Panggung
Volume 36
Number 3. Reimagining Arts and Culture: Tradition, Innovation, and Social Transformation Article 5

September 1, 2026

Outerwear Design Aligned with Zero-Waste Concept: From Flat Pattern to Three-Dimensional Simulation

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Recommended Citation
Rifaah, I., Hutama, T.S., Kuswinarti, Arief, M. Outerwear Design Aligned with Zero-Waste Concept: From Flat Pattern to Three-Dimensional Simulation. *Panggung,* Vol. 36, No. 3, Article 5.

Available at: https://jurnal.isbi.ac.id/index.php/panggung

Outerwear Design Aligned with Zero-Waste Concept: From Flat Pattern to Three-Dimensional Simulation

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Abstract
In this modern day, fashion products can be developed and visualized using 3D garment simulation software, enabling designers to transform flat pattern into three dimensional formns on digital models. While conventional flat patterns typically follow basic shapes, zero-waste design requires pattern shapes to be developed in relation to fabric dimensions and material utilization. In this study, the zero-waste concept refers to the alignment between pattern shapes and fabric utilization to minimize material waste. The research focuses on loose-fitting, unisex outerwear as the object of study. A qualitative method is employed to examine the transformation of flat patterns into three-dimensional garments. The objective is to identify simple pattern configurations that correspond efficiently with marker layouts used in fabric cutting. The findings reveal that rectangular shapes with strategically placed cut-line openings provide the most effective solution for zero-waste outerwear. These results are demonstrated through 3D garment simulation to enhance understanding of pattern transformation.
Keywords:
Flat pattern, three-dimensional simulation, zero-waste concept, transformation, marker.

Received on April 15, 2026; Accepted August 5, 2026

INTRODUCTION

Outerwear products are one of the items in the production of fashion collection apparel. Apparel means various types of clothing and accessories released from a seasonal fashion collection. Fashion is related to design, designing various apparel that has a basic material in the form of fabric must has be thought carefully. Consideration about the effectiveness and efficiency of the fabric consumption and the waste is necessary.

The innovative way to make this happen is by making a design from a designer who has knowledge of basic flat patterns, followed by a marker (the placement plan of the pattern on the fabric before the fabric is cut). An innovative approach in contemporary fashion design involves the use of software equipped with 3D garment simulation, which enable designers to observe how fabric behaves and drapes on the human body. This technology provides a dynamic and realistic method for evaluating garment forms beyond traditional visualization techniques. The simulation process begins with the input of flat garment patterns, followed by the arrangement of stitching lines and the selection of fabric properties that closely resemble real-world textiles. These parameters play a crucial role in determining the accuracy of garment fit, fabric drape, and overall structural behavior. Through this system, designers can assess how different materials influence the final appearance of a garment.

Furthermore, there are animation features within the software allow for dynamic visualization of transformations. The transition becomes particularly evident when the simulation is activated, as the system directly demonstrates the gradual change from two-dimensional flat patterns into fully realized three-dimensional forms. This real-time transformation not only enhances design understanding but also supports more precise decision-making in the development of garments.

Outerwear consists of three primary components: the upper body pattern (front and back) and the sleeves. Within the upper body pattern, the curved lines at the neckline and armholes represent critical and complex construction points, as their curvature must adapt to both design intent and the wearer's body shape. The integration of front and back patterns further increases complexity, particularly in forming the armholes, which must correspond precisely with the sleeve pattern to ensure proper fit and mobility. These three components must be carefully arranged within the marker, which refers to the layout of pattern pieces on fabric prior to cutting. Marker making is the process of determining the most efficient layout of pattern pieces for a particular style of fabric and size distribution (Puranik, 2017: 30)

In relation to fabric structure, the placement of patterns is closely aligned with the direction of the yarns, namely the warp and weft. Fabrics are produced through the interlacing of warp and weft yarns, resulting in a continuous rectangular form when distributed in rolls. In the Image 1., the warp direction is positioned horizontally along the length of the fabric, while the weft runs in the opposite direction (vertical). Marker planning generally aligns pattern pieces with the warp direction to maintain structural stability and consistency in garment behavior.

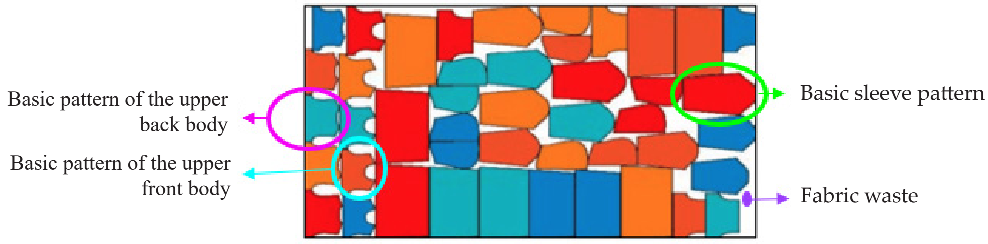

Image 1. Example of marker plan with details of basic pattern shapes (fabric consumption) and waste.
(Source: Puranik, 2017)

When graded patterns are involved (e.g., sizes S, M, L, XL), the same directional principle is maintained; however, the arrangement of different sizes may vary and be positioned more flexibly to maximize fabric efficiency. This strategic placement is essential in supporting the zero-waste concept, as it ensures optimal use of fabric area while accommodating all necessary garment components.

The zero-waste concept refers to the relationship between pattern shapes and fabric consumption, with the aim of minimizing fabric waste. The European Environmental Agency (EEA) has identified fashion and textiles as the industry with the fourth highest consumption of primary resources, trailing only food, housing, and transportation (EEA2019) (Aponte, 2024:1). Consumption in the fashion industry is a significant contributor to waste. Implementing the zero-waste concept is one approach to reducing material waste in the fashion industry. Fabric waste in garment production is commonly estimated to range between 10% and 20%, with an average of approximately 15% (Feyerabend, 2004; Cooklin, 1997; Abernathy, 1999; as discussed in Rissanen & McQuillan, 2018).

The use of rectangular shapes in zero-waste garment design is grounded in the fundamental structure of woven textiles. From the Image 1. it is known that there are pattern configuration, fabric consumption, waste, and boundaries of fabric area (indicated by the black outline of the rectangle representing the fabric edge). This rectangular shape reflects the fundamental construction of woven textiles, which warp and weft yarns inerlace perpendiculary to form a structured surface with defined length and width. Consequently, the geometric characteristics of woven fabric make rectangular pattern configurations a logical and efficient approach to garment pattern development. By adapting pattern shapes to inherent geometry of the fabricn the available fabric area can be utilized more efficiently, with the result minimizing fabric waste. The rectangular pattern simplifies marker planning, as it can be systematically arranged along the warp, which is essential for maintaining fabric stability and consistent stretch. Compared to conventional patterns that involve curved and irregular shapes, rectangular configurations reduce unused negative spaces within the marker layout.

From a design perspective, the use of rectangular shapes also encourages a rethinking of

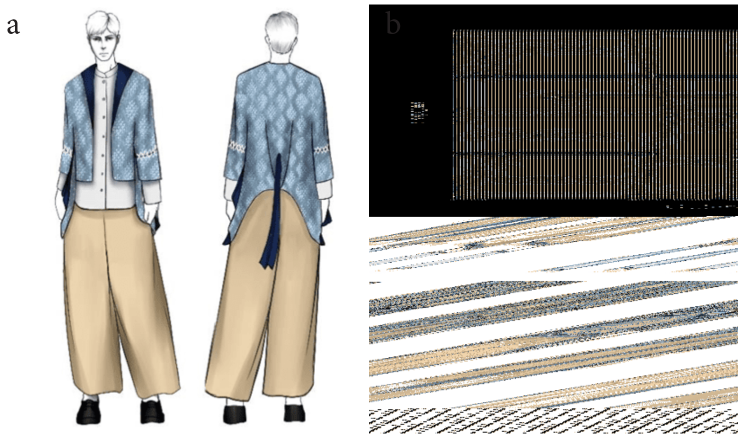

Image 2. (a) Illustration of Outerwear 1; (b) Illustration of Outerwear 2.
(Source: Personal Documentation, 2024)

traditional garment construction. Rather than imposing shape through excessive cutting, garments' shapes emerge through strategic folds, arrangements, and openings. Therefore, when designer create an illustration of the outerwear, these elements must be considered in alignment with the zero-waste principle, where material efficiency and design innovation are integrated into the pattern-making process.

This outerwear design incorporates a layered construction consisting of a light blue viscose fabric with a diamond pattern as the outer layer and a dark blue satin fabric as the inner layer. The use of a two-layer system is functionally justified, as outerwear is intended to provide protection against environmental factors such as wind and temperature variation, which generally requires a certain level of thickness and insulation. Viscose as the primary material is lightweight and possesses good draping qualities. However, the relatively low structural density of the viscose fabric necessitates the addition of an inner layer to improve thermal performance, opacity, and overall garment stability. The selection of satin as the inner layer contributes not only to increased thickness but also to a smoother surface finish that improves wearing comfort. The garment is designed with a loose-fitting silhouette to accommodate the concept for unisex wear, allowing flexibility of movement and adaptability across different body types.

The design exploration is further developed through two outerwear variations, each emphasizing different fabric orientations and opening constructions. The first design (in Image 2a) follows a more conventional approach, featuring a vertically oriented opening aligned with a horizontally positioned grain direction (weft), ensuring structural stability and predictable drape behavior. In contrast, the second design (in Image 2b) maintains the same grain orientation but introduces a diagonal pattern, allowing the fabric to fall along the bias direction. This approach enhances fluidity and creates more dynamic folds, demonstrating how directional fabric properties can influence both the aesthetic and structural outcomes of the garment.

Method

The methodology used in this research is qualitative, focusing on the process of transforming a flat pattern into a three-dimensional garment using CLO 3D software. The software provides tools for pattern creation and realistic three-dimensional garment visualization, enabling the researcher to evaluate the transformation of flat pattern into three-dimensional visualization.

The software interface consist of two main display sections, the left side is a realistic three-dimensional garment simulation, while the right side displays the flat pattern. It offers various features, such as fabrics selection, motif placement, stitching, and avatars costumization. However, because this study focuses on developing the outerwear shapes that aligns with zero-waste concept, motif placement, stitching, and avatars costumization are not explored extensively. Viscose and Satin fabrics, along with their respective colors, are available within the sooftware. Therefore, the exploration focuses on directing the transformation flat patterns into three-dimensional simulations and examining the result of fabric drape on the human body .

Following a field survey, it was identified that viscose fabric—particularly those produced by jacquard weavers in Garut—commonly has dimensions of 110 × 250 cm, which corresponds to the standard size used for traditional bottom garments. In comparison, satin fabric produced by textile manufacturers typically has a width of 125 cm. However, in this study, the satin is adapted as an interlining layer with a length adjusted to 250 cm, matching the dimensions of the viscose fabric to ensure compatibility in construction.

Based on these material constraints, the design development adopts a zero-waste approach, where the entire fabric area is utilized without leaving unused remnants. This requires the pattern configuration to fully correspond to the rectangular dimensions of the textile. Consequently, the rectangle is selected as the primary geometric basis for the flat pattern design, as it aligns directly with the inherent form of the fabric. The fabric is conceptually divided into two sections along its length, each measuring 250 cm, where outerwear 1 is positioned on one side (left or the blue area) and outerwear 2 on the other (right or the yellow area). Furthermore, the additional 15 cm width available in the satin fabric is strategically utilized for smaller garment components, such as belts and collars. This allocation demonstrates an optimization strategy in zero-waste design, where even marginal fabric areas are systematically incorporated into the overall garment construction. Through this approach, material efficiency is maximized while maintaining design functionality and coherence.

In the illustration, Outerwear 1 features a center-front opening. The different lengths of the left and right sides of the hem are achieved through rectangular or trapezoidal pattern shapes. Outerwear 2 features a draped shape at the hem; therefore, a diagonal line is incorporated into the flat pattern to create a bias direction. This concept is translated into the pattren configuration shown in Image 5. The solid red lines from the flat pattern indicate the opening and cutting lines of the fabric, while the red dashed lines indicate the fabric folds that contribute to the formation of the three-dimensional garment shapes.

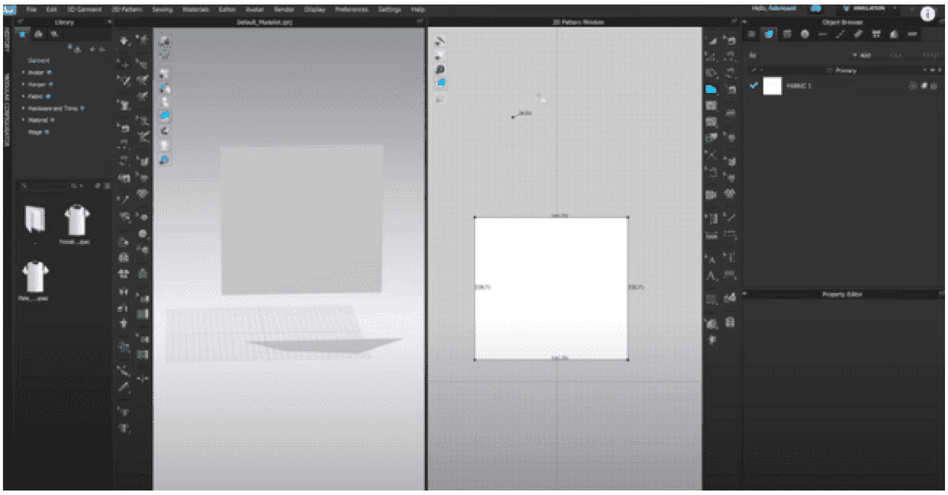

Image 3. 3D CLO view.
(Source: Personal Documentation, 2024)

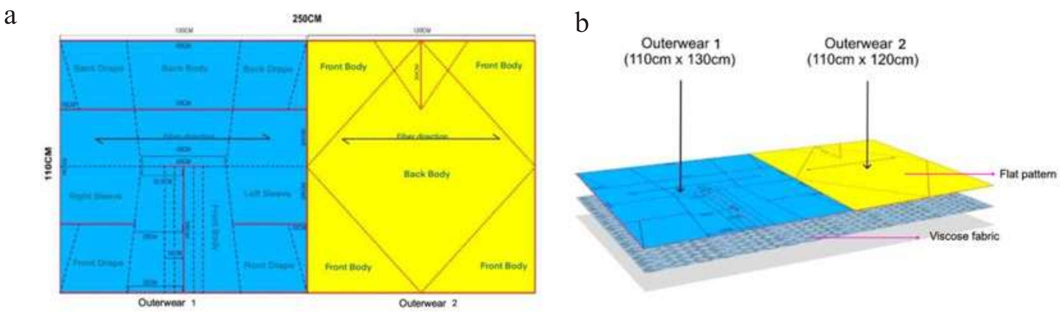

Image 4. (a) the marker of two outerwear in main fabric;
(b) the marker or flat pattern placed above the main fabric (Viscose).
(Source: Personal Documentation, 2024)

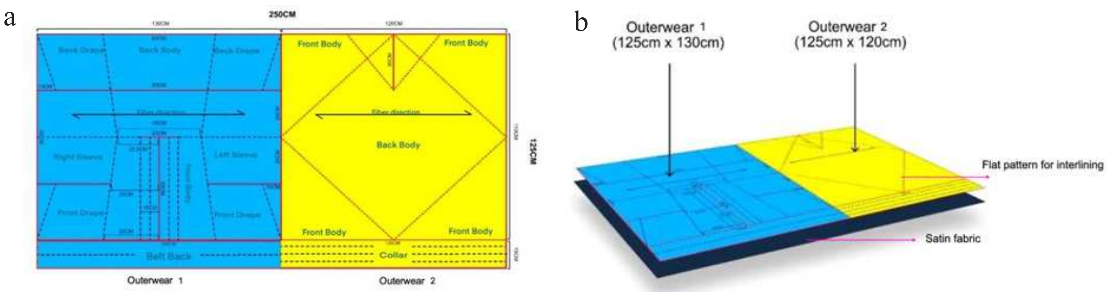

Image 5. (a) the marker of two outerwear in interlining fabric;
(b) the marker or flat pattern placed above the interlining fabric (Satin).
(Source: Personal Documentation, 2024)

RESULT AND DISCUSSION

The outerwear designs developed using flat patterns and the expected fabric drape illustrated in the initial designs were evaluated using CLO 3D software with 3D garment simulation. Through 3D garment simulation, the transformation of the garment from a flat pattern into a three-dimensional form can be clearly visualized. The software provides features for fabric selection and pinch tools that help control the direction of fabric drape according to the material's characteristics and gravity.

From Image 6. shows Outerwear 1 constructed with viscose fabric (light blue) as the main material, while Image 7. shows dark blue satin used as the interlining (inner layer) of the garment Outerwear 1. In this Image, the transformation process is characterized by several cutting lines arranged predominantly in horizontal and vertical directions. These cutting lines generate structural folds that define the final garment shape. Without simulation, the interpretation of such pattern configurations may be difficult, particularly for individuals without a background in pattern making, as the relationship between flat pattern and the final three-dimensional form is not immediately apparent. However, the 3D garment simulation clearly demonstrates how each pattern component contributes to the overall garment construction. In Image 6b, the horizontal cut lines reveal the distribution of garment components, where the central sections form the sleeves, the lower portions develop into the front body, and the upper sections become the back body. Additionally, in Image 7. scene (b) the triangular shapes visible above the main pattern represent supplementary components, such as belt accessories.

Importantly, the simulation results confirm that outerwear 1, which follows a conventional rectangular pattern approach with horizontal–vertical cutting directions, produces a garment characterized by a flared drape. This flare appears as folded extensions on the lower left and right sides in the bottom of the garment, resulting from the structured alignment of the pattern with the warp and weft directions. The outcome demonstrates a relatively predictable and controlled fabric behavior, consistent with conventional pattern making logic.

In contrast, as shown in Image 8. and Image 9., outerwear 2 shows a transformation process based on fewer but more strategically placed cutting lines oriented along the diagonal (bias) direction of the fabric. In scene (a), the flat pattern appears ambiguous and does not directly indicate the final garment form. During scene (b), the simulation process reveals how the fabric flips and adapts dynamically as it transitions into a three-dimensional structure. The final result in scene (c) shows a distinct draped form concentrated at the lower edges of the garment. The simulation further demonstrates that the diagonal orientation of the pattern significantly influences fabric behavior. Unlike outerwear 1, the bias direction allows the viscose and satin fabrics to exhibit increased flexibility, resulting in softer and more fluid drape characteristics. The lower part of outerwear 2 forms natural draping effects rather than structured flares, indicating a more organic response to gravity and movement.

These findings highlight the critical role of pattern orientation in determining garment form. While horizontal–vertical configurations produce structured and predictable silhouettes, diagonal (bias) configurations generate more dynamic and fluid outcomes. The use of 3D garment simulation in this study successfully validates these differences, providing a clear visualization of how flat patterns are transformed into three-dimensional garments and enabling a more accurate evaluation of design intentions.

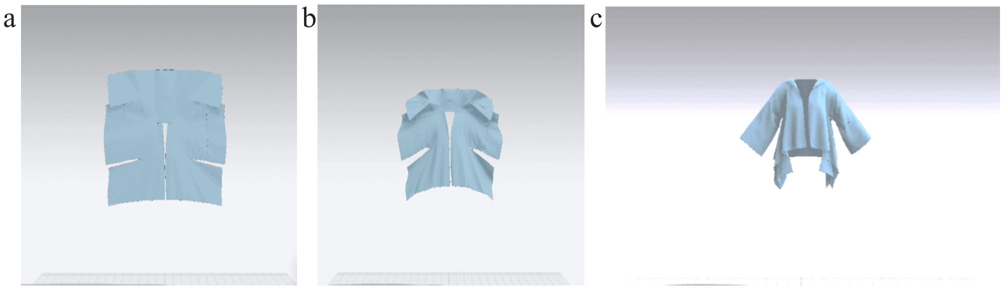

Image 6. (a) the first scene of the flat pattern outerwear 1; (b) the second scene of the transformation; (c). the third scene is the outerwear 1 in three-dimensional simulation using main fabric (Viscose).
(Source: Personal Documentation, 2024)

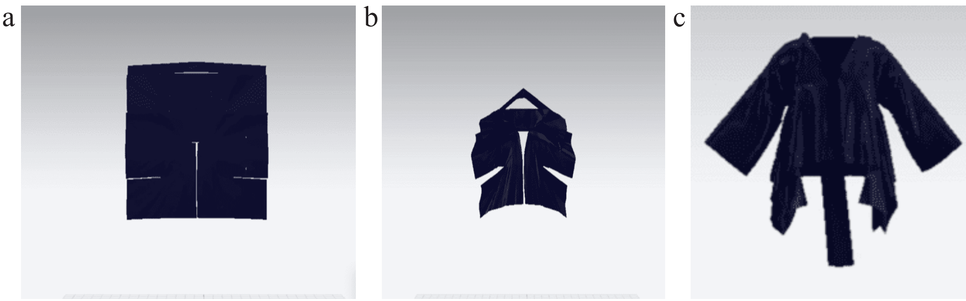

Image 7. (a) the first scene of the flat pattern outerwear 1; (b) the second scene of the transformation; (c). the third scene is the outerwear 1 in three-dimensional simulation using interlining fabric (Satin).
(Source: Personal Documentation, 2024)

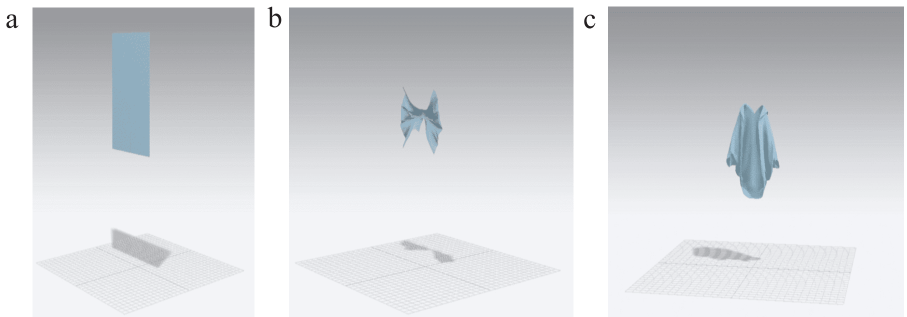

Image 8. (a) the first scene of the flat pattern outerwear 2; (b) the second scene of the transformation; (c). the third scene is the outerwear 2 in three-dimensional simulation using main fabric (Viscose).
(Source: Personal Documentation, 2024)

3D garment simulation provides a realistic and analytical approach to evaluating fashion design, as demonstrated through the use of CLO3D software, which enables detailed three-dimensional visualization of garments. This technology allows designers to observe not only the transformation process from flat patterns to three-dimensional forms, but also the interaction between fabric properties, garment construction, and gravitational forces. Through

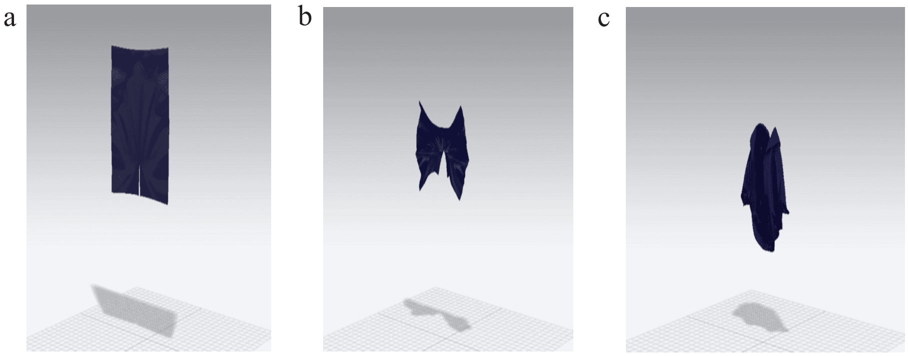

Image 9. (a) the first scene of the flat pattern outerwear 2; (b) the second scene of the transformation; (c). the third scene is the outerwear 2 in three-dimensional simulation using interlining fabric (Satin).
(Source: Personal Documentation, 2024)

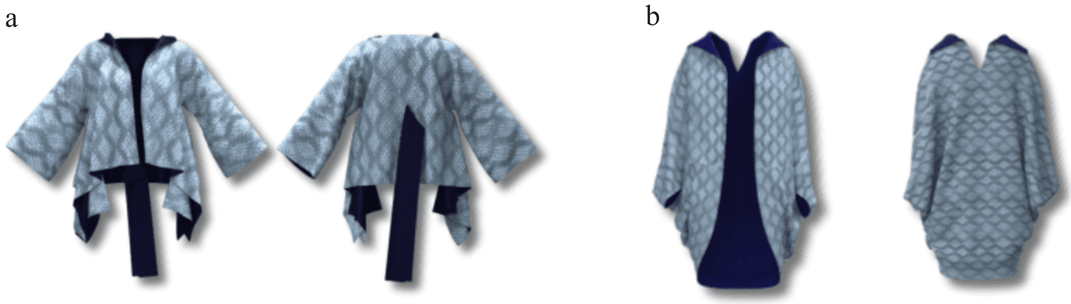

Image 10. (a) Outerwear 1 final look; (b) Outerwear 2 final look.
(Source: Personal Documentation, 2024)

this simulation, aspects such as fabric weight, drape behavior, and structural response can be assessed with a high degree of accuracy prior to physical production.

Based on Image 10, the final simulated appearance of both outerwear designs can be clearly observed and compared with the initial fashion illustrations. Outerwear 1 demonstrates a high level of consistency between the conceptual design and the simulation outcome. The overall silhouette, proportion, and fabric fall align closely with the designer's initial expectations. The structured pattern configuration, which follows horizontal and vertical alignment, results in a controlled drape with subtle flare effects on the lower sides of the garment. This indicates that conventional pattern orientation produces predictable and stable garment behavior when translated into three-dimensional form.

In contrast, Outerwear 2 exhibits a significant variation between the initial illustration and the simulation results. While the general form is maintained, the behavior of the fabric differs notably due to the diagonal (bias) orientation of the pattern. The simulation reveals that the lower side areas of the garment develop pronounced pleats that naturally fold toward the center front opening. These folds emerge as a direct response to gravity acting on the bias-cut fabric, which allows greater flexibility and movement compared to warp-aligned structures.

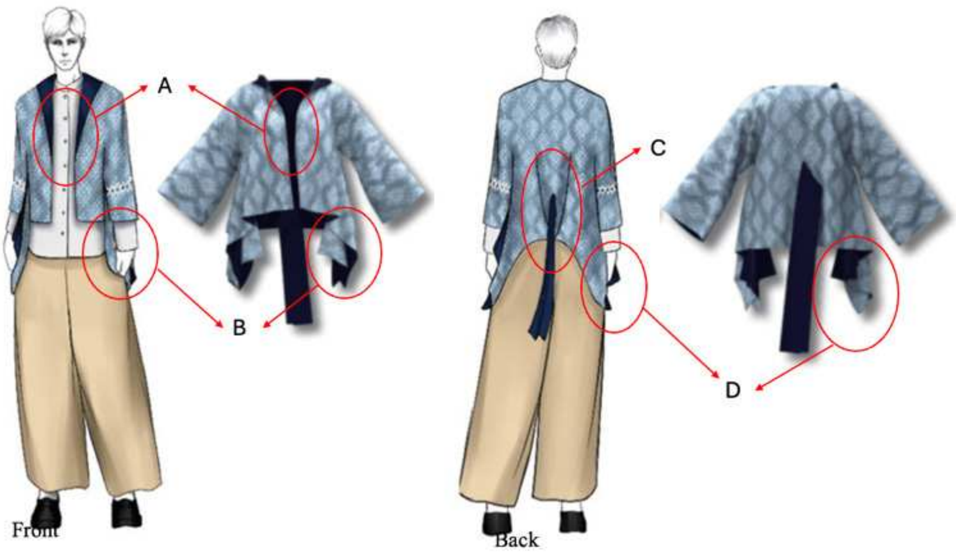

Image 11. The comparison between illustration and digital final look of outerwear 1
(Source: Personal Documents, 2024)

This outcome highlights an important finding: while design illustrations can suggest intended forms, the actual behavior of fabric (especially when manipulated along the bias) can produce unexpected yet realistic results. The 3D garment simulation thus serves as a critical tool for validating and refining design intentions, bridging the gap between conceptual visualization and material reality.

Based on the comparison presented in the figure, the overall form of the outerwear shows a strong visual consistency between the initial fashion illustration and the 3D garment simulation results. The general silhouette, proportion, and structural composition remain aligned, indicating that the translation from conceptual design to three-dimensional simulation is largely successful. However, several notable differences can be identified in specific areas.

At the front view, section A demonstrates that the neckline opening appears shorter in the simulation compared to the illustration, where it was initially envisioned to extend further downward. This difference suggests that the behavior of the fabric and the structural constraints of the pattern influence the final length of the opening. In sections B and D, the flared drape located at the lower sides of the garment exhibits a variation in form, where the folds in the simulation create two distinct angular edges rather than the smoother, more fluid drape illustrated in the original design.

At the back view, section C reveals another discrepancy. In the illustration, the wider pattern shape was expected to generate pronounced folds at the back of the garment. However, the simulation indicates a more controlled and less exaggerated fold formation. This outcome highlights a critical insight: although viscose and satin are individually known as lightweight and fluid materials, their combination and construction within a layered garment result in a

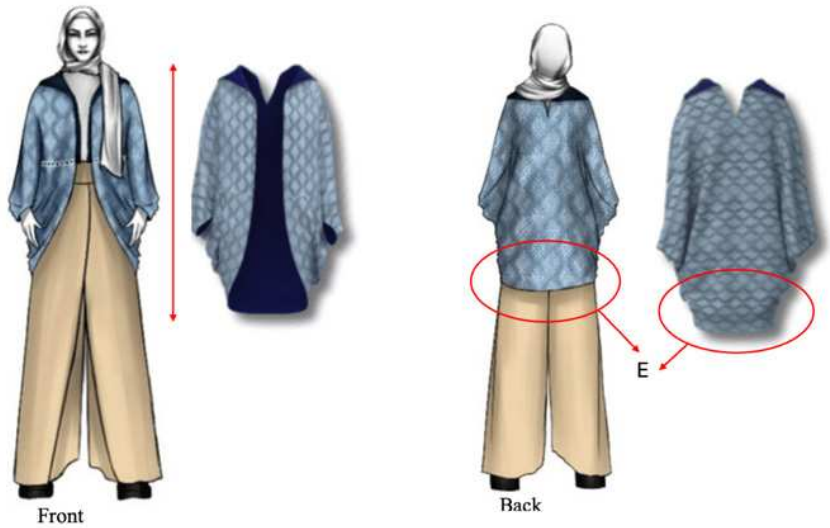

Image 12. The comparison between iluustration and digital final look of outerwear 1
(Source: Personal Documents, 2024)

more structured and stable drape. Consequently, the fabric falls in a firmer manner than initially anticipated in the illustration, which tends to depict a softer and more exaggerated flow. This difference underscores the importance of simulation in accurately predicting material behavior beyond intuitive design assumptions.

Based on the comparison between the initial illustration and the simulation results, the overall design of this outerwear demonstrates a clear correspondence in silhouette and concept; however, several notable differences can be observed. One of the primary distinctions lies in the perceived garment length. In the initial illustration, the outerwear appears shorter, reflecting a more intuitive and interpretative approach by the designer. In contrast, the 3D garment simulation presents a longer and more proportionally accurate garment. This difference is attributed to the use of measurable and structured pattern construction within the simulation process, which produces a more precise representation of garment dimensions compared to the subjective estimation in illustration.

Additionally, a variation can be observed in the lower section of the outerwear, particularly at the back view (section E). In the illustration, the lower silhouette appears wider and more relaxed, suggesting a looser drape. However, the simulation reveals that the garment gradually tapers inward toward the hip area, resulting in a more compact and controlled form. This outcome is influenced by the interaction between pattern geometry, fabric weight, and gravitational forces, which are accurately calculated within the simulation environment.

However, despite its advantages, the software still presents several technical limitations that affect the accuracy of the simulation results. As illustrated in Image 13, visual inconsistencies such as glitches and fabric penetration ("fabric through") occur during the transformation

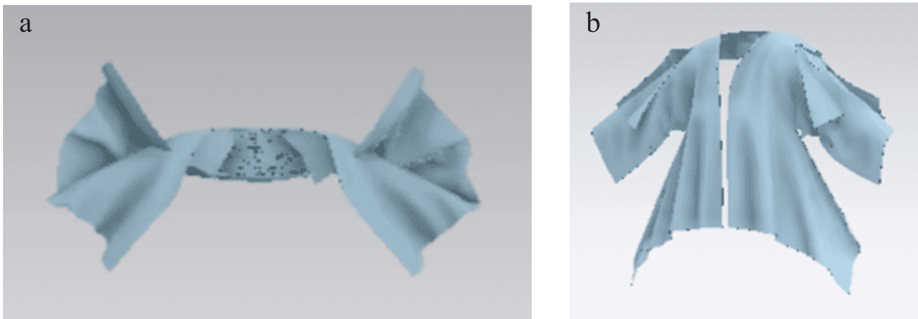

Image 13. (a) glitches; (b) fabric penetration during the transformation simulation process.
(Source: Personal Documents, 2024)

process from flat patterns to three-dimensional forms. In Figure 13(a), the distortion in the central area indicates instability in the simulation when handling complex folds or tension between pattern pieces. Meanwhile, Figure 13(b) shows fabric intersecting unnaturally at the shoulder area, suggesting that collision detection and layering between garment components are not fully optimized.

These issues highlight limitations in the software's physics engine, particularly in simulating the interaction between multiple fabric layers and structural stress points. In addition, the software does not yet allow precise control over variations in fabric thickness and density according to specific fiber types or textile structures. As a result, the simulated drape and volume may not fully represent real-world material behavior, especially when combining lightweight fabrics such as viscose with smoother, denser materials like satin. Therefore, while 3D garment simulation is highly useful for visualizing garment transformation, its results must still be interpreted critically and supplemented with material knowledge and physical prototyping to ensure design accuracy.

Conclusion

The findings of this study demonstrate that the transformation of flat patterns into three-dimensional garments can be effectively analyzed through 3D garment simulation. The comparison between initial fashion illustrations and simulation results reveals both alignment and deviation in garment form and fabric behavior. These differences highlight the limitations of manual illustration in predicting exact garment proportions and fabric behavior, while emphasizing the advantage of 3D garment simulation as a tool for achieving more reliable and realistic design validation. Through simulation, the interaction between pattern structure, fabric properties, and gravity can be observed more objectively, providing a more accurate representation of the final garment.

In today's era, where Artificial Intelligence (AI) is increasingly accessible and integrated into everyday life, its application in the fashion sector continues to expand significantly. AI enables designers to visualize garments in realistic three-dimensional forms, enhancing both the design process and decision-making. Various software and applications now support the development of fashion products, ranging from assembling garment components into a complete look to transforming flat patterns into avatar-based simulations that closely resemble real-life conditions. As technology continues to evolve, AI-driven tools are expected to become more advanced, offering improved accuracy, efficiency, and creative possibilities in fashion design.

Regarding the objective of this research, which is to explain the transformation of outerwear flat patterns based on the zero-waste concept into three-dimensional forms using 3D garment simulation, the study can be considered successful. The results show that each outerwear design, constructed from distinct flat pattern configurations and combining two different fabrics and colors, presents its own level of complexity in the transformation process. Furthermore, directing fabric behavior within the simulation environment requires a certain level of technical familiarity, as designers must understand how to manipulate digital tools to achieve the intended garment form.

Finally, this research confirms that the use of rectangular pattern shapes, aligned with the original dimensions of the fabric, is an effective strategy in implementing the zero-waste concept to minimize production waste. By utilizing the full fabric area and optimizing pattern placement, material efficiency can be achieved without compromising design innovation. The outcomes of this study are presented through AI-based three-dimensional simulations, demonstrating the transformation of flat rectangular patterns into wearable outerwear designs. This approach not only contributes to sustainable fashion practices but also serves as a visual and educational reference for broader public understanding of pattern transformation in contemporary fashion design.

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