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VIRTUAL PROTOTYPING FOR CIRCULAR FASHION: A CLO 3D CASE STUDY ON MODULAR TRAVEL WEAR

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ABSTRACT

The textile industry – already the world's second most polluting industry continues to rely heavily on traditional, resource-intensive sample development, in which large volumes of paper and physical fabric are consumed before a design is finalized. Advances in three-dimensional (3D) garment simulation offer a route toward reducing this waste. This paper evaluates CLO 3D, a purpose-built 3D apparel design platform, as a tool for eco-friendly fashion sampling and for the development of a detachable travelling jacket aimed at modern travelers. Detachable garments, which allow interchangeable or removable components, are examined as a strategy for extending garment life, supporting a circular economy, and enabling rapid, low-waste styling changes. Using CLO 3D, virtual samples were developed for female and male apparel, rompers, and a multi-part detachable jacket, and each was evaluated using the software's fit-map, stress-map, strain-map, and pressure-point analysis tools. None of the developed garments exhibited non-wearable (red) zones, and an average tolerable pressure of approximately 14-15 kPa was recorded across pressure points for both woven and knitted fabrics. A cost and capability comparison between CLO 3D and the 2D pattern-engineering platform Gerber AccuMark is also presented. The findings indicate that 3D virtual prototyping in CLO 3D reduces reliance on physical samples, shortens design-iteration cycles, and supports the creation of adaptable, multifunctional garments, positioning it as a practical tool for advancing sustainability in apparel design and production.

Keywords: *CLO 3D; virtual garment simulation; sustainable fashion; detachable jacket; 3D avatar; stress-strain analysis; eco-friendly sampling*

1. Introduction

1.1 Background and Significance

Garment-making is among the oldest of human technologies, evolving from animal hides, furs, grasses, and bones into the structured industrial process used today: fabric layout, pattern marking, cutting, stitching, quality inspection, finishing, pressing, and packaging. Contemporary apparel production continues to prioritize comfort, durability, and cost-effectiveness, but conventional sample development remains materially and temporally expensive physical prototypes consume fabric, paper patterns, and skilled labor before a design is finalized.

Digital three-dimensional (3D) modelling and visualization technologies increasingly reproduce the drape, fit, and appearance of garments virtually, integrating computer graphics with traditional pattern-making techniques (Spahiu et al., 2014a). 3D modelling has already demonstrated value across a range of protective and technical-clothing applications from medical textiles and firefighter protective gear to yoga apparel and virtual-fitting systems for industrial robot suits improving fit, comfort, and functional performance while reducing reliance on physical iteration (Lin et al., 2022).

1.2 CLO 3D Software

CLO (Clothing, Leather, Objects) 3D is a garment-simulation platform that enables designers, pattern makers, and manufacturers to build and evaluate virtual prototypes with high visual and mechanical fidelity. Unlike traditional workflows, which are constrained by the cost and lead time of physical samples, CLO 3D allows fabric behavior, drape, and fit to be simulated computationally, using a cloth continuum model in which mechanical calculations replicate the physical properties of a given textile as it is mapped onto a virtual dummy (avatar) (Lee, 2005; Hee Sook Kim & Mi Hee Na, 2014).

Within the software, garment patterns are constructed in a 2D workspace and simultaneously rendered in a 3D viewport, mirroring the logic of physical draping. This dual-view workflow shortens iteration cycles: designers can adjust fabric elasticity, weight, and texture in real time and immediately observe the resulting drape and silhouette, informing material selection on aesthetic, functional, and performance grounds. The same infrastructure supports rapid pattern refinement, an expanding library of reusable templates, and — where physical measurement is impractical digital modelling of the body-garment relationship as a substitute for direct anthropometric capture.

The adoption of CLO 3D and comparable 3D platforms is widely regarded as a driver of efficiency, innovation, and customer engagement in ready-made apparel. Virtual try-on and prototyping reduce time-to-market and physical sample waste, support cross-disciplinary collaboration, and enable increasingly personalized, made-to-measure design workflows (Hee Sook Kim & Mi Hee Na, 2014).

1.3 Detachable Travelling Jacket

The detachable travelling jacket examined in this study combines historical outerwear influences with features tailored to modern travel: strategically placed quilted sections for warmth and a flattering silhouette, generously sized pockets for essentials, a dual-purpose hood, and adjustable closures that allow the fit to be tuned to the wearer and the environment (Bissonnette, 2013). Modularity of this kind is also relevant to adaptive clothing: magnetic and rear-access zippers, quilted linings, and detachable mitts or hoods have been used to support wearers with mobility limitations, such as hemiparesis following a stroke, while preserving independence and dignity (Shahani & Duncan, 2019; Badr & El-Nahrawy, 2016).

Because detachable components can be removed, replaced, or repaired independently, this design approach extends garment lifespan and aligns with circular-economy principles, offering a practical route to more durable, multifunctional apparel for travelers and general use alike.

1.4 Fabric Selection

Fleece was selected as the primary fabric for the jacket owing to its combination of moisture management, breathability, and thermal performance, properties that are particularly relevant to travel and outdoor use.

Property	Description
Moisture management	Efficient transfer of moisture away from the skin, maintaining dryness during activity.
Quick moisture absorption	Rapid absorption prevents the garment from feeling sticky against the skin.
Breathability	Promotes airflow, aiding evaporation and stable body temperature.
Fast drying	Minimizes discomfort from damp clothing, useful for travel and outdoor activity.

Property	Description
Thermal insulation	Reliable warmth while remaining lightweight and breathable.
Durability	Withstands repeated use and outdoor conditions.
Versatility	Suitable for sportswear, travel jackets, and general active attire.

(Table adapted from fabric property data; Badr & El-Nahrawy, 2016.)

1.5 Avatar Customization in CLO 3D

CLO 3D provides three avatar categories — women, men, and kids — each of which can be adjusted for pose, hairstyle, footwear, and body shape/size, allowing the virtual model to approximate the intended wearer population.

1.5.1 Women Avatar

The women's avatar module offers three pose options, a range of footwear, multiple hairstyles, and a body-shape matrix (straight/curvy body types across petite, normal, and plus proportions), supporting inclusive representation of diverse body types.

1.5.2 Men Avatar

The men's avatar module mirrors this structure, with three selectable poses, footwear options sized for inclusivity, and a range of hairstyles for personalization.

1.5.3 Kids Avatar

The kids' avatar module allows customization of pose, clothing, footwear, and hairstyle for both male and female child avatars, supporting design work across age groups.

1.6 Tools in CLO 3D

CLO 3D organizes its functionality into 2D and 3D toolsets, summarized in Table A below.

2D Tools	3D Tools
Pattern design	Avatar editor
Print layout	Sewing and tacking
Size grading	Fabric kit
UV editor	Simulation
	Rendering
	Animation
	Colorway
	Pressure points
	Modular mode
	Pleats and folds

1.7 Stress, Strain, Fit, and Pressure-Point Analysis

CLO 3D includes four complementary virtual test modes used to evaluate garment performance prior to physical sampling.

- Fit map — visualizes tightness (red) and looseness (blue) across the garment surface, flagging areas requiring pattern adjustment.
- Stress map — measures fabric stress at each point of the garment; red zones indicate a garment area that would be non-wearable in practice.
- Strain map — evaluates strain at points directly influenced by body movement and structure (spine, elbows, knees, shoulders, back of neck), which require

stress relief in both static and dynamic positions.

- Pressure-point test — reports pressure values (kPa) at key contact points (knees, elbows, buttocks, shoulders, thighs), enabling comparison against tolerances observed for volunteer test subjects; average pressure at these points was found to be approximately 14-15 kPa for both woven and knitted fabrics.

Table B. Summary of virtual test modes

Virtual Test	What It Measures	Wearable Result Indicator
Fit map	Tightness / looseness across the garment	No red (tight) or unintended blue (loose) zones
Stress map	Fabric stress at each garment point	Red = non-wearable; none observed
Strain map	Strain at movement-critical points (elbows, knees, spine, neck)	No red zones in rest or motion
Pressure-point test	Pressure (kPa) at knees, elbows, buttocks, shoulders, thighs	~14-15 kPa average, within tolerance

A case study cited from MTM (a garment manufacturer) illustrates the practical value of this workflow: "CLO is helping us in reducing the number of physical samples — before this software we had to arrange raw materials to create a product, but with CLO we do everything virtually and present it to our customers, which helps in terms of both time and waste and supports more sustainable development."

1.8 Objectives

- Develop a detachable travelling garment for sustainable fashion.
- Enhance garment performance through visible, functional design elements.
- Study garment parameters relevant to casual and travelling use.
- Compare the accuracy and compatibility of 3D and traditional (2D) pattern-making methods.

2. Literature Review

2.1 Traditional Methods of Garment Manufacturing

Garment design has historically relied on hand sketching and physical draping on dress forms. The introduction of computer-assisted design (CAD) systems, and in particular 3D virtual mannequins, has substantially replaced physical mannequins in much of the fashion industry, improving design efficiency while retaining the underlying logic of traditional craftsmanship (Spahiu et al., 2014b).

2.2 CLO 3D in the Fashion Industry

Comparative studies between manual body measurement and CLO 3D-based virtual measurement report comparable accuracy to manual methods while improving process efficiency and strengthening communication between designers and end users (Hartono et al., 2023). Related work has combined traditional fabric techniques with CLO 3D to develop smart-textile materials and patterns intended to balance comfort, security, and fit within three-dimensional design environments, an area where two-dimensional pattern logic is often insufficient (Vrljanac et al., n.d.-a; Roth, n.d.).

The integration of 3D and augmented-reality (AR) tools is also reshaping how digital garments are presented and monetized, including through virtual environments such as the Metaverse and via non-fungible tokens (NFTs) in online marketplaces (Boothby-Shoemaker et al., 2022). As social media and demand for novel styles accelerate change across the fashion ecosystem (Marniati, 2020), 3D modelling tools are expected to become the predominant design medium,

underscoring the need to train designers and pattern makers in digital tailoring (Vrljanac et al., n.d.-b).
Case studies applying CLO 3D to national costume design report improved clarity, flexibility, and design-workflow efficiency relative to conventional methods (Ranathunga, 2015; Cao & Wang, 2023a). In apparel manufacturing specifically, comparisons of 3D and traditional real-world methods for producing plus-size jackets found no significant difference in outcome quality between the two approaches, while indicating potential time and fabric-waste savings from 3D adoption (Apeagyei, 2010a; Mohamed et al., 2023). Studies of CLO 3D in design education report that structured, well-resourced online learning modules are an effective way to teach digital pattern-making to students (Kosasih et al., 2023).

2.3 Application of 3D Modelling in Sustainable Fashion

Design strategies that extend garment lifespan — including modularity and incremental design — are directly applicable to detachable garments, in which interchangeable or removable components allow repair, replacement, and adaptation, supporting a more circular approach to apparel (Stutman, n.d.). A related application demonstrates the same modular logic in wearable textile antennas, where snap-on components allow a single base design to be reconfigured for different functional characteristics (Vrljanac et al., n.d.-c; Politecnico di Torino et al., n.d.).
The environmental cost of the fashion industry's wasteful, energy-intensive practices — accelerated in visibility by the COVID-19 pandemic — has pushed brands toward digital tools that speed garment development, reduce cost, and support sustainability, even as fashion-design education has been comparatively slow to adapt its curricula (Melnyk, 2020; Lin & Ingaramo, 2023). CLO 3D has, for example, been combined with foam-based dress forms to develop half-scale maternity forms, enabling virtual fitting and flat-pattern prototyping and iterative refinement for optimal fit against scanned body measurements (Carrera-Gallissà et al., 2017; Apeagyei, 2010b). Similarly, CLO 3D-based intelligent design systems that draw on image retrieval and parameter libraries have been used to generate and refine national costume designs, streamlining cost-effective modification while preserving cultural detail (Pant & Jain, 2014; Ji et al., 2006; Jankoska & Demboski, 2017; Cao & Wang, 2023b).

2.4 Fashion Industry and Emerging Technologies

Pioneering digital-fashion companies such as Atacac and The Fabricant illustrate how 3D design technology is reshaping garment creation and consumer engagement, establishing digital fashion as a distinct discipline within fashion design, with its own principles, methodologies, and practitioner community (Adeleke et al., 2023; Magnenat-Thalmann & Volino, 2005; Särmäkari, 2023). As these tools mature, they are expected to continue narrowing the gap between physical and virtual fashion practice.

3. Materials and Methods

3.1 Materials

- CLO 3D software
- Fabric (knitted fleece terry, plus supporting wovens)
- Measuring tools
- Sewing machine

3.2 Methods

The overall workflow proceeded from concept design through to a physical, stitched sample: Design → Pattern → 2D sketch → Fabrication and tech pack → 3D designing → Stitching.

3.2.1 Designing of the Detachable Travelling Jacket

The design concept was generated at the research and material-selection stage, with each design decision considered against the requirements of travel use — storage, adjustability, and modular detachability.

3.2.2 2D Sketch

A 2D sketch establishing the overall garment silhouette was produced in Adobe Illustrator, with body-part labelling and seam lines (dotted and straight) used to communicate construction detail.

3.2.3 Fabrication and Tech Pack

Fabric selection matched weight and texture between the virtual and physical garment to ensure that drape and fit corresponded across both domains. A tech pack was produced in Excel to record fabrication and measurement detail for use on the stitching line.

Category	Type of Fabric	Color	Thickness
Knitted fabric	Knit fleece terry	Blue	1.17

3.2.4 2D Pattern of the Travelling Jacket

The 2D pattern was constructed in Gerber AccuMark for its accuracy in pattern generation, then transferred into CLO 3D for 3D simulation. Pattern-making followed the industrial "cut, trim, make" convention; subjective measurements used in the virtual design stage were carried into the physical pattern, and allowances were reserved for buttonholes, seam allowances, stitch widths, and other closures.

3.2.5 2D Patterns for Sustainable Sampling

After the avatar was adjusted to the required proportions, patterns were drawn in the software's 2D workspace and mirrored automatically in the 3D viewport.

Table 1. Detachable jacket body measurements

No.	Measurement	Value
1	Body length	141.05 cm
2	Chest, one inch below armhole	29.36 cm
3	Across shoulders	37.04 cm
4	Sleeve length	15.33 cm
5	Armhole	15.11 cm
6	Neck opening	12.11 cm
7	Sleeve opening	6.77 cm
8	Collar length	44.0 cm
9	Collar width	5.02 cm
10	Collar stand	44.66 cm

Table 2. Pants measurements

No.	Measurement	Value
1	Size	105.3 cm
2	Rise	31.23 cm
3	Waist	24.47 cm
4	Thigh	18.36 cm
5	Hip	37.41 cm
6	Boot	17.37 cm

3.2.6 3D Modelling

The 3D modelling stage followed three steps: (1) development of an avatar for each participant profile within CLO 3D; (2) measurement and adjustment of the avatar; and (3) review of the resulting avatar against intended proportions. The software's split-screen workspace — 2D pattern on one side, 3D simulation on the other — was used throughout to move directly from pattern edits to visual fit feedback.

3.2.7 Measurement of the Avatar

The avatar functions as a virtual substitute for the human body; garments are designed to its dimensions, and its measurements are adjusted to represent the intended body shape and size within the Avatar tool.

Table 3. Avatar measurements

No.	Avatar Part / Measurement	Female	Male
1	Total height	175.26 cm	187.96 cm
2	Bust/chest circumference	80.64 cm	96.52 cm
3	Neck base circumference	35.56 cm	40.96 cm
4	High hip circumference	80.33 cm	88.26 cm
5	Low hip circumference	95.57 cm	95.25 cm
6	Across-shoulder curvilinear	37.78 cm	44.13 cm
7	Inseam height	84.14 cm	86.36 cm
8	Thigh circumference	54.93 cm	55.88 cm
9	CF neck to waist	33.97 cm	42.54 cm
10	CB neck to waist	38.10 cm	48.58 cm
11	CB neck to wrist (arm)	77.19 cm	87.31 cm
12	Bicep circumference	25.40 cm	32.39 cm
13	Hand	16.10 cm	19.65 cm
14	Total rise	72.39 cm	74.61 cm
15	Head	54.40 cm	53.07 cm
16	HPS to apex	25.08 cm	82.55 cm

3.2.8 Garment Sewing

Virtual seams were applied using the software's sewing tool, which supports both free sewing and segment sewing, allowing seam allowances and construction sequence to be represented digitally before physical stitching.

3.2.9 Color Selection

CLO 3D's Property Editor provides colorway and Pantone-referenced color selection alongside other fabric properties (texture, roughness, reflectivity), enabling rapid comparison of finish options on a single virtual sample.

3.3 Printing on Fabrics

Custom print designs can be added to the object browser and applied directly to a virtual fabric, allowing multiple print variants of the same garment to be produced and compared within minutes.

3.4 Stress, Strain, Fit, and Pressure-Point Testing

Each sample was evaluated virtually for stress, strain, fit, and pressure-point performance; parameters were adjusted iteratively wherever the software flagged a non-wearable or excessively tight zone.

4. Results and Discussion

This section presents the outcomes of the virtual experiments performed in CLO 3D, together with discussion of their implications for eco-friendly sampling and detachable-garment design.

4.1 CLO 3D for Eco-Friendly Fashion Sampling

Traditional sampling relies on paper-based pattern development, consuming significant quantities of paper and generating fabric waste at each iteration. A series of virtual samples was produced in CLO 3D to evaluate the software's suitability as a lower-waste alternative.

4.1.1 Garment: Trousers and Shirt (Female)

A female two-piece garment (trousers and shirt) was developed, with fabric and color finalized after the general silhouette was confirmed virtually.

Table 4. Female garment fabric and color

Garment Part	Fabric	Color
Pants	Cotton Oxford	PANTONE 19-1117 TSX | Chocolate Cremoso
Shirt	Knit cotton / rayon jersey	PANTONE 14-0938 TSX | Ancient Grain

4.1.2 Garment: Hood and Trousers (Male)

A corresponding male garment (hooded top and trousers) was developed using the same workflow.

Table 5. Male garment fabric and color

Garment Part	Fabric	Color
Trousers	Knit cotton / rayon jersey	PANTONE 19-1117 TSX | Chocolate Cremoso
Hood	Wool melton	PANTONE 18-2054 TSX | Bossy Pink

4.1.3 Garment: Rompers (Female)

A romper-style garment was developed with a floral print applied to a woven base fabric, illustrating the speed with which multiple print variants can be generated and compared in the software.

Table 6. Romper fabric and color

Garment Part	Fabric	Color
Body	Knit cotton / rayon jersey	PANTONE 19-1117 TSX | Chocolate Cremoso
Print	Floral print	White / white / multiple colors

Figure 4. Printed romper variants generated in CLO 3D within minutes of one another.

Producing multiple print variants of the same garment in minutes, rather than requiring a new physical sample for each option, gives designers a faster and lower-waste basis for comparing finishes before committing to production.

4.1.4 Detachable Travelling Jacket

The core garment of this study — a detachable travelling jacket — was developed in a knitted fleece terry fabric (PANTONE 19-4040 TSX | Blue Pans).

Table 7. Detachable jacket fabric and color

Category	Type of Fabric	Color
Knitted fabric	Knit fleece terry	Blue — PANTONE 19-4040 TSX | Blue Pans

for travelers is designed by using CLO 3D. Here is

on of the sample

Figure 1. Detachable travelling jacket rendered in CLO 3D, with color-effect variant.

The garment was designed with removable pocket and sleeve/torso sections, allowing wearers to reconfigure the jacket for different climates, occasions, or luggage-carrying needs without owning multiple separate garments. This directly addresses the study's central design goal: a flexible, low-waste solution to the ongoing evolution of fashion. By enabling wearers to reconfigure their attire rather than purchase additional pieces, the design reduces both overspending and wardrobe clutter.

Beyond its aesthetic and functional benefits, the detachable structure promotes sustainability by reducing the need for constant purchases and minimizing textile waste, aligning with the growing demand for eco-friendly fashion options and encouraging further innovation in modular garment construction.

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4.1.5 Fit-Map Test Result

The fit map visually represents areas of tightness (red) or looseness (blue) across the garment. Across all evaluated samples, no zones were flagged as non-wearable, indicating that the pattern and avatar measurements were well matched.

4.1.6 Stress Map

The stress map quantifies stress concentration across the garment surface; red zones would indicate a non-wearable area. Isolated yellow markers were observed at points requiring intentional tightness — for example, cuffs and waistbands — rather than indicating a fit defect; these correspond to the expected behavior of the woven fabric components.

Figure 4. 10 Stress Map

Figure 2. Stress-map evaluation across garment samples; no red (non-wearable) zones were recorded.

4.1.7 Strain Map

Because strain is directly related to the body's stress points, strain management was treated as a foremost requirement for an adaptive garment. Priority strain-relief zones included the points of direct garment contact — the spine, elbows, knees, shoulder bones, and back of neck — evaluated in both resting and moving positions. No red (high-strain) points were recorded, indicating the garments were wearable across the tested range of motion.

4.1.8 Pressure Points

The pressure-point test reported values at the body's principal contact points (knees, elbows, buttocks, shoulders, thighs) in kilopascals (kPa), referenced against a 0-100 kPa scale calibrated using volunteer test subjects. Average tolerable pressure across the evaluated points was approximately 14-15 kPa for both woven and knitted fabrics.

The pressure point test was a unique test of the 3D software. It gave the pressure values at the specific pressure points of the body like knees, elbows, buttocks, shoulders,thighs, etc. At specific points, their values varied according to the volunteering disable persons in kilo-Pascal ranging from 0 – 100. However, the average pressure to withstandat the above-discussed pressure points was found to be approximately 14-15 kilo-Pascal both in the case of woven and knitted

Figure 3. Pressure-point analysis at key body-contact locations.

4.1.9-4.1.10 Repeated Stress and Fit Verification on the Detachable Jacket

A second pass of stress-map and fit-map analysis was applied specifically to the detachable jacket to confirm that the addition of removable components did not introduce new fit or wearability issues. The stress map again showed no red (non-wearable) zones, and the fit map confirmed comfort and wearability were preserved despite the added modularity, supporting the viability of detachable construction as a design strategy that does not compromise garment performance.

4.2 Cost Comparison: CLO 3D and Gerber AccuMark

Gerber AccuMark and CLO 3D both offer advanced solutions for fashion designers but differ in platform support, target audience, and licensing structure. Gerber AccuMark, delivered as a web-based SaaS platform, is oriented toward fashion professionals requiring a controlled transition from 2D to 3D garment engineering. CLO 3D, available on Windows, Mac, and web platforms, targets designers who prioritize visualization, iteration speed, and rendering realism within a virtual environment.

Table 8. Licensing cost comparison

Platform	Package	Starting Price
CLO 3D	Individual license	$50 / month
CLO 3D	Student license	$25 / month
CLO 3D	Individual (annual)	$225 / year
Gerber AccuMark	TechDesign Bundle	from $599 / month
Gerber AccuMark	AccuMark 2D	from $389 / month
Gerber AccuMark	YuniquePLM	from $150 / month

CLO 3D's individual and student pricing tiers make it comparatively accessible for small studios, students, and independent designers, while Gerber's bundled offerings are priced for larger production and pattern-engineering workflows; both vendors additionally offer business and academic institution pricing scaled to organizational requirements. Considered together with the fit, stress, strain, and pressure-point outputs reported above, CLO 3D presents a lower cost of entry for design-stage virtual prototyping, while Gerber AccuMark remains oriented toward high-precision, production-scale 2D pattern engineering.

5. Conclusion and Future Work

The findings of this study indicate that CLO 3D represents a meaningful advancement in the development of sustainable clothing relative to conventional, paper- and fabric-intensive sampling methods. The software's integrated measurement and analysis tools — covering pattern creation, sewing, color and fabric selection, and fit evaluation — reduced waste and time at the design stage while allowing fabric properties, suitability, and draping behavior to be assessed before any physical material was cut.

A key advantage of CLO 3D observed in this study is its capacity to support adaptable, modular garments such as the detachable travelling jacket, which is more difficult to prototype efficiently using purely 2D pattern-engineering tools such as Gerber AccuMark. This adaptability responds to growing demand for multifunctional, sustainable fashion — particularly relevant to modern travelers seeking practical, versatile, and stylish apparel.

Looking ahead, extending CLO 3D-based workflows to other areas of textile production — including non-woven materials and other technical end products — offers a promising direction for further reducing sample waste and informing fabric selection against specific end-use requirements, reinforcing the broader case for digital-first, sustainability-oriented practice across the textile sector.

Alignment with Sustainable Development Goals

- SDG 9 (Industry, Innovation, and Infrastructure): CLO 3D, as an innovative fashion-industry technology, is shown to enhance manufacturing processes and infrastructure for sustainable garment production.
- SDG 12 (Responsible Consumption and Production): the focus on sustainable textiles and adaptable travel jackets advocates for responsible consumption and production by reducing waste, minimizing environmental impact, and supporting sustainable fashion practice.

REFERENCES

Adeleke, O., Woelfle, H., & Dunne, L. (2023). Tangible E-Textile Interface for Digital Patternmaking with Soft Goods.

Apeagyei, P. R. (2010a). Application of 3D body scanning technology to human measurement for clothing fit. International Journal of Digital Content Technology and Its Applications, 4(7).

Apeagyei, P. R. (2010b). Application of 3D body scanning technology to human measurement for clothing fit. International Journal of Digital Content Technology and Its Applications, 4(7).

Badr, A. A., & El-Nahrawy, A. (2016). Moisture properties of raised 3-thread fleece fabric knitted with different face and fleecy yarns. Alexandria Engineering Journal, 55(3), 2881-2892.

Bissonnette, A. (2013). 2013 Proceedings New Orleans, Louisiana: Travelling Brunswick Day to Evening Reversible Mode.

Boothby-Shoemaker, W. T., Mohammad, T. F., Ozog, D. M., & Lim, H. W. (2022). Photoprotection by clothing: A review. Photodermatology, Photoimmunology and Photomedicine, 38(5), 478-488.

Cao, Y., & Wang, S. (2023a). Research on the application of CLO3D technology in the structure design of national costume (Issue 6).

Cao, Y., & Wang, S. (2023b). Research on the application of CLO3D technology in the structure design of national costume (Issue 6).

Carrera-Gallissà, E., Capdevila, X., & Valldeperas, J. (2017). Evaluating drape shape in woven fabrics. Journal of the Textile Institute, 108(3), 325-336.

Hartono, M., Kurniawan Jaya, B., Prianka, D., & Annora Parung, C. (2023). Awareness of 3D body-scanning and prospective update of Indonesian anthropometry for virtual fashion design. Jurnal Teknik Industri, 18(1).

Hee Sook Kim, & Mi Hee Na. (2014). Effects of bending properties and drapability on the hand and appearance of wool-blended fabrics: Comparison of real clothing with online and 3D virtual garments. Fibers and Polymers, 14, 2148-2156.

Jankoska, M., & Demboski, G. (2017). Comparison of mechanical properties, hand and tailorability of wool blended fabrics for outerwear clothing. Industria Textila, 68(1), 69-74.

Ji, F., Li, R., & Qiu, Y. (2006). Simulate the dynamic draping behavior of woven and knitted fabrics. Journal of Industrial Textiles, 35(3), 201-215.

Kosasih, Y., Sutopo, Y., Wahyuningsih, E., Raya, J. H., & Regency, S. (2023). The development of CLO3D software e-module for digital creation of party attire patterns and designs. Journal of Vocational Career Education, 8(1), 9-16.

Lee, S. H. (2005). A CAD-CAE integration approach using feature-based multi-resolution and multi-abstraction modelling techniques. CAD Computer Aided Design, 37(9), 941-955.

Lin, Y., Wang, C., Miao, D., Cheng, N., Meng, N., Babar, A. A., Wang, X., Ding, B., & Yu, J. (2022). A trilayered composite fabric with directional water transport and resistance to blood penetration for medical protective clothing. ACS Applied Materials and Interfaces, 14(16), 18944-18953.

Lin, X., & Ingaramo, M. O. (2023). [Sustainable curriculum development in fashion design education].

Magnenat-Thalmann, N., & Volino, P. (2005). From early draping to haute couture models: 20 years of research. Visual Computer, 21(8-10), 506-519.

Marniati, M. (2020). Comparative study of construction/flat patterns and grading patterns application in clothing making: A case study on women's clothing practices. International Journal for Educational and Vocational Studies, 2(12).

Melnyk, V. (2020). Sewing pneumatic textures: Three-dimensional digital design based on the craft of dressmaking.

Mohamed, S., et al. (2023). Comparative evaluation of 3D and traditional methods for plus-size jacket production.

Pant, S., & Jain, R. (2014). Comfort and mechanical properties of cotton and cotton blended knitted khadi fabrics. Studies on Home and Community Science, 8(3).

Politecnico di Torino, Macquarie University, IEEE Antennas and Propagation Society, & IEEE-APS Topical Conference on Antennas and Propagation in Wireless Communications. (2016). Proceedings of the 2016 International Conference on Electromagnetics in Advanced Applications (ICEAA), Cairns, Australia.

Ranathunga, G. M. (2015). Subject of cloth: Its manipulations and ramifications.

Robson, D., Robson, C. C. L., & Long, D. (2000). Drape analysis using imaging techniques. Clothing and Textiles Research Journal, 18(1).

Roth, B. (n.d.). 3D zero waste: NISHIJIN weaving meets HAORI.

Särmäkari, N. (2023). Digital 3D fashion designers: Cases of Atacac and The Fabricant. Fashion Theory - Journal of Dress, Body and Culture, 27(1), 85-114.

Shahani, M., & Duncan, H. (2019). 2019 Proceedings Las Vegas, Nevada: Style meets function - The inclusive winter jacket.

Spahiu, T., Shehi, E., & Piperi, E. (2014a). Advanced CAD/CAM systems for garment design and simulation.

Spahiu, T., Shehi, E., & Piperi, E. (2014b). Advanced CAD/CAM systems for garment design and simulation.

Stutman, M. B. (n.d.). Measurement of detachable submicrometer particles and surface cleanliness of clean room garments.

Vrljanac, M., Šikman, K., & Simić, M. (n.d.-a). Computer simulation [material transformation and support in garment design].

Vrljanac, M., Šikman, K., & Simić, M. (n.d.-b). Computer simulation [digital tailoring and training].

Vrljanac, M., Šikman, K., & Simić, M. (n.d.-c). Computer simulation [wearable textile antennas with detachable components].