designers have turned to digital platforms to showcase their collections through live streams, pre-recorded videos, or interactive digital experiences. These strategies have allowed them to continue to present their works while reaching a global audience, thus experimenting with new visual formats and narrative codes and simultaneously introducing changes and new operational settings to the traditional fashion design process (Figure 2). In fact, creative and technical back-end design processes - trend and color choice; fabric and raw material research and choice;

sketching; colors approval and technical files development - were directly impacted, as shown in the following cases.

A couple of examples can particularly illustrate the potential and impact of the dematerialization of fashion in communication, from fashion shows to visual and marketing campaigns. "Out of This World SS2021" was the first virtual and appropriately "multi-format" fashion show proposed by the young brand GCDS, realized in collaboration with the international AR, VR and MR production studio Emblematic Group. It represents one of the first cases that used digital avatars not only for the presentation of the collection, but also for the realization of an immersive and narratively complete experience offered to an active and involved community. The virtualization of the garments took place starting from the sketches of the creative director Giuliano Calza, thus disrupting the conventional process of prototyping and product development (GCDS Had the Most Surreal Front Row, 2020). In this way, the creation of the digital fashion show and the entire collection production process followed parallel, non-sequential processes, allowing the former to be released well in advance of the latter and expanding the opportunities for interaction between the brand and its community (Moore, 2020). The fashion show was part of a more comprehensive communication and exhibition format that, based on an interactive digital platform, enabled augmented reality community socialization through playable video games, interaction with avatar-like front-row guests, and behind-the-scenes content.

Another example of a digital pipeline being used to produce a fashion show, and more generally, to promote a new and more sustainable model of visual content production and marketing, is 'Bacon's Version Show', presented at Milan Fashion Week 2021 by Bacon Clothing and developed in collaboration with TwinOne (Essere sostenibili nella moda usando la realtà virtuale, 2022). TwinOne recreated the 3D digital collection, starting with sketches and paper patterns and then, using the 3D game tool Unreal Engine technology, developing a potentially unlimited number of fabric-colour-pattern variations. This new digital pipeline impacted both the traditionally long prototyping phase and the equally costly production phase of visual communication content (Goodine, 2021) by promoting a new sustainable framework that reduces waste, accelerates timelines, and eliminates redundant investments.

## Digital Twin-empowered tailored and sustainable buying and retail dynamics

As discussed previously, Digital Twins have been introduced and implemented within distribution processes for various purposes, ranging from supply-chain optimization to improving the user experience, to promoting new and more sustainable operating procedures. From the point of view of sustainable supply-chain optimization, for example, they can help retailers to manage inventory more efficiently, reduce waste, and improve responsiveness to changing demand (dos Santos et al., 2021). Similarly, from the point of view of improving the user experience, Digital Twins allow customers to make more informed purchasing decisions by creating virtual try-on experiences (Riedelsheimer et al., 2020), with a positive impact, particularly for online retailers or by offering garments' ID cards thus improving transparency and traceability. In the following described cases, the back-end processes affected concerns mainly campaigns and online distribution

channels' management, such as market analysis, merchandising strategy and assortment planning.

In this context, SUNNEI Canvas - a project developed from 2020 onwards by the streetwear brand SUNNEI with the support of the 3D production agency Pezzo di Studio - represents an interesting example of connecting and hybridizing the digital dimension of fashion with its physical connection to the retail channel, implementing new services and forms of interaction between the brand and its audience, from buyers to end customers (Iannilli & Linfante, 2022) (Figure 3).

SUNNEI Canvas is an ongoing project launched with the SS21 collection of the brand's signature pieces delivered in all white and designed to be customized and developed with selected stores worldwide: the clothing and accessories could be modified to meet the specific preferences and needs of each store. To facilitate this customization process, SUNNEI created an online platform - only accessible with a password - that utilizes 3D engineering and customization technology to allow buyers to modify shapes, fits, and fabrics digitally. In order to enhance the virtual experience, SUNNEI developed male and female avatars with human-like features and a 100% SUNNEI aesthetic. These avatars can be used to showcase the clothing and accessories in the SUNNEI Canvas collection and allow buyers to see how they would look on a virtual model. The customization process, therefore, will result in different collections resulting in "Made for..." tags for different retailers (Leitch, 2020). The SUNNEI Canvas collection was launched as part of Milan Digital Fashion Week, with the buyers' platform also going online on that day. A second part of the collection was released in September, focusing on end customers' experience. The second part of the project focuses on community involvement by proposing an "endless video game" without objectives or levels to overcome. The avatars in the game are dressed in outfits and look chosen by game players, who are part of the SUNNEI community. The whole project is a reflection on the potential of the venture between fashion and the game industry to generate and test new ways of consumer engagement and involvement (Salibian, 2021).

### Digital Twin-empowered phygital and immersive retail experiences

The third operating model refers to a complete integration of a digital pipeline assuming, different from the previous cases, a complete consumer and retail-oriented perspective. In the exemplary case considered, the adoption of Digital Twin has the main objective of experimenting and taking opportunities with new emotional and highly interactive models in the final client relationship. The opportunity for collaboration between the retailer I.T Honk Kong and The Fabricant, a pioneering agency in the fashion dematerialization field, arises on the retailer's 30th anniversary. For the occasion, a travelling pop-up exhibition is planned to showcase a unique collection of global exclusives created in collaboration with leading fashion designers (The Fabricant, 2022). The adoption of Digital Twins, together with other technologies that "activate" and "augment" the physical space of the exhibition/retail space, represents one of the first and most interesting experiments of phygital reality (Iannilli & Spagnoli, 2021). This approach connects the tangibility of the physical experience with the interactivity and smoothness so typical of the digital dimension (Figure 4).

The travelling pop-up exhibition was held at various locations, including Hong Kong, Shanghai, and Beijing, in the winter

of 2018 and in Europe at the beginning of 2019. Designed to showcase a unique mix of physical and digital garments featuring interactive displays, the exhibition was intended to provide a unique and immersive shopping experience that showcased the capabilities of digital fashion and the potential for omnichannel retail. The exhibition included a digital collection of garments from brands such as Marques Almeida, Helmut Lang, and Alexander McQueen, only available for pre-purchase viewing in digital form at the pop-up locations. Customers could purchase these garments by scanning QR codes using a specially developed app. The retailer's goal was to attract various consumers with this unusual presentation and shift the perception of what a fashion retailer could deliver (Morris, 2019). Moreover, the interactive digital displays included a surreal maze of humanoid figures rendered in real-time 3D and buyable garments. The humanoids were programmed to respond to shoppers' movements, which were tracked using object detection cameras mounted above the screens. The 3D models were rendered using the three.js library and were synchronized with videos of the digital garments, which were displayed across 16 LED displays ('I.T Hong Kong', 2019).

This third operating model focuses on the experimentation of new codes and forms of emotional, immersive, and interactive connection traditionally about the exhibition sphere, which is reframed and performed in a hybrid space between the pop-up store and the travelling exhibition. This implicates the back-end processes from the design phase to distribution, logistics and retailing, until delivering the experience to the consumer. In addition, the perspective shift reflected the potential of the dematerialization of fashion from a communication and retail point of view and made it possible to renew and revolutionize the traditional supply chain and, therefore, the connected business model, starting from the innovation of the consumer experience, with promising and positive future implications.



Figure 2. Digital Twin-Empowered fashion supply-chain with impacts on visual and marketing campaigns' phases.



Figure 3. Digital Twin-Empowered fashion supply-chain with impacts on B2B and B2C buying and selling phases.

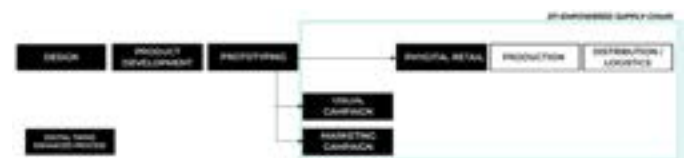


Figure 4. Digital Twin-Empowered fashion supply-chain with impacts on phygital products and services offerings.

## Improve Design-led Sustainable Innovation in Fashion Retail

Increasing sustainable actions in creation, production and consumption processes has become an urgent issue and challenge involving the fashion industry along with the whole stakeholder ecosystem. Awareness about sustainable fashion is growing, even though most operating models and applied experiences are exclusively focused on the fashion product development phase (Kozłowski et al., 2018), going from waste reduction design strategies to raw material control to product lifecycle management. More recently, new agendas are emerging, acting on different levels and contributing to bridging a gap both in terms of operational practices and strategic conceptualization in the field of sustainable fashion: on one hand, the growing interest in the retail sector (Ruiz-Real et al., 2019) that, together with the communication domain, represents the interface between fashion product and consumer and which, by adopting sustainable approaches, has the potential to affect both the consumer experience and business models (Dodds et al., 2022); and on the other hand, the need to integrate the concept of sustainability into the fashion design processes (Kozłowski et al., 2018) with a systemic approach to generating long-term and viable sustainable innovation in the fashion system.

Concerning specifically the fashion retail design field, technological and digital acceleration very quickly increased the implementation of advanced technologies (among others AI, VR/AR, MX and, not least, Digital Twins) in all back end and front-end distributive processes (Bulović & Čović, 2020; Casciani et al., 2022). In addition, as big data is increasingly being used in trend forecasting research/consumer behavior analysis and data centers and data transmission networks are responsible for nearly 1% of energy related GHG emissions (Iea, 2022), the use of data also integrates debate regarding sustainability. These technological applications have often been used to improve specific retail chain knots. However, a systemic reflection on the potential of technology to sustainably rethinks the fashion value chain, shaping a virtuous integration of retail design, marketing, management, and ICT disciplines is still in its infancy (Dodds et al., 2022; Iannilli & Spagnoli, 2021).

Similarly, a reflection on the peculiarities, practices, and tools of "Design for Sustainability" has been pursued. Taxonomic definitions (Arnette et al., 2014) and analytical frameworks (Rocha et al., 2019) are flanked by evolutionary readings of the Design for Sustainability domain. Design for Sustainability has seen a progressive broadening from a predominantly technical and product-centric level of innovation to a broad socio-technical and systemic innovation scale (Ceschin & Gaziulusoy, 2016). In a context in which "the current understanding suggests that sustainability is a system property and not a property of individual elements of systems (...) achieving sustainability requires a process-based, multi-scale and systemic approach to planning for sustainability guided by a target/vision instead of traditional goal-based optimization approaches" (Ceschin & Gaziulusoy, 2016, p.119).

Starting therefore from the previously investigated operating models - which highlighted both the potential of the Digital Twins in the distribution, promotion and valorization processes of the fashion product and the consequent transformation of the value chain - a first and tentative critical interpretation of design-led innovation for fashion retail is proposed (Figure 5).



**Figure 5.** Design-led Sustainable Innovation in Fashion Retail enhanced by adopting advanced technologies (with a focus on Digital Twins implementation).

Design-led innovation oriented to promote sustainable solutions through the exploitation of advanced technologies operates on several interdependent levels: on business models' innovation, the supply chain and, finally, the customer experience innovation. The valuable impacts that adopting Digital Twins can bring in these three domains range from the improvement of customer service (e.g. Real Time B2B and B2C customization as in the case of SUNNEI Canvas) to performance efficiency (e.g. time reduction in marketing and visual contents' production as in the case of Bacon's Version), to the creation of new hybrid and phygital consumption formats (e.g. offering new products and/or services as in the case of the I.T Honk Kong exhibition/pop-up). Within this framework, it is also important to highlight how design-led innovation for sustainability can act at different levels: strategic, tactical, and operational. These levels, systematized by Rocha, Antunes and Partidário (Rocha et al., 2019) and used as an analytical framework to explore different Design for Sustainability models, here similarly return the different dimensions that a systemic approach to sustainability for fashion retail should take charge of. In particular, the strategic level refers to the highest layer of corporate policies and macro-strategies; this level acts mainly at the business model scale and systemic supply-chain transformations. The tactical level refers to the operating processes and the system of relationships that regulate specific business units; for this reason, the tactical level has impacts that predominantly involve the supply chain and the customer experience when its transformation entails changes in processes, services, and distribution channels. Finally, the operational level acts within the micro-level of project management approaching primarily incremental sustainable innovation and focusing on streamlining traditional processes or flanking them.

Concurrently, addressing these different levels becomes mandatory to drive and implement sustainable innovations in the areas of fashion retail and communication. Within this context, design is required to encompass the system's complexity once again and embrace technological innovation (together with other contemporary drivers) by embedding it within positive and long-term signifying frameworks.

## Conclusion

In the light of the dematerialized economy that is being shaped in the attempt to fulfill new sustainable demands through advanced technologies (AI, VR, MX, Digital Twins), fashion embraced digitization as a facilitator in the process of rethinking smart solutions for its value chain. In this context and aiming to study the impact of Digital Twins technology within the fashion system and how it can be used throughout the supply chain as a mean of feasible practices, this paper analyzed three different operational models. The first model "Digital Twin-empowered hyper-real visual campaigns", mostly regarding visual and marketing campaigns; the sec-

ond model "Digital Twin-empowered tailored and sustainable buying and retail dynamics", inclined to the traditional supply chain transformation from the early stages of product design; and the third model "Digital Twin-empowered phygital and immersive retail experiences", drawing up phygital solutions. The research then, based on the analyses of the three operational models, presents a critical interpretation of design-led innovation for fashion retail, showing that the application of advanced technologies (in particular Digital Twins) can, from a sustainable point of view, improve customer service, increase efficiency and create new phygital consumption formats.

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This book contains academic papers and posters of the Cumulus Antwerp conference, held in Antwerp on 12-15 April 2023. The Cumulus community, designers, artists, and educators were invited to submit contributions on how culture and creative industry can offer resilience, consolation, and innovation models on human scale, in line with the conference theme 'Connectivity and Creativity in times of Conflict'.

The contributions were double blind reviewed in the tracks

- 1) Nature positive/Design for transformation,
- 2) Digital futures/Hybrid reality,
- 3) Handle with care/Inclusivity, and
- 4) PhD network.

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