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Design development and CLO3D-based virtual prototyping of a four-style contemporary men's hoodie collection

Abstract

Digital apparel development connects creative garment concepts with technical pattern development and virtual evaluation. This practice-based descriptive case study documents the development of four contemporary men's pullover hoodie styles through hand-drawn sketches, two-dimensional (2D) technical flats prepared in Adobe Illustrator, digital pattern layouts, and three-dimensional (3D) virtual prototypes developed in CLO3D. The four styles share a common garment category and principal components but differ in colour distribution and panel geometry: angular and centrally organized blocking, curved wave-like transitions, geometric tonal framing, and diagonal, partly asymmetric blocking. The study compares how these design characteristics are represented across sketches, technical flats, CLO3D pattern-layout screenshots, and virtual garment views. The available size-M specification sheet records 320 GSM cotton fleece terry for the body, sleeves, hood, and pocket, and 468 GSM 2×2 rib for the cuffs and hem. The manuscript reports that the same base measurements were applied across the four styles; however, only one formal specification sheet, identified as Style HD-0123HD-01, was supplied. A combined CLO3D fit, stress, strain, and pressure-point diagnostic image is available for one style and is interpreted as a software-generated output rather than independent evidence of wearer comfort or ergonomic validity. No physical prototype comparison, movement assessment, or wearer evaluation was supplied. The study contributes a documented design-to-virtual-prototype workflow and identifies the technical records and physical assessments required for subsequent validation.

Keywords: men's apparel, hoodie design, garment development, Adobe Illustrator, CLO3D, technical flats, panel-based design, pattern engineering, virtual prototyping, garment fit

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Introduction

Contemporary apparel development requires designers to coordinate aesthetic direction, garment construction, material selection, sizing, and product communication.[1–3] A successful garment-development process must translate an initial creative concept into a technically interpretable product while maintaining consistency between the intended appearance and the eventual construction. This requirement is particularly relevant to hoodies, which combine a recognizable silhouette with opportunities for variation in pan
el geometry, colour distribution, hood design, pocket treatment, sleeve construction, and ribbed finishing.[4]

Men's pullover hoodies provide a useful context for examining the relationship between visual creativity and technical development. Their familiar construction allows designers to vary colour distribution, panel geometry, hood and sleeve details, pocket placement, and ribbed finishing without changing the basic garment category. A fashion illustration communicates design direction, but it does not necessarily provide the information required for pattern development, panel assembly, measurement control, or fit assessment. Sketches, technical flats, pattern pieces, and virtual prototypes therefore serve complementary functions in the development process.[5]

Apparel fit is a related but distinct concern. Garment dimensions, ease allowance, fabric mechanical properties, body morphology, construction, and wearer movement should be considered together rather than treated as independent design variables.[6,7] A convincing virtual render demonstrates visual prototyping, but it does not independently validate physical fit accuracy or wearer comfort. Static appearance, movement compatibility, physical garment measurements, and wearer feedback represent different forms of evidence and should not be treated as interchangeable.[7]

This study addresses the gap between visually developed design artefacts and a transparent account of how design intent is translated into technical and digital representations. By examining four styles within one workflow, it connects creative development with apparel pattern engineering. Its scope is descriptive: it documents the design and virtual-prototyping stages, evaluates the completeness of the available technical records, and distinguishes demonstrated outputs from fit, ergonomic, and process-efficiency outcomes that require additional testing.

Research objectives

General objective

To document and analyze the development of a four-style contemporary men's hoodie collection through an integrated workflow combining hand-drawn design sketches, Adobe Illustrator technical flats, CLO3D-based virtual prototyping, and garment-specification documentation.

Specific objectives

1) To examine how four initial hoodie concepts translate into structured 2D technical representations while retaining their individual design characteristics.

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2) To analyze the use of color blocking, panel configuration, hood detailing, sleeve construction, and kangaroo-pocket placement across the four styles.

3) To document the role of CLO3D in presenting the developed hoodie designs as three-dimensional virtual garments.

4) To assess the contribution of garment measurement and fabric specification documentation to the technical communication of the collection.

5) To establish an appropriate framework for future evaluation of garment fit, movement compatibility, and ergonomic performance.

The objectives are deliberately separated. The first three concern design development and representation; the fourth concerns the completeness and usefulness of technical documentation. The fifth establishes a framework for future performance validation rather than assuming that fit or ergonomic validation has already been completed.

Research questions

The study is guided by three research questions:

1) RQ1. How can an integrated sketch-to-technical-flat-to-CLO3D workflow support the development and communication of four contemporary men's hoodie designs?

2) RQ2. Which visual and construction-related characteristics distinguish the four hoodie styles while maintaining collection-level design consistency?

3) RQ3. What technical documentation and additional validation procedures are required to assess the fit and ergonomic suitability of the resulting virtual prototypes?

The research questions connect observable design outputs with the technical requirements of subsequent product development. They do not assume that the collection has achieved a measured improvement in comfort, manufacturing efficiency, material utilization, or physical fit accuracy.

Literature review

Apparel design development and technical representation

Apparel design development translates visual concepts into garment forms that designers, pattern makers, and production personnel can interpret.[8] Sketches communicate style direction, while technical drawings provide a more controlled representation of visible garment structure.[9,10] Illustrations alone may not specify pattern relationships, seam lines, or finished dimensions. The purpose of technical representation is therefore not simply to improve appearance, but to communicate the design in a form that can be interpreted consistently during technical development.

Technical flats use front and back views to communicate garment proportions, visible construction, and component placement.[11] Their usefulness depends on consistent line work, legible panel boundaries, accurate detail placement, and a clear distinction between outer contours and internal construction lines. Measurement points and callouts can connect a flat to a specification sheet. Vector-illustration software such as Adobe Illustrator supports this stage through editable paths, anchor points, alignment tools, colour fills, and reusable graphic elements.[12]

A technical flat should not be confused with a complete production pattern.[13] The flat communicates visible garment features, whereas a pattern contains the geometry and construction information needed to cut and assemble the garment.[14,15] Pattern engineering additionally involves seam allowances, grain lines, notches, panel relationships, sleeve-cap geometry, and seam-length compatibility. These details must be recorded separately when they are not represented in the flat. A visible colour boundary should not automatically be interpreted as a sewn seam: it may represent a separate pattern piece, an applied surface treatment, or a graphic colour division. The underlying pattern pieces and sewing relationships are needed to establish its technical status.

Three-dimensional virtual garment prototyping

Three-dimensional garment prototyping represents how 2D pattern pieces form a garment around a digital body. Pattern pieces are arranged around an avatar, corresponding edges are connected through digital sewing relationships, and simulation generates a three-dimensional garment surface. The resulting appearance depends on the correspondence among pattern geometry, construction, avatar dimensions, and material properties.[16]

CLO3D supports pattern arrangement, digital sewing, fabric assignment, avatar interaction, and garment simulation.[17] The resulting silhouette, wrinkles, panel positioning, and garment–body interaction depend on pattern geometry, fabric parameters, construction details, avatar dimensions, collision settings, and simulation configuration. A reproducible virtual-prototyping record should therefore identify the avatar and its relevant measurements, the material inputs assigned to each pattern piece, and the principal simulation settings.

Virtual prototyping should not be treated as an automatic substitute for all physical product-development procedures.[18] Comparative studies have reported both useful correspondences and discrepancies between virtual and physical fit assessments, including differences around the neckline, shoulder slope, sleeve cap, and other garment regions . Virtual fitting can also support design communication and collaborative review, but its effectiveness depends on the preparation of the digital garment and the interpretation of the simulation. A convincing render may still contain unverified construction, material, or fit assumptions; the relationship between virtual and physical fit must be examined rather than assumed.

Garment ease, fit, and ergonomic considerations

Garment fit describes the relationship among body dimensions, garment dimensions, intended silhouette, fabric behaviour, construction, and wearer activity. Ease allowance contributes to movement accommodation and design expression, but a loose silhouette does not automatically ensure mobility. Fabric tensile, bending, and shear properties can influence simulated strain and distance ease, while pattern geometry and body morphology affect the distribution of garment pressure and displacement.[19]

Ergonomic evaluation extends beyond static appearance.[20,21] For a hoodie, relevant assessment points include chest and body ease, shoulder and armhole configuration, sleeve length and mobility, hood positioning, pocket accessibility, and ribbed openings. Controlled arm elevation, forward reaching, and cross-body movement can help identify restriction or unwanted garment displacement. These observations should be documented using consistent garment and body measurements and, where possible, compared across virtual and physical prototypes.[20,21]

Ergonomic suitability must be supported by evidence. Without documented assessment, a collection can be described as design-developed and virtually prototyped, but not as ergonomically validated.

Software-generated fit classifications and stress or strain maps may identify areas for further inspection; they do not, by themselves, establish wearer comfort, injury risk, or physical fit accuracy.

Panel-based design rationale and conceptual framework

Panel-based design provides a means of organizing colour, shape, and construction lines across a garment surface. In technical development, however, a visible colour boundary should not automatically be interpreted as a sewn seam. Its status must be established by examining the 2D pattern pieces and the corresponding digital sewing relationships. This distinction is particularly important when a design is transferred from a technical flat to a 3D virtual garment, because the pattern-piece arrangement determines how the garment is assembled and how panel boundaries appear after simulation.[14–17]

The four hoodie styles are treated in this study as a comparative design set rather than as four unrelated garment categories. The pullover hoodie silhouette and principal components provide a common design basis, while the panel arrangements vary across four visual strategies: angular and centrally organized grey-and-black blocking; curved, wave-like light-blue-and-white transitions; geometric burgundy-and-black framing; and diagonal beige, white, and brown blocking with a partly asymmetric sleeve treatment. This selection permits a descriptive examination of how different panel geometries are communicated through technical flats and translated into CLO3D pattern layouts and virtual garment views. The conceptual framework links five stages: design concept development, technical-flat representation, pattern-piece development and construction definition, CLO3D assembly and simulation, and technical or physical validation. Feedback between stages may require revisions to the pattern, construction details, technical flat, and virtual garment. The present study documents the stages supported by the supplied artefacts and identifies physical fit and ergonomic validation as subsequent work.

Methodology

Research design

This study adopts a practice-based descriptive case-study approach. The case comprises four men's hoodie designs represented through hand-drawn sketches, Adobe Illustrator technical flats, CLO3D pattern-layout screenshots and renders, and a garment-specification record. The analysis examines the supplied design and technical artefacts without claiming causal effects, wearer satisfaction, production efficiency, sampling reduction, or physical fit accuracy. The unit of analysis is the individual hoodie style and its representation across the design-to-virtual-prototype sequence.

Design artefacts and data sources

The documented materials comprise four sets of front-and-back pencil sketches, four corresponding sets of 2D technical illustrations, four CLO3D front-and-back render sets, four CLO3D workspace screenshots showing 2D pattern layouts alongside 3D garments, one combined fit/stress/strain/pressure-point diagnostic image, and one technical specification sheet. The four styles are identified descriptively by their principal colour palettes and panel arrangements because a complete set of four official style codes was not included in the supplied documentation.

The supplied technical specification sheet is identified as Style HD-0123HD-01, size M, and records points of measurement, garment dimensions, and material weights. The manuscript's original project description states that the same base measurements and material specifications were applied across the four designs; however, only one formal sheet was supplied, and separate style-specific measurement records or construction callouts were not available for independent verification. The four pattern-layout screenshots provide visual evidence of the digital pattern arrangements, but editable native pattern files and complete sewing relationships were not supplied. The avatar type and body measurements, CLO3D version, fabric mechanical-property inputs, and detailed simulation settings were also not recorded in the materials available for this review. These limitations are considered when interpreting the results.

Stage 1: Hand-drawn concept development

The sketches were examined for the placement of the hood, neckline, sleeves, cuffs, hem, front pocket, and principal colour-blocking or panel boundaries. Attention was also given to how the front and back treatments relate to one another, because a feature visible on the front may continue, terminate, or change direction across the back or sleeve. The sketches provide evidence of concept development and visual exploration; they are not treated as dimensionally verified patterns.

Stage 2: Adobe Illustrator technical flats

The second stage translated the design concepts into clearer 2D garment illustrations in Adobe Illustrator. The resulting flats clarify the silhouettes, visible panel boundaries, pocket shapes, hood configurations, sleeve treatment, and finishing lines. For technical interpretation, colour fills are treated as visual design information rather than proof of separate fabric construction unless the corresponding pattern layout supports that interpretation.

The front and back views were examined for consistency in proportion, component placement, and visible design features. Construction lines were distinguished from the outer garment contour wherever the drawings allowed. The flats were then compared with the CLO3D pattern-layout screenshots to identify whether visible colour divisions corresponded to separate digital pattern pieces. Where the available evidence did not establish this correspondence, the boundary is described as a visual colour-blocking feature rather than a confirmed construction seam.

Stage 3: CLO3D pattern development, assembly, and virtual prototyping

The third stage involved developing 3D virtual prototypes of the four hoodie designs in CLO3D. According to the supplied project description, 2D pattern pieces were developed from the technical designs and garment specifications. The documented component categories include the front and back bodice, sleeves, hood, kangaroo-style pocket, sleeve cuffs, and lower hem components, together with contrasting pattern regions where shown in the style-specific layouts. The pattern pieces were arranged in the 2D workspace and positioned around a virtual avatar in the 3D environment. Corresponding pattern edges were connected through digital sewing relationships, fabric properties were assigned, and the garments were simulated. The resulting virtual garments were inspected for overall silhouette, panel alignment, front-to-back continuity, fabric drape, and visible positioning or collision issues. Front and back views were then used to compare the virtual appearance with the original sketches and technical flats. The available fit, stress, strain, and pressure-point visualizations were examined for one design only. Because the native project archive, avatar measurements, complete sewing relationships,

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fabric mechanical-property inputs, and simulation settings were not supplied, this description records the reported workflow but does not permit independent reproduction of every digital operation. Figure 1 summarizes the reported CLO3D workflow: 2D pattern development; avatar selection and pattern arrangement; digital sewing and fabric assignment; 3D simulation; inspection and refinement; and virtual-prototype presentation and diagnostic review.

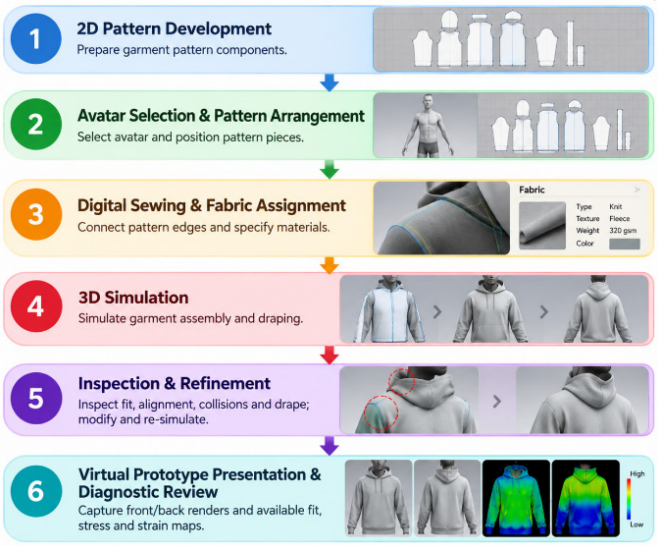


Figure 1 Reported CLO3D workflow sequence.

Stage 4: Technical specification documentation

The technical specification sheet connects the visual design with measurable garment characteristics. The supplied sheet records a size-M measurement schedule and material allocation for Style HD-0123HD-01. The project description states that the same base measurements and material specifications were used for all four designs; nevertheless, no separate style-specific sheets were supplied. Accordingly, the current manuscript reports the values as recorded in the available sheet and does not imply that four independently verified technical packs are available. A complete production-oriented technical pack would additionally identify measurement methods, tolerances, style-specific pattern differences, construction callouts, grading rules where applicable, fibre composition, and relevant fabric mechanical properties.

Analytical procedure

A descriptive cross-style comparison was conducted using six dimensions:

1) Silhouette and component configuration: the overall pullover form, hood, sleeves, cuffs, lower hem, and front pocket.
2) Panel geometry and colour distribution: the shape, direction, location, and visual continuity of contrasting regions.
3) Front-to-back and sleeve continuity: the correspondence of visible design features across adjacent garment views.
4) Representation consistency: the relationship among the pencil sketch, technical flat, 2D pattern layout, and 3D render.
5) Technical documentation: the availability and completeness of garment measurements, material allocation, and construction information.

Validation evidence: the availability of simulation diagnostics, physical fit checks, movement assessments, and wearer feedback

Ergonomic validation is treated as a subsequent research stage rather than a completed experiment. A defensible protocol would include the following activities:

1) Anthropometric matching: document the avatar's height, chest, waist, hip, shoulder, upper-arm, and other relevant dimensions, and establish their relationship to the intended garment size.
2) Garment measurement verification: compare the digital pattern measurements, specification-sheet values, and finished-garment measurements using identical points of measurement and defined tolerances.
3) Static and dynamic fit assessment: inspect garment balance, silhouette, ease distribution, seam placement, sleeve hang, hood positioning, pocket accessibility, and rib openings; then assess arm elevation, forward reaching, and cross-body movement while recording garment displacement and localized tension.
4) Virtual-to-physical comparison: where physical samples are produced, compare corresponding measurements and fit observations with the virtual prototypes under matched avatar, garment-size, and material conditions.

Evaluation criteria, sample size, participant recruitment, measurement equipment, and acceptance thresholds must be established before testing. Any human-participant study should follow the applicable institutional ethics and informed-consent requirements. This proposed protocol is not presented as an experiment conducted in the current study (Table 1).

Table 1 Methodological framework and evidence sources

Development stage	Available artefact	Analytical focus	Evidence status
Concept development	Four pencil-sketch sets	Silhouette and design intent	Available
2D technical representation	Four front-and-back flat sets	Panel lines, color regions, component placement	Available
3D virtual presentation	Four CLO3D render sets	Simulated appearance and front-to-back continuity	Available
Technical specification	One size-M specification sheet for Style HD-0123HD-01; shared base measurements reported for all styles	Measurements and material allocation	Partial; no separate style-specific sheets supplied
Fit and ergonomic validation	No test records supplied	Ease, movement, wearer feedback, virtual-to-physical comparison	Not established

Citation: Habib A, Sarker A, Mim TA. Design development and CLO3D-based virtual prototyping of a four-style contemporary men's hoodie collection. *J Textile Eng Fashion Technol.* 2026;12(5):322–331. DOI: 10.15406/jteft.2026.12.00479

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Results and analysis

Overview of the four-style collection

The four designs represent a coordinated men's pullover hoodie collection with a hood, long sleeves, ribbed sleeve openings and lower hem, and a front pocket treatment. Their differences arise primarily from panel geometry and the distribution of contrasting colours. This common garment category establishes collection-level consistency without making the styles visually identical. The progression from pencil sketches to technical flats, 2D pattern-layout screenshots, and 3D renders provides multiple representations of the same design concepts. The sketches communicate initial visual direction; the flats clarify visible panel arrangements; the pattern-layout screenshots show the digital arrangement of pattern pieces; and the renders present the simulated garments in three dimensions.

The available evidence supports a qualitative comparison of the four styles and their representations. The CLO3D workspace screenshots show the 2D pattern layouts beside the corresponding 3D garments, making the relationship between the digital pattern arrangement and the virtual appearance easier to inspect. However, screenshots do not provide the same level of verification as editable pattern files and complete sewing-line records.

Style 1: High-contrast grey-and-black construction

Style 1 combines a light-grey body with a black hood, a dark central front region, and darker details around the front pocket and lower sleeve areas. The central dark area anchors the front composition, while the darker sleeve regions visually connect the contrasting blocks. In the back view, a related dark lower-central region maintains a visual relationship with the front while preserving the overall grey-and-black palette. The composition is comparatively angular and centrally organized. The available CLO3D workspace screenshot places the 3D garment beside its 2D pattern layout, allowing the viewer to inspect the digital arrangement associated with the central and sleeve colour regions. The formal size-M specification sheet is identified as Style HD-0123HD-01. The supplied records do not establish whether every visible colour boundary is a separate sewn panel or a surface treatment.

The sketch, technical flat, and virtual render collectively communicate the high-contrast central composition. The back view retains the light-grey body and dark lower-central region, creating visual continuity with the front. Figure 2 presents the three design representations, while Figure 3 shows the corresponding CLO3D pattern layout. The render and layout support a visual comparison, but production-level seam matching and the status of each contrasting boundary require the native pattern and sewing records.

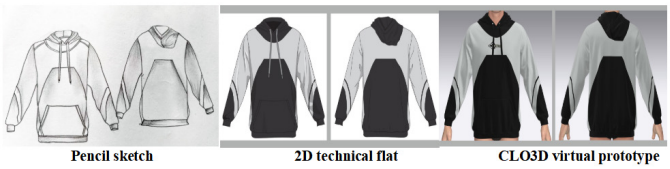


Figure 2 Style 1 design development.

Figure 3 shows the CLO3D pattern layout for Style 1. The screenshot presents the grey-and-black virtual hoodie alongside its 2D pattern pieces and documents the digital layout associated with the central colour-blocking arrangement.

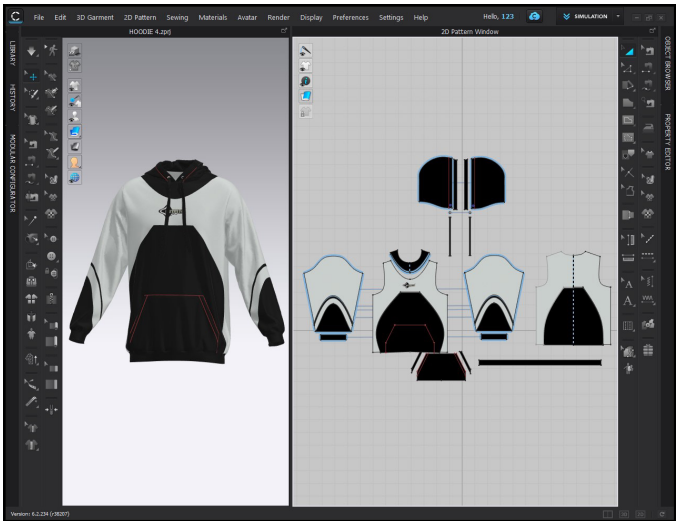


Figure 3 CLO3D pattern layout for Style 1.

Style 2: Light-blue-and-white organic panel design

Style 2 uses a light-blue upper region with curved, wave-like transitions into white lower-body and sleeve regions. These curved boundaries create a more organic visual rhythm than the angular arrangement of Style 1. The front pocket is located within the lower front region, while the back view carries the principal curved colour treatment across the body. The CLO3D pattern-layout screenshot shows the virtual hoodie alongside the corresponding 2D pattern pieces. The screenshot supports a visual comparison between the shaped pattern regions and the flowing colour-blocking concept; the exact status of each boundary as a sewn seam should be confirmed from the native pattern and sewing relationships.

Figure 4 illustrates the development of Style 2 from the original pencil sketch through the Adobe Illustrator technical flat to the CLO3D virtual prototype. The sequence highlights the light-blue-and-white palette and the curved panel arrangement across the front and back.

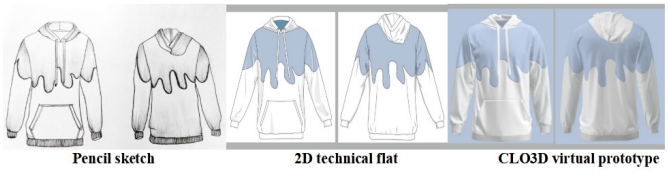


Figure 4 Style 2 design development.

Figure 5 shows the CLO3D pattern layout for Style 2. The screenshot presents the light-blue-and-white virtual hoodie alongside its 2D pattern pieces, including the shaped regions associated with the flowing colour-blocking concept.

Style 3: Burgundy-and-black geometric blocking

Style 3 combines burgundy and black to create a strong tonal contrast. The burgundy upper torso is visually framed by darker side, sleeve, and lower-body regions, producing a structured geometric composition. The back view retains the principal colour relationship so that the design remains recognizable from both sides. The CLO3D workspace screenshot shows the virtual hoodie beside its 2D pattern components. Particular attention is required at side seams, shoulder joins, and sleeve connections, where contrasting regions meet across adjacent pattern pieces. The render communicates the intended visual

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continuity, but it does not independently establish dimensional seam compatibility or production accuracy (Figure 6).

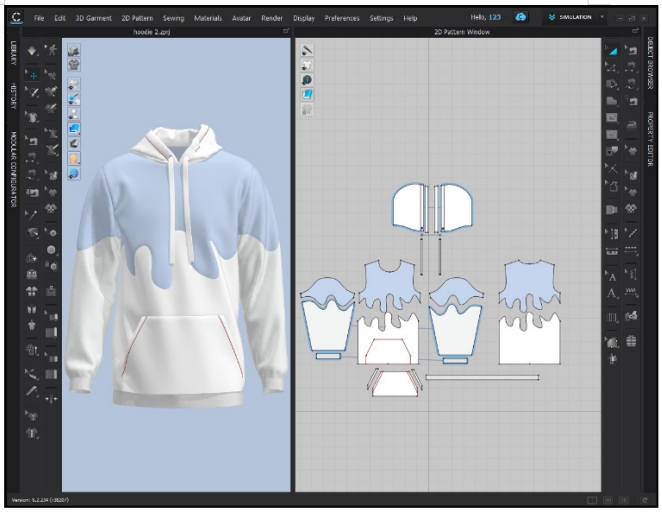


Figure 5 CLO3D pattern layout for Style 2.

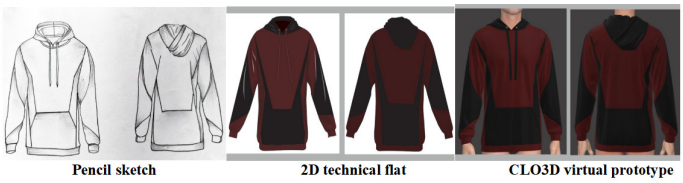


Figure 6 Style 3 design development.

Figure 7 shows the CLO3D pattern layout for Style 3. The screenshot presents the burgundy-and-black virtual hoodie with its 2D pattern components, documenting the digital layout associated with the geometric colour-blocking design.

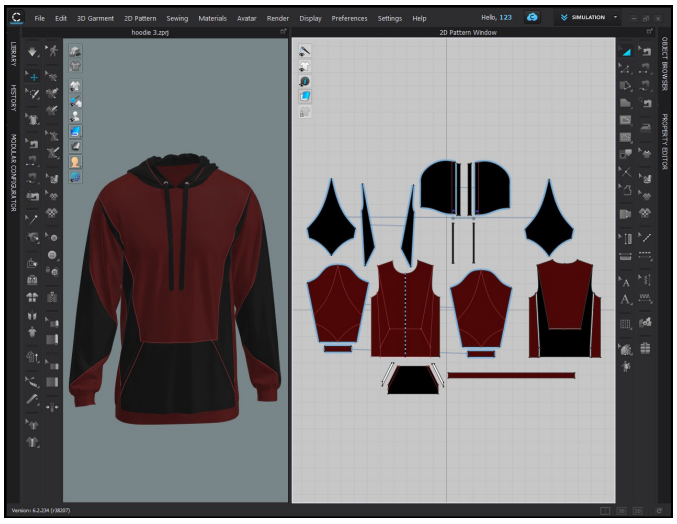


Figure 7 CLO3D pattern layout for Style 3.

Style 4: Beige, white, and brown diagonal blocking

Style 4 combines a beige upper region, a contrasting white diagonal band, and a deep-brown lower section. The diagonal boundary creates directional movement and distinguishes the design from the more centrally organized arrangements of Styles 1 and 3. The front and back views retain the broad diagonal colour-blocking concept, while the supplied representation also shows an asymmetric sleeve treatment. The CLO3D workspace screenshot presents the virtual garment alongside its 2D pattern pieces. For technical development, the diagonal joins require verification of seam orientation, panel matching, grain-line placement, and corresponding edge lengths.

The upper portion of the left sleeve in Figure 8 was identified by the reviewer as potentially inconsistent in colour or panel placement. The supplied screenshot alone does not establish whether this arrangement is intentional or a pattern/colour-assignment error. The sleeve treatment is therefore described as shown in the available representation, and the final design intent must be confirmed against the approved sketch and native pattern before the figure is accepted for production documentation. No correction has been inferred from the screenshot.

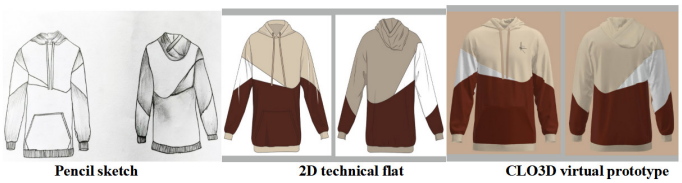


Figure 8 Style 4 design development.

Figure 9 shows the CLO3D pattern layout for Style 4. The screenshot presents the beige, white, and brown virtual hoodie alongside its 2D pattern pieces and documents the digital layout associated with the diagonal colour-blocking arrangement.

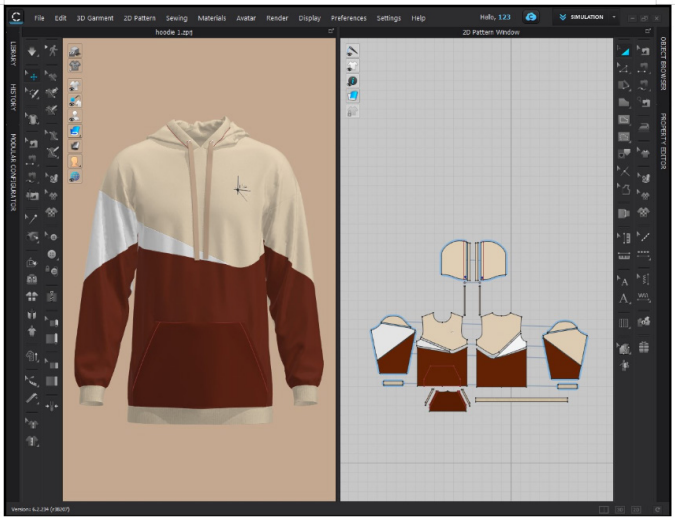


Figure 9 CLO3D pattern layout for Style 4 (left-sleeve colour/panel placement requires author verification).

Comparative design analysis

The collection demonstrates four approaches to surface composition within a shared garment category. Design differentiation is achieved primarily through colour distribution and panel geometry rather than through a change in the fundamental pullover-hoodie structure. Style 1 emphasizes a central angular contrast; Style 2 uses curved, wave-like transitions; Style 3 employs geometric framing and tonal contrast; and Style 4 introduces a diagonal, partly asymmetric composition. This common-category/different-geometry structure supports a focused analysis of how panel strategies are represented in technical flats and translated into 2D pattern layouts and 3D virtual garments. The comparison is descriptive and does not imply that one design has superior fit, comfort, or production performance (Table 2).

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Table 2 Comparative analysis of the four hoodie styles

Design dimension	Style 1	Style 2	Style 3	Style 4
Principal colors	Grey and black	Light blue and white	Burgundy and black	Beige, white, and brown
Panel geometry	Predominantly angular and central	Curved, wave-like boundaries	Strong geometric blocking	Diagonal and partly asymmetric
Visual emphasis	Central dark region	Organic color transitions	Tonal contrast and dark framing	Directional diagonal composition
Pocket treatment	Integrated with dark front region	Located in lower front region	Located within dark front area	Located within lower front region
Main distinction	High-contrast central composition	Flowing panel boundaries	Structured geometric contrast	Diagonal color segmentation
Specification supplied	One shared base sheet; no separate sheet supplied	One shared base sheet; no separate sheet supplied	One shared base sheet; no separate sheet supplied	One shared base sheet; no separate sheet supplied

Technical specification analysis

The available specification sheet records measurements for Style HD-0123HD-01 in size M. The project description states that the same base measurement schedule was applied across the four styles, but only the Style 1 sheet was supplied. The values below are therefore reported as recorded in that sheet; they should not be interpreted as four independently measured style-specific schedules.

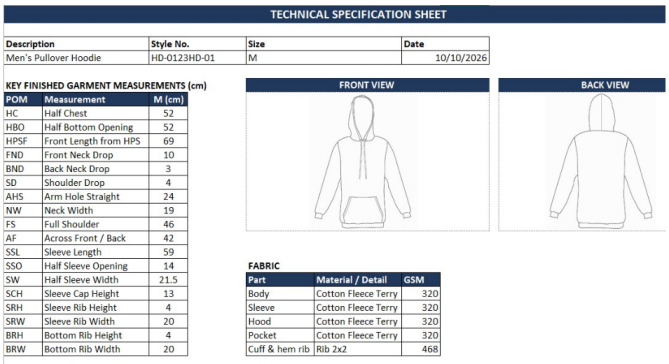
The sheet records half-chest and half-bottom-opening measurements rather than full circumferences. HC and HBO are both listed as 52 cm. This equality is a feature of the supplied record, but the available materials do not establish whether the finished garment is intended to gather at the lower hem or whether the drawing uses a schematic representation. The body-hem and relaxed rib-band measurements must be rechecked against the approved pattern or finished sample before a gathering ratio can be reported. The table also lists a single AF value for "Across Front / Back" (42 cm); because front and back bodice geometries differ, separate across-front and across-back values are needed for a complete technical specification. The source sheet does not define whether BRW = 20 cm is a cut-piece dimension, a finished flat width, or a half/full measurement. These ambiguities are reported as limitations rather than resolved by assumption (Table 3).

Table 3 Garment measurements transcribed from the supplied Style HD-0123HD-01, size-M specification sheet

POM	Measurement	M (cm)
HC	Half Chest	52
HBO	Half Bottom Opening	52
HPSF	Front Length from HPS	69
FND	Front Neck Drop	10
BND	Back Neck Drop	3
SD	Shoulder Drop	4
AHS	Arm Hole Straight	24
NW	Neck Width	19
FS	Full Shoulder	46
AF	Across-front / across-back (combined in supplied sheet)	42
ACF	Across front (not separately recorded)	Not reported
ACB	Across back (not separately recorded)	Not reported
SSL	Sleeve Length	59
SSO	Half Sleeve Opening	14
SW	Half Sleeve Width	21.5
SCH	Sleeve Cap Height	13
SRH	Sleeve Rib Height	4
SRW	Sleeve Rib Width	20
BRH	Bottom Rib Height	4
BRW	Bottom Rib Width	20

Figure 10 reproduces the supplied technical specification sheet for Style HD-0123HD-01, size M. It combines selected finished-garment measurements with front and back technical views and a component-level fabric specification. The sheet is the only formal style-specific specification document included in the supplied materials.

Figure 10 Technical specification sheet for Style HD-0123HD-01, size M.



Fabric specification and evidence status

The supplied sheet identifies 320 GSM cotton fleece terry for the body, sleeves, hood, and pocket, and 468 GSM 2×2 rib for the cuffs and lower hem. GSM denotes fabric mass per unit area and does not, by itself, fully characterize fibre composition, stretch and recovery, tensile behaviour, bending, shear, drape, compression, or thermal comfort. The supplied specification does not state the fibre percentages of the rib fabric or whether elastane is present. It also does not specify whether the hood is single- or double-layered, whether the drawstring channel is a separate casing or an integrated/folded construction, or how the kangaroo-pocket opening is finished. These details are important for accurate CLO3D material assignment and production documentation but cannot be established from the supplied sheet and screenshots. No claim about elastane content, hood layering, channel construction, or pocket finish is therefore made. Where supplier data or laboratory measurements are available, the material record should be expanded to include fibre composition and relevant mechanical properties (Table 4).[6,7]

Citation: Habib A, Sarker A, Mim TA. Design development and CLO3D-based virtual prototyping of a four-style contemporary men's hoodie collection. *J Textile Eng Fashion Technol.* 2026;12(5):322–331. DOI: 10.15406/jteft.2026.12.00479

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Table 4 Fabric allocation and construction information recorded in the supplied specification

Garment component	Recorded material	GSM	Composition / construction information in supplied record
Body	Cotton fleece terry	320	Fibre percentages and mechanical properties not stated.
Sleeves	Cotton fleece terry	320	Fibre percentages and mechanical properties not stated.
Hood	Cotton fleece terry	320	Layer count and drawstring-channel construction not stated.
Pocket	Cotton fleece terry	320	Kangaroo-pocket opening finish not stated.
Cuffs and hem	2×2 rib	468	Fibre blend and elastane content not stated.

CLO3D fit, stress, strain, and pressure-point maps

A combined CLO3D diagnostic screenshot is available for the beige, white, and brown hoodie shown in the corresponding virtual prototype. It presents four views: Fit Map, Stress Map, Strain Map, and Show Pressure Points. In the Fit Map view, the interface reports 0.0% for both "Can't Wear" and "Tight" under the displayed simulation setup. These values are reported strictly as software outputs for the shown avatar, garment state, and settings. They should not be interpreted as proof of wearer comfort, physical fit accuracy, or ergonomic validity.

The Stress Map uses a kilopascal (kPa) legend, while the Strain Map uses a percentage legend. The displayed colour distributions vary across the garment, with visible changes around the neckline/hood region and selected cuff and hem areas. The pressure-point view overlays blue markers across portions of the shoulders, upper torso, sleeves, cuffs, and lower garment. These patterns may identify locations for further inspection, but the screenshot does not provide an independently validated measure of discomfort or injury risk. Interpretation depends on avatar dimensions, pattern geometry, material parameters, simulation state, and the software thresholds used.[7,17,18]

The diagnostic maps add an exploratory layer beyond a beauty render because they make the software's fit classification and simulated stress/strain visualizations visible. However, only one combined diagnostic image was supplied, so the findings cannot be generalized to all four styles. The manuscript reports that the same base measurements were used across styles, but this does not establish identical fit behavior because panel geometry, seam arrangements, and material assignments may differ. The 0.0% "Tight" and "Can't Wear" classifications do not independently establish ergonomic validity. A stronger assessment would document the avatar and simulation settings, repeat the analysis for each style, and compare virtual observations with movement-based fit checks and, where feasible, physical garment or wearer evaluation.[18–21] Figure 11 presents the available diagnostic views for the displayed hoodie.



Figure 11 CLO3D fit, stress, strain, and pressure-point diagnostic views for the displayed hoodie.

Evidence status and validation requirements

The findings should be interpreted according to the type and completeness of the available evidence. The four designs are documented through sketches, technical flats, CLO3D renders, and screenshots of 2D pattern layouts. The supplied technical specification provides a size-M measurement and material record identified as Style HD-0123HD-01; the project description states that its base measurements were used across the four styles, but separate style-specific sheets were not supplied. Editable native pattern files, complete sewing relationships, detailed material inputs, and full simulation settings were not available for independent verification. No physical garment comparison, movement assessment, or wearer feedback was provided (Table 5).

Table 5 Evidence matrix for design documentation and performance validation

Outcome	Evidence available	Status
Four hoodie design concepts	Four sketch and visual-design sets	Documented
2D design representation	Four front-and-back technical-flat sets	Documented
3D virtual presentation	Four CLO3D front-and-back render sets	Documented as visual output
2D pattern layouts	Four CLO3D workspace screenshots; editable native files not supplied	Visible in screenshots; not independently verified
Garment measurement documentation	One size-M specification sheet for Style HD-0123HD-01; shared base measurements reported for all styles	Partially documented
Material specification	Component-level material descriptions and GSM values; fibre blend/mechanical properties incomplete	Partially documented
Virtual fit diagnostics	One combined diagnostic screenshot for the displayed Style 4 garment	Available for one style only
Virtual-to-physical fit agreement	No physical comparison data supplied	Not established
Movement compatibility	No documented movement assessment supplied	Not established
Wearer comfort	No participant feedback supplied	Not established
Development-time reduction	No time-study data supplied	Not established
Reduction in sampling or material waste	No comparative process data supplied	Not established

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Discussion

Contribution to integrated apparel design development

The contribution of this study lies in documenting the translation of four related panel-based hoodie concepts through complementary design and technical representations. The sketches establish design intent, the Illustrator flats clarify visible panel geometry and component placement, the CLO3D pattern-layout screenshots show the digital arrangement of pattern pieces, and the 3D renders communicate the resulting simulated garment form. Considered together, these artefacts provide a more traceable account of design development than a presentation of final renders alone. The workflow is not an automatic conversion from sketch to finished garment: each transition requires interpretation and technical decisions concerning pattern geometry, panel matching, sewing relationships, material assignment, and simulation.

Implications for apparel pattern engineering

The four styles demonstrate how different panel geometries can differentiate garments within a shared product category. However, the technical status of each visible boundary must be established. A contrasting region may be a separate cut component, an applied surface treatment, or a colour representation in the technical illustration. Production-oriented documentation should connect each confirmed panel seam to its pattern pieces and corresponding sewing lines. The current measurement schedule also requires separate across-front and across-back values, verified front/back armhole geometry, clearly defined rib dimensions, and annotated points of measurement. These additions are necessary to make the design record interpretable by pattern makers and product-development personnel.

Interpreting CLO3D simulation

The CLO3D renders and diagnostic maps provide useful visual information for examining the simulated garment, but their interpretation depends on the avatar, pattern geometry, material parameters, sewing relationships, and simulation settings. Fabric mass alone does not describe mechanical behaviour; tensile, bending, shear, and structural properties can influence virtual ease and strain distribution.[6,7] Comparative research has also identified differences between virtual and physical fit assessments, emphasizing the need for carefully defined avatars and physical comparison where fit accuracy is a research outcome.[7,18,20] The 0.0% "Tight" and "Can't Wear" outputs in the available Fit Map are therefore reported as software results for one displayed simulation, not as validated evidence of comfort or ergonomic suitability.

Ergonomic implications and validation

The current evidence does not establish that the four hoodies are ergonomically validated. Ergonomic suitability depends on the relationship among the garment, wearer anthropometry, intended movement, pattern geometry, construction, and material behaviour. A subsequent assessment should combine static and dynamic fit evaluation. Static review should examine garment balance, chest and body ease, shoulder and armhole configuration, sleeve hang, hood positioning, pocket accessibility, and rib openings. Dynamic review should examine arm elevation, forward reaching, and cross-body movement, recording garment displacement and localized tension. Physical samples and wearer feedback would be needed to assess tactile comfort and compare the virtual prototype with actual garment behaviour.[18,20,21]

Limitations and future research

This study has several limitations. First, the analysis is based on the supplied design artefacts and screenshots rather than a complete native CLO3D project archive. Editable pattern files, complete sewing relationships, avatar measurements, fabric mechanical properties, and full simulation settings were not available for independent verification. Second, the supplied technical measurement sheet is identified as Style HD-0123HD-01. Although the project description states that the same base measurements were applied to all four styles, equivalent style-specific specification sheets and construction callouts were not supplied.

Third, the available measurement schedule combines across-front and across-back into one value and does not define the measurement convention for the 20 cm bottom-rib width; the chest and bottom-opening values are both recorded as 52 cm, but the intended hem-to-rib relationship could not be independently verified. The material record does not identify the rib fibre composition or elastane content, hood layer count, drawstring-channel construction, or kangaroo-pocket opening finish. Fourth, the combined diagnostic-map screenshot is available for one style only and cannot establish fit behaviour across the collection. Finally, no physical prototypes, wearer-based evaluations, movement assessments, or virtual-to-physical comparisons were supplied.

Future work should complete the technical packs for all four styles, verify the front and back pattern measurements, define the hem-rib and pocket/hood construction details, and obtain supplier or laboratory data for fibre composition and relevant fabric mechanical properties. The avatar dimensions and CLO3D material and simulation inputs should also be documented. Structured static and dynamic fit assessments should then be conducted for each style. If physical samples are produced, their measurements and fit observations should be compared with the corresponding virtual prototypes under matched conditions. A wearer study could subsequently assess comfort, mobility, and perceived design quality under appropriate ethical approval and informed-consent procedures.

Conclusion

This study documents the development of four contemporary men's pullover hoodie styles through hand-drawn sketches, Adobe Illustrator technical flats, CLO3D pattern-layout screenshots, three-dimensional virtual garment views, and the available technical specification record. The styles share a common garment category while differing in colour distribution and panel geometry, including angular, curved, geometric, and diagonal arrangements. The combined artefacts demonstrate a structured approach to translating design concepts into technical representations and virtual prototypes. The available CLO3D diagnostic image provides exploratory software-generated information for one design, but it does not establish physical fit accuracy, wearer comfort, or ergonomic validity.

The principal requirements for further development are complete and consistent specification sheets for all four styles, verified front/back pattern measurements, explicit hood, pocket, and rib construction details, documented fabric composition and mechanical properties, and reproducible CLO3D avatar and simulation settings. Physical prototype comparison and structured wearer-based assessment would provide the evidence needed to evaluate actual garment fit and movement compatibility. The study therefore contributes a traceable design-to-virtual-prototype workflow while clearly distinguishing

documented design outputs from performance outcomes that remain to be validated.

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Conflicts of interest

The authors declare that they have no conflicts of interest.

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