A study of types of silhouettes in women's clothing

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ABSTRACT – REZUMAT

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This research focuses on reviewing fashion trends from the past decade, with a particular emphasis on identifying unique silhouettes that deviate from traditional classifications. These new silhouettes often combine two existing shapes, straight and A-line, or feature unusual combinations like fitted and colourful styles. The study seeks to expand the classification of women's fashion silhouettes by introducing new combined shapes that reflect modern trends and consumer preferences. By integrating traditional and contemporary designs with qualitative and quantitative analysis, the research enhances statistical reliability and supports designers and retailers in creating and presenting more stylish, tailored garments.

The study enhances silhouette classification for dresses and skirts by identifying four distinct groups of dresses and three groups of skirts using Principal Component Analysis (PCA). Combined with an advanced system that integrates both qualitative and quantitative analyses, this approach provides deeper insights into consumer preferences and emerging trends. The use of aspect-based form factors offers an efficient method for classifying silhouettes and contributes to improving upon previous research in this area.

The findings of this study have practical applications for fashion designers, enabling them to create garments that more effectively express consumer tastes and better showcase clothing and decorations. Additionally, retailers can utilize these insights to improve the arrangement of merchandise in stores, thereby personalizing the shopping experience and boosting sales.

Keywords: *principal component analysis, dress silhouettes, skirt silhouettes, algorithm, sketches*

Studiu asupra tipurilor de siluete în îmbrăcămintea pentru femei

Această cercetare reprezintă o trecere în revistă a tendințelor modei din ultimul deceniu, punând un accent deosebit pe identificarea siluetelor unice care se abat de la clasificările tradiționale. Aceste siluete noi combină adesea două forme existente, cum ar fi linia dreaptă și linia A, sau includ combinații neobișnuite, precum stiluri mulate și colorate. Studiul își propune să extindă clasificarea siluetelor din moda feminină prin introducerea unor forme combinate noi, care reflectă tendințele moderne și preferințele consumatorilor. Prin integrarea design-urilor tradiționale și contemporane cu analize calitative și cantitative, cercetarea îmbunătățește validitatea statistică și sprijină designerii și retailerii în crearea și prezentarea unor articole de îmbrăcăminte mai stilate și personalizate.

Studiul îmbunătățește clasificarea siluetelor pentru rochii și fuste, identificând patru grupuri distincte de rochii și trei grupuri de fuste, utilizând Analiza Componentelor Principale (PCA). Combinată cu un sistem avansat ce integrează atât analize calitative, cât și cantitative, această abordare oferă perspective mai profunde asupra preferințelor consumatorilor și tendințelor emergente. Utilizarea factorilor de formă bazați pe aspect asigură o metodă eficientă de clasificare a siluetelor și contribuie la îmbunătățirea cercetărilor anterioare din acest domeniu.

Rezultatele acestui studiu au aplicații practice pentru designerii de modă, ajutându-i să creeze articole care exprimă mai bine gusturile consumatorilor și pun în valoare îmbrăcămintea și elementele decorative. În plus, retailerii pot utiliza aceste informații pentru a îmbunătăți aranjarea produselor în magazine, personalizând experiența de shopping și crescând vânzările.

Cuvinte-cheie: *Analiza Componentelor Principale, siluete de rochii, siluete de fuste, algoritm, schițe*

INTRODUCTION

The design elements are shape, colour and material. The shape can be viewed from the perspective of silhouette, contour, colour, type of textile fabric and detail [1]. Online shopping platforms pose a challenge for consumers and designers to make decisions when choosing clothing. Quickly identifying the apparel product will greatly improve the efficiency of both the shopping and design experience. Online platforms are a convenient way to find information about clothing, usually through images. While displaying an image is convenient for browsing, the information conveyed is limited and each user may perceive different features of the same image. If the clothing features in the images can be extracted objectively, these methods can provide consumers with a more convenient service.

The silhouette is a key element in conveying clothing style and aesthetics. There are five types of silhouettes

known in modern women's fashion (A, H, X, T and O) [2]. Traditionally, defining the silhouette of a garment has depended on a visual, subjective assessment, with no explicit connection between subjective assessments and objective measurements.

Through the data analysis, Stangerup et al. [3] investigated and identified six silhouettes: A, H, O, T, X, and S. These became the main silhouettes: A, H, O, T, and X, with a special category of S. Although the technique has a useful way of predicting clothing trends, it is relatively less relevant for online clothing shopping.

Some classifications complement the basic silhouettes, such as "tunic", "balloon", and "hourglass" [4].

It is known that the silhouette of clothing has been used to establish, maintain, or even mask certain defects in the human body [5]. However, it remains unclear whether clothing styles can establish multiple identities determined by a particular culture. In the study by Zou et al. [6], the authors identify research limitations while providing a general, comprehensive literature review, as there are still challenges in this area: increased international collaboration, multilingualism of publishing platforms, and innovative approaches where historical perspectives can be presented within modern digital technologies and virtual fashion. The approach is aimed at academics, designers and practitioners interested in the development of this area of fashion design. Many researchers have shown interest in silhouette extraction and recognition.

According to Jiang et al. [7] Research is currently underway on intelligent silhouette recognition of pants to improve efficiency for both designers and consumers using online shopping platforms. The methodology uses DeepLabV3+ semantic segmentation with deep separable convolution, mainly to accelerate the computational speed and accurately detect H-shaped silhouettes. This can be seen in improvements in recognition accuracy and efficiency through the analysis and redefinition of pant silhouettes, more specifically in the optimization of dataset labels. Key findings include that improved recall rates, IoU, and PA metrics were achieved for various silhouettes. This means that overall classification and prediction accuracy for silhouette categories improves.

However, some limitations are also noted, particularly related to the fact that the dataset focuses on pants in standing poses and therefore generalizations are limited to other clothing poses only. Therefore, the goal of future research is to expand this dataset and improve these models for real-world applications in different clothing configurations.

Kumari's [8] research is based on the interrelationship between fashion and architecture, based primarily on the architectural monuments of India's Mughals and their influence on the silhouettes and motifs of clothing. By analysing the motifs and silhouettes – Monul monuments, Humayun's Tomb, Buland Darwaza, Itimad-ud-Daulah's Tomb, Taj Mahal and Badshahi Masjid – fashion designers developed contemporary Mughal clothing designs that reflect the same geometric, botanical and symmetrical motifs in these monuments. Other functional aspects, such as thermal comfort, also combine the curved architectural element with the bell-shaped silhouette of the garments, thus allowing free air circulation. This would therefore mean that some kind of standardized model for cross-cultural and trans-historical comparisons between architectural structure and clothing silhouette is likely to be developed, suggesting ways in which heritage conservation and modern fashion design can come together in this research.

At the end of his book, Lee [9] examines the relationship between clothing silhouettes through a theoretical framework that explains how clothing shapes and authenticates social identities. She applies modern clothing theory to ancient Greek evidence by analysing individual garments and their silhouettes in terms of how they were used to express aspects of identity such as gender, status, and cultural norms. The studies by Jalil et al. [10] and Atanasova et al. [11] suggest several advantages and limitations of silhouette analysis in children's clothing sizing. Benefits include solving problems with inconsistent sizing by producing garments tailored to both the garment type and the child's exact body characteristics and body shape. By using higher cutting techniques and 3D virtual fitting software such as CLO3D, sufficient precision is achieved in garment evaluation and construction. Variations in the shapes of children's silhouettes are identified that do not correspond to standard market sizes. Therefore, the fit is mainly affected by non-standard silhouettes such as spoons or oval shapes. This discrepancy highlights the need to design revised sizing charts and pattern-making techniques for the different body shapes of children to minimize fit and post-use waste in the production of children's clothing. Further research into international variations in silhouette shapes could ultimately help develop a more comprehensive sizing standard that would benefit consumers worldwide.

Online resources such as Treasury [12] and SewGuide [13] via resources that provide very detailed guidance on different dress silhouettes, such as A-line, sheath-line, and trumpet, and discuss how these shapes can accentuate or complement different body types. As Lee explains, part of this idea is to reveal social status and identity in ancient Greece through forms of clothing. Contemporary fashion trends like those on Byrdie [14] recognize the asymmetry of fashion dress silhouettes - for example, maxi dresses, mini dresses and drop waists – while shaping them to reflect personal identity and taste. Of course, the information presented in online resources is subject to further research in the available scientific literature.

Zhang et al. [15] achieved automatic measurement of traditional Chinese suits with A-line silhouettes based on the fuzzy C-means clustering method and key point positioning algorithm. Although this approach is efficient and flexible enough to measure the A-line of

traditional Chinese costumes, it typically requires pattern adjustment for specific silhouettes.

According to Kazlacheva [16], fashion design theorists define silhouettes in four ways: depending on the degree of fit in the waist area, designation with letters, designation with geometric figures or comparison with a specific object. The analysis of silhouette types shows that there is no complete overlap between the four types of designations and the whole variety of silhouettes in modern clothing can be represented not only by the degree of fit in the waist area but only by letter designations, geometric shape designations and comparison with a specific subject. A match can only be found between the literal meaning and the similarity to a geometric figure. For example, A-shaped and trapezoidal, U-shaped and rectangular silhouettes are the same. Based on the study and analysis of the geometric shape and depending on the degree of fit of the product in three of the main areas of the female body (chest, waist and hips), a classification of silhouettes can be made (the S-shaped silhouette is not included in the classification, as it hardly finds a place in modern clothing): Close-fitting: Close-fitting on the chest, waist and hips, with a straight cut, no seam and a small opening at the bottom. Fitted: Cut lower at the waist, with a straight, small or no slit at the bottom. Semi-Fitted: Very slightly fitted, straight and with little or no slit at the bottom. Straight: This means that the fit from the waist down is very slight or non-existent. The cut is straight and typically features minimal or no slit at the bottom of the garment. Y-Shape: The bottom is straight but with very little or no cleavage, the top is visually enlarged with flared shoulders, including the collar and sleeve details. Inverted Y: fitted above the waist, cropped hem that starts below the hip line. X-shaped: Visually enlarged top with flared shoulders, details such as collar and sleeves and flared hem. Inverted V-waist: fitted cut with domed hem. O-Waist: Tapered at the waist with a flared, balloon-shaped hem [17]. A-Line: No tightness at the waist with flared A-line hem. O-line: Extra wide waist and hips, rounded shoulders and narrower hem. V-shaped – wide at the shoulders and then narrow at the bottom.

This classification is quite complete and includes the types of silhouettes introduced by great fashion designers such as Christian Dior and Yves Saint Laurent, as well as all the silhouettes included in the publications of other authors. Qin et al. [18] studied the silhouettes of a women's jacket. The authors identify waist, length, and hemlines as critical design elements in consumer perceptions of women's suit silhouettes and quantitatively demonstrate how variations in these elements affect consumers' fashion evaluations.

Hadija et al. [19] point out that qualitative methods – observation, interview and documentation – enable an in-depth study of clothing forms and their constructive details. Only this methodological approach enabled the development of a comprehensive and in-depth understanding of the characteristics and fit issues of the dresses studied by the authors. A disadvantage of this research is that qualitative methods allow deeper level insights; Reliance solely on observations, interviews, and documentation may have missed quantitative data that would have allowed for statistical validity or more comprehensive trend analysis.

According to McCoy [20], who examines Norman Norell's combined silhouette, the historical understanding of fashion and its relationship to societal norms, particularly misogyny, the idea here is to contextualize how fashion's creations reflect and perpetuate cultural attitudes towards women. Tsuru et al. [21] investigate the clusterability of dress silhouettes. The authors use principal component analysis, mean square shift and cluster analysis methods to group. The authors suggest dividing the silhouettes into three categories. A limitation of this study is that only dress silhouettes are considered.

Nie et al. [22] use region of interest and analysis of variance to quantify the factors corresponding to the X-shaped silhouette. Although the study measures the waist, chest, hem, hips and shoulders, it is not clear enough how these features are perceived and prioritized by a person when choosing clothing.

According to Radieva [23], who studies the relationships between the shapes of the lower part of the garments and the silhouettes developed by Christian Dior and Cristobal Balenciaga. The author uses the correspondence analysis method. A disadvantage of this development is that only the silhouettes and shapes of the two designers mentioned are analysed.

Lee et al. [24] analysed 1389 photos of wedding dresses. Key elements are identified by ranking and categorizing 15 top designs, 11 sleeve designs and eight skirt silhouettes that are most popular and sought after by consumers. The results are useful for designers and manufacturers who want to create modern and aesthetically pleasing wedding dresses. A limitation of the study is that it is limited to wedding dresses published in a specific magazine over a specific period. The analysis of available literary sources shows that it is necessary to look for methods of quantitative analysis to ensure sufficient accuracy of results in the study of clothing silhouettes, the results of which can be effectively used in the design and identification of consumer preferences. It is necessary to leverage elements of artificial intelligence and machine learning to more accurately predict trends and group silhouettes and shapes, compared to traditional methods that use qualitative analysis and basic statistical techniques. In most cases, a specific type of silhouette and shape is examined. A more comprehensive analysis of silhouette and clothing types is required. Dress silhouettes are one of the most studied elements. Few studies were found on other clothing items such as skirts. It is necessary to find a sufficiently effective method of grouping the silhouettes of women's clothing. This grouping should be suitable for online applications where silhouettes are used in consumer clothing selection. The study of fashion trends of the last decade (2014–2024) shows

that the following silhouettes can be found in the collections of fashion designers: fitted, semi-fitted, Y-shaped, Y-shaped reverse, X-shaped and U-shaped below the waist, as well as silhouettes that cannot be called one of the most complete of the studied classifications, the 12-silhouette classification of Kazlacheva [16, 17]. These silhouettes, presented in the last fashion season, cannot be labelled in any of four possible ways: by the fit in the waist area, by the letter designation, by being identified by a geometric figure or an object. Some of these silhouettes are extremely asymmetrical, which again contradicts the idea of silhouette representation. However, these silhouettes can be presented as a combination of several existing silhouettes, for example, a silhouette that combines straight and A-shaped, or a silhouette that combines fitted and floral. Therefore, the classification of the twelve silhouettes can be supplemented by another combined silhouette.

The purpose of the study is to develop and expand the classification of silhouettes in women's clothing by identifying and introducing new combined silhouettes that meet the requirements of modern design trends and consumer tastes. This development adds more completeness and sophistication to the categorization system by including not only the classic but also the more modern silhouette shapes that would be suitable for the dress and skirt design trends. It is also expected to bring together qualitative and quantitative analysis, increasing the statistical validity and utility of silhouette classifications to help designers and retailers design and present more fashionable, tailored garments.

MATERIAL AND METHODS

29 silhouettes of dresses were analysed in the work. Also, 40 silhouettes of skirts and 19 necklines are available in the available literature [25, 26]. A total of 24 basic formulas were used to determine silhouette shape coefficients [27]. They have the following form:

$$K_1 = \frac{P^2}{A} \quad (1)$$

$$K_2 = \frac{D}{d} \cdot 100,\ \% \quad (2)$$

$$K_3 = \frac{P^2}{4\pi A} \quad (3)$$

$$K_4 = \frac{1}{K_3} \quad (4)$$

$$K_5 = \frac{A}{A_{ideal}} \quad (5)$$

$$K_6 = \frac{A}{A_{mr}} \quad (6)$$

$$K_7 = \left(\sqrt{\frac{D}{2}} + \sqrt{\frac{d}{2}}\right)\frac{\sqrt{\frac{D}{2}}}{d} - 1 \quad (7)$$

$$K_8 = \frac{\frac{d}{2}}{\frac{D}{2}} \quad (8)$$

$$K_9 = \left(\frac{D}{2} - \frac{d}{2}\right)\frac{D}{d^2} \quad (9)$$

$$K_{10} = \frac{d}{D} - 1 \quad (10)$$

$$K_{11} = \frac{\frac{D}{2} - \frac{d}{2}}{d} \quad (11)$$

$$K_{12} = \frac{D - d}{D} \quad (12)$$

$$K_{13} = \frac{dD}{2} - 1 \quad (13)$$

$$K_{14} = \frac{(D + 2)(d + 2)}{2D^2(-dD + D + 2)} \quad (14)$$

$$K_{15} = \frac{P^2}{4\pi A} - 1 \quad (15)$$

$$K_{16} = \frac{d}{D} \quad (16)$$

$$K_{17} = \frac{D}{d} - 1 \quad (17)$$

$$K_{18} = \frac{D}{d} \quad (18)$$

$$K_{19} = \frac{dD}{2} \quad (19)$$

$$K_{20} = \frac{D - d}{2d} \quad (20)$$

$$K_{21} = \frac{P}{D} \quad (21)$$

$$V = \frac{4}{3}\pi\,\frac{D}{2}\left(\frac{d}{2}\right)^2 \qquad K_{22} = \frac{3V}{4\pi D d^2} \quad (22)$$

$$K_{23} = \frac{P}{D - P} \quad (23)$$

$$K_{24} = \frac{D}{D - P} \quad (24)$$

where d is a minor axis of the silhouette; D is a major axis of the silhouette; P is the perimeter; A is the area; A_{ideal} is the ideal area calculated along the major and minor axis of the silhouette; A_{mr} is the area of the rectangle enclosing the silhouette; V is volume calculated along the major and minor axis.

The silhouettes of dresses are presented in figure 1. They are not grouped but presented in the order of the literary sources listed above. The silhouettes of the dresses with their serial numbers are marked Dx. Dress silhouettes range from fitted D1 and sheath D3 to loose including tent D7 and peasant dress D19. Functional and versatile styles like the shirt dress and wrap dress provide comfort without sacrificing style, so they can be worn for any occasion. The ball gown and empire are formal silhouettes that exude classic elegance for special occasions. The innovative and

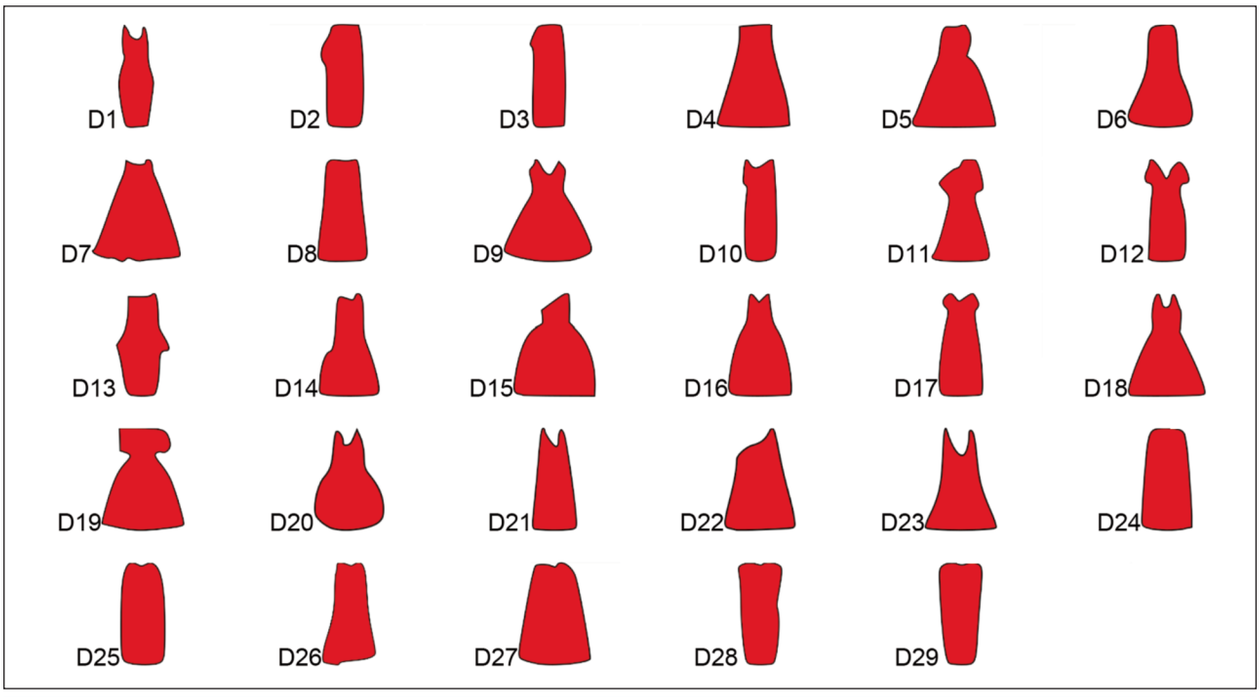

Fig. 1. Dress silhouettes

modern contours are the low waist and trapeze models that refresh the modern fashion look. Peplums and bouffants are silhouettes that pay more attention to structural elements for their visual impact. Casual clothing consists of a sheath dress and a tunic, which emphasizes freedom of movement and calm. In addition, nostalgic and charming dresses reflect themes related to history and culture. Different silhouettes suit different tastes, occasions and body types. They embody timeless and innovative fashion.

Table 1 shows the names of the used silhouettes of dresses.

Skirt silhouettes are shown in figure 2. They are not grouped but presented in the order of the literary sources listed above. The silhouettes of the skirts with their serial numbers are marked Sx. Skirt silhouettes range from some of the all-time classics such as Pleated (S1), A-line (S9) and Straight (S3) to later innovations such as Asymmetrical (S27) and Trumpet (S28). The silhouettes have different lengths and different cuts, suitable for many occasions and tastes. Some styles emphasize textural and textural elements such as accordion (S17 or rustle (S18) and introduce practical elements into their design such as wrap (S11). Gypsy (S15) and sarong (S21) represent cultural inspirations, where Complicated constructions are visible Fix Box Pleat, S23. Variations suit taste, occasion and different body types – all classic and contemporary trends.

Table 2 shows the names of the skirt silhouettes used.

A basic image analysis algorithm was used [28–30]. It consists of the following steps: the RGB (Red, Green and Blue) image is loaded; it can be converted into an HSV (Hue, Saturation, Value) model; The colour component S (HSV) is taken and the data in this matrix is normalized to the range [0, 1]. The image is converted to black and white with a binarization threshold of T = 0.22. The Region Props feature defines the major and minor axes, area and perimeter based on the object (silhouette) in the image. These features were used in the calculation of 24 silhouette form factors. Figure 3 shows the steps of the algorithm used. First, the original RGB image is presented, followed by conversion to S(HSV) colour space. A black-and-white image was then cre-

Table 1

NAMES OF DRESS SILHOUETTES									
№	**Name**	**№**	**Name**	**№**	**Name**	**№**	**Name**	**№**	**Name**
D1	Body-con	**D7**	Tent	**D13**	Peplum	**D19**	Peasant	**D25**	Tunic
D2	Shift	**D8**	Blouson	**D14**	Drop waist	**D20**	Balloon	**D26**	Princess
D3	Sheath	**D9**	Halter	**D15**	One shoulder	**D21**	Baby-doll	**D27**	Trapezoid
D4	Strapless	**D10**	Slip	**D16**	Ball gown	**D22**	Jumper	**D28**	Pegged
D5	Bouffant	**D11**	Shirt	**D17**	Empire	**D23**	Sun	**D29**	V-Line
D6	A-Line	**D12**	Wrap	**D18**	Apron	**D24**	Yoke	-	-

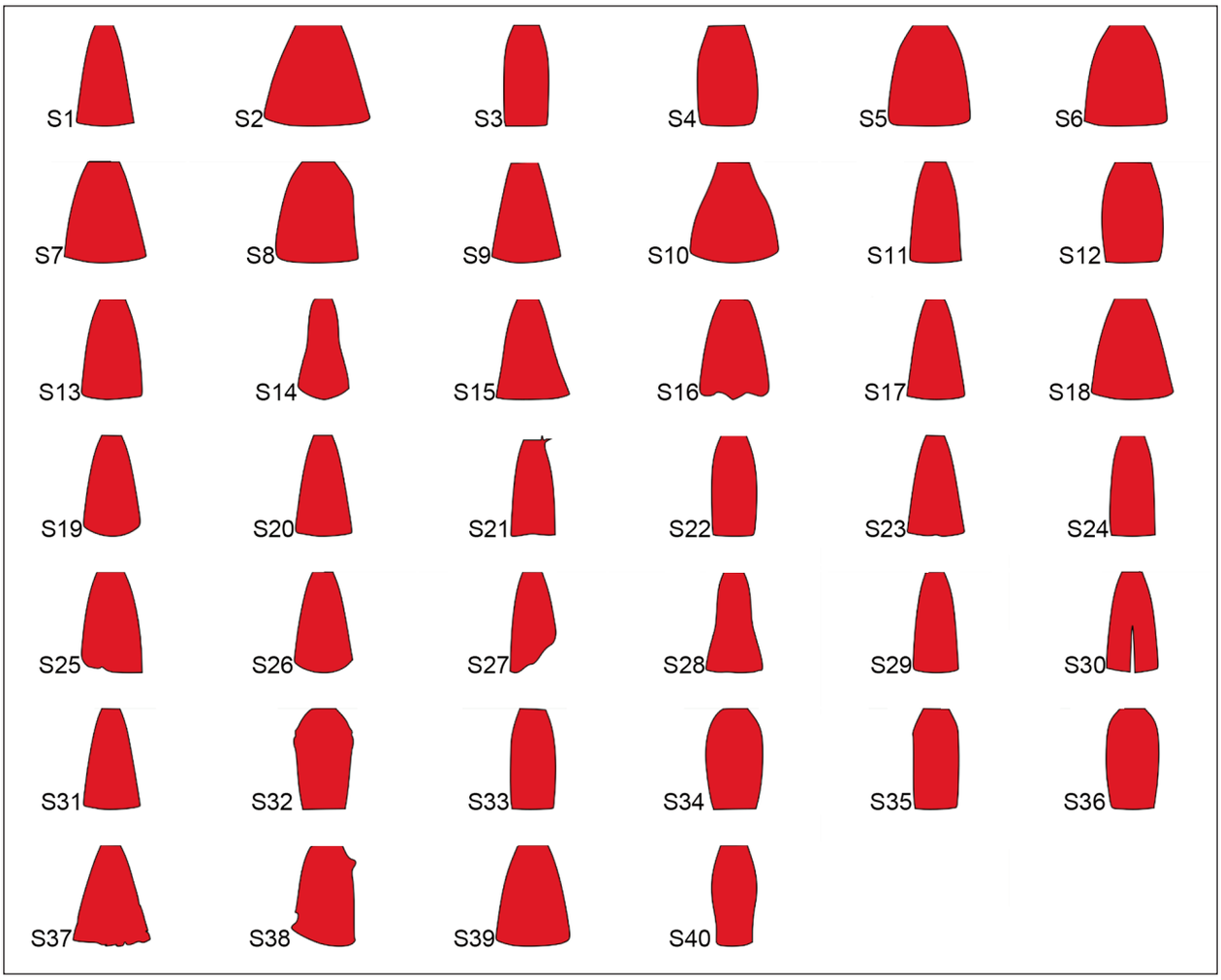

Fig. 2. Skirt silhouettes

Table 2

NAMES OF SKIRT SILHOUETTES									
№	**Name**	**№**	**Name**	**№**	**Name**	**№**	**Name**	**№**	**Name**
S1	Pleated	**S9**	A-Line	**S17**	Accordion	**S25**	Layered	**S33**	Fall
S2	Short	**S10**	Bell-Shaped	**S18**	Ruffled	**S26**	Panelled	**S34**	Sheath
S3	Straight	**S11**	Wrap	**S19**	Full	**S27**	Asymmetrical	**S35**	Peplum
S4	Underskirt	**S12**	Mini	**S20**	Gored	**S28**	Trumpet	**S36**	Pegged
S5	Bubble	**S13**	Wraparound	**S21**	Sarong	**S29**	Circle	**S37**	Tulle
S6	Tulip	**S14**	Mermaid	**S22**	Fly	**S30**	Culottes divided	**S38**	Ruffled
S7	Knife pleated	**S15**	Gypsy	**S23**	Fix box peat	**S31**	Fixed box pleat	**S39**	Inverted pleated
S8	Draped	**S16**	Godet	**S24**	Buttoned straight	**S32**	Cowl	**S40**	Pencil

ated with only the silhouette isolated for easier analysis. Basic dimensions are then extracted from the black-and-white image to identify and measure the properties of the regions present. Finally, the calculated shape coefficients describing the properties of the silhouette shapes are displayed for further study and classification.

The selection of meaningful shape indices was carried out using the ReliefF method [31]. This method solves the problem of dividing data into classes. Essentially, the data set is repeatedly sampled and then the relevance of the features is assessed in terms of their ability to distinguish between instances that are close to each other, within the same class, or across classes. The important steps by which the method works are: A random sample is taken from the data set; the nearest neighbours of the same class and different classes are found; and the weights of the data are analysed based on how well they could distinguish the sampled instance from its neighbours. The ReliefF method captures relationships between features and has the advantage of

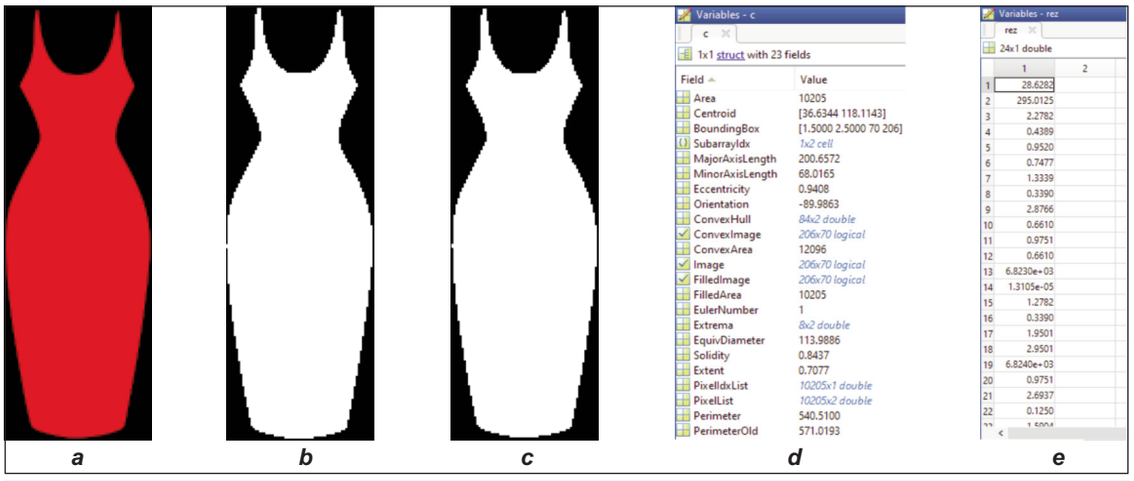

Fig. 3. Stages of the algorithm for calculation of silhouettes form coefficients: *a* – original RGB image; *b* – S(HSV) image; *c* – black and white image; *d* – results from the implementation of *region props* function; *e* – calculated coefficients of the form

being robust to noise. Shape indices whose weight coefficients have a value greater than 0.6 are considered meaningful [32].

Feature vectors are defined from the selected shape coefficients. The principal component analysis (PCA) method [33] was used to group silhouette types based on reduced data from the selected feature vectors. It is a statistical dimensionality reduction technique that preserves as much variability as possible in the data set. PCA basically does the following: the data set is standardized to a mean of zero and a standard deviation of one for each feature. The covariance matrix was calculated, thereby determining the relationship between the different features. The eigenvalues and eigenvectors of the covariance matrix were calculated. The eigenvectors of the selected principal components (PC) are identified as those corresponding to the directions of maximum variance consistent with the eigenvalues; The data is projected onto a new subspace containing the selected principal components. PCA converts the input data into a new coordinate system, reducing the number of dimensions in the data and preserving the important information.

The software products Matlab 2017a (The Mathworks Inc., Natick, MA, USA) and MS Office 2016 (Microsoft Corp., Washington, USA) were used for data processing.

RESULTS

A selection of meaningful shape coefficients was made. The results are shown in figure 4. Those features whose weighting coefficients have a value above 0.6 are significant. In the figure, this limit is marked “0.6 Circle”. For the silhouettes of dresses and necklines, 5 features are informative, while for skirts there are 4 features. This shows that the silhouettes of skirts can be described with a smaller

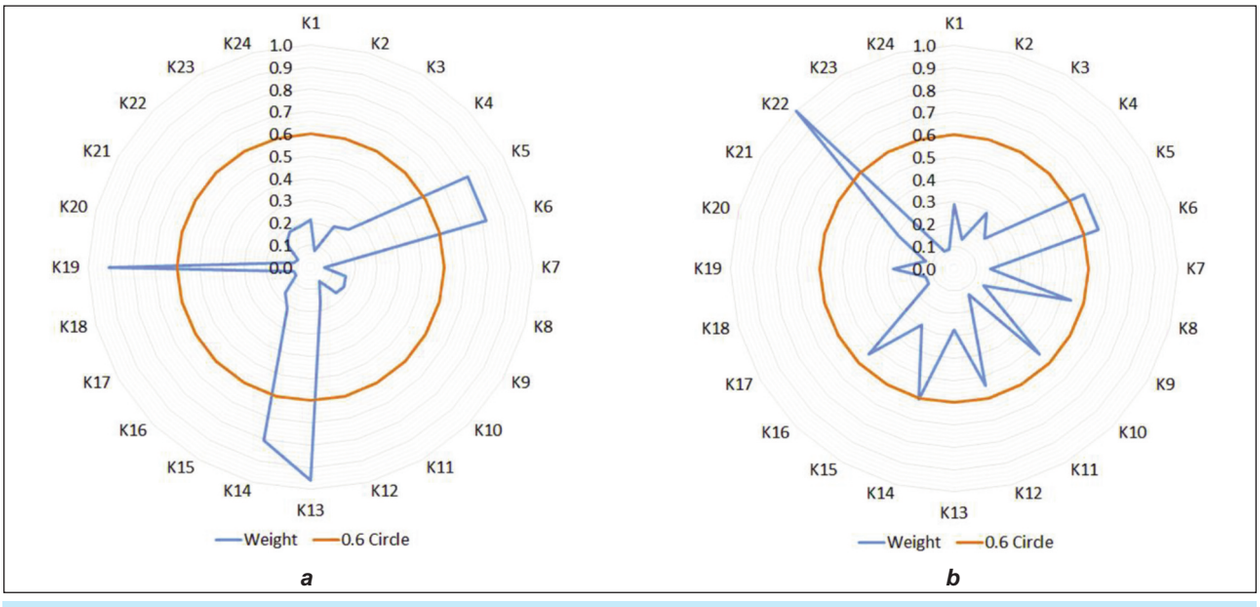

Fig. 4. Selection of informative coefficients of form for silhouettes: *a* – dress; *b* – skirt

number of features. The 24 features are analysed and then only informative are used. There are two feature vectors. FVD contains 5 informative features of dresses, and FVS contains 4 features for skirts. These feature vectors are reduced to 2 principal components.

After selection, vectors of the most meaningful shape coefficients of the object groups under consideration were obtained. Feature vectors for dress silhouettes (FVD) and skirts (FVS) each consist of five informative shape coefficients. The silhouettes of skirts and dresses have in common the coefficients K5, K6 and K14. In summary, there is a sufficiently large agreement in the information coefficients for skirts and dresses.

The vectors of informative shape coefficients have the form:

$$FVD = [K5\ K6\ K13\ K14\ K19] \quad (25)$$

$$FVS = [K5\ K6\ K14\ K22] \quad (26)$$

The feature vectors were reduced to two principal components using the PCA method. The two principal components for all cases describe over 95% of the variance in the data. The obtained results are visualized together with the resulting groups of silhouettes in figure 5.

With the silhouettes of the dresses, four groups can be formed, which are located in the four quadrants of the diagram. In the first quadrant (+PC1, +PC2), a group of X-shaped silhouettes is formed, which have a more modern look. In the second quadrant (–PC1, +PC2), a group of A- and I-shaped silhouettes is formed. In the third quadrant (–PC1,–PC2) again, the group mainly consists of A- and I-shaped silhouettes, which embody the traditional and minimalist style. X- and Y-shaped silhouettes are grouped in the fourth quadrant (+PC1,–PC2).

In skirt graphics, three groups of silhouettes are formed. The first group covers the first and fourth quadrants. This group includes silhouettes with an innovative, practical, and flexible design. The second group is in the second quadrant, covering silhouettes with a structured formal design, and the third group is in the third quadrant, containing classic and conservative silhouettes. The first group covers the most silhouettes.

When analysing combined silhouettes, several main types can be distinguished: Combined symmetrical silhouette; combined asymmetrical silhouette; combined silhouette of two or more parts; Combined silhouette transformer; and A combined silhouette of two or more basic silhouettes. If you look at the silhouette trends of the last few years, you'll notice how difficult it is to define the silhouette of women's clothing. This is due to the increasing consumer demand for clothing with an unusual and different appearance as well as a unique and memorable effect. The design of women's clothing in a combined silhouette is shown in figure 6. The silhouettes consist of a combination of a Y-shape above the waist and an O-shape below the waist. The combination of V shape, asymmetrical Y shape at the top and O shape below the waist. A combination of a Y-shaped bodice above the waist with a fitted peplum and a separate straight skirt. A combination of a bustier dress in a fitted silhouette and a detachable peplum. A combination of fitted and X-shaped.

To visualize how the combined silhouette designs will look in the finished garments (figure 7), the AI art generation tool NewArc.ai [34] was used. The software allows us to transform our sketches into stunning images. NewArc.ai is transforming design education in fashion, textiles, products and architecture through its AI-driven rendering technology. Users can create high-quality renderings by providing initial images and prompts and viewing a range of fabrics and styles. This innovation allows designers to effectively explore different fabrics and materials, increasing creativity and learning outcomes. In the fashion and textile sector, NewArc.ai stands out for its clear representation of various fabrics such as satin, velvet, silk and cotton. This tool is invaluable for designers as it allows them to visualize their designs in different materials without the need for physical prototypes.

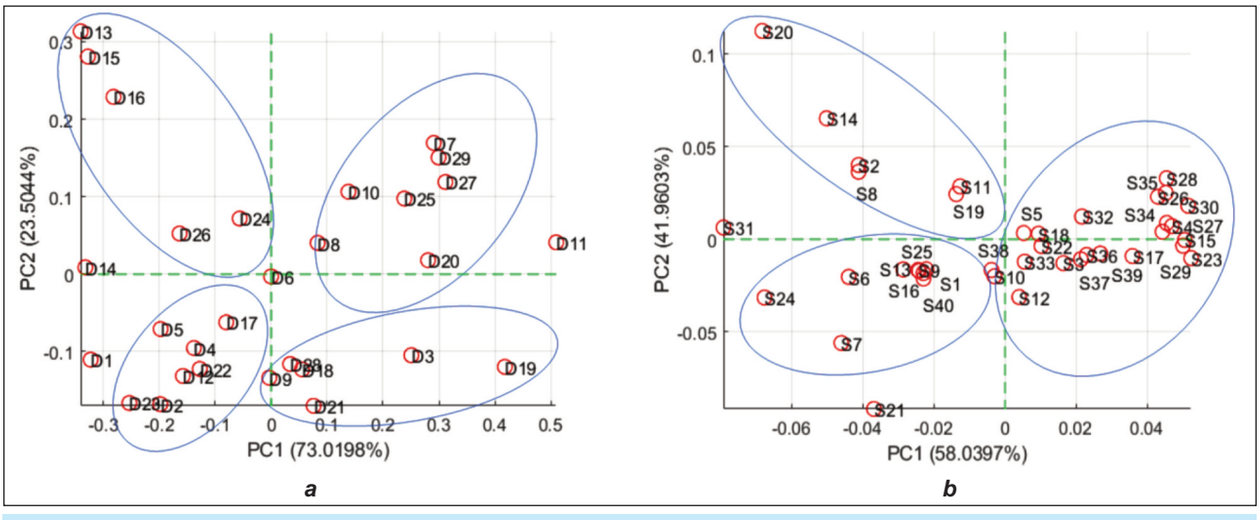

Fig. 5. PCA for grouping of silhouettes: *a* – dress; *b* – skirt

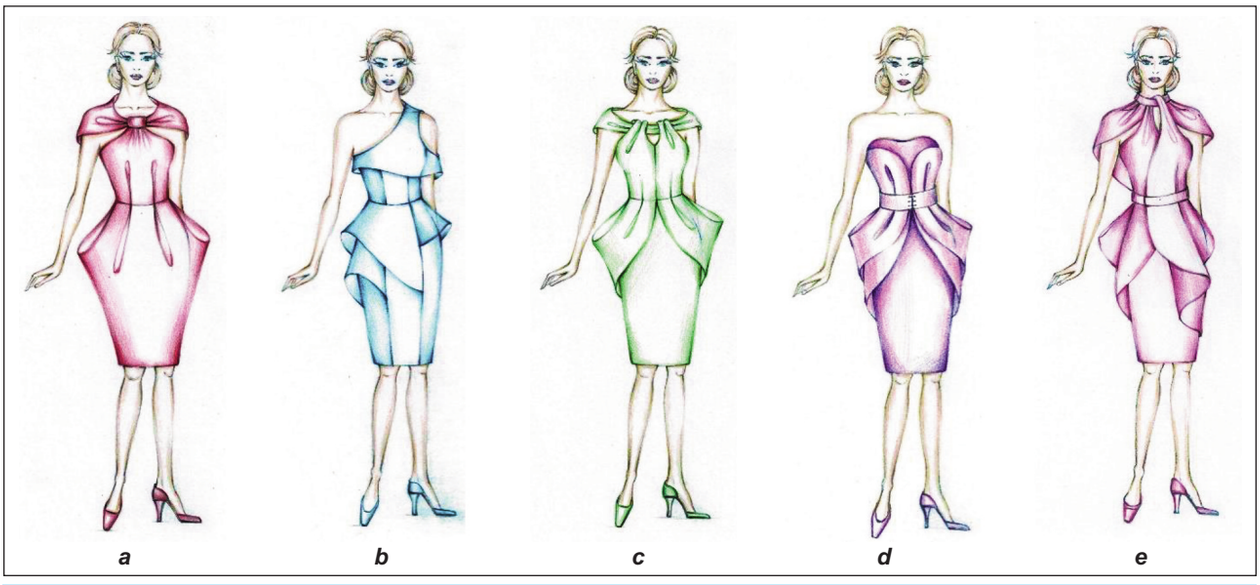

Fig. 6. Results from the design of combined silhouettes: *a* – combined symmetrical silhouette; *b* – combined asymmetric silhouette; *c* – combined silhouette of two parts; *d* – combined silhouette transformer; *e* – combined silhouette of two basic silhouettes

Fig. 7. The combined silhouettes generated in NewArc.ai

DISCUSSION

The results of Tsuru et al. [18] have been supplemented and refined. The authors only analyse the silhouettes of dresses. They use PCA, MSD (Mean Squared Displacement) and cluster analysis. The four clothing groups obtained in this work directly solve the MSD grouping problem. Using PCA-reduced form factors, four groups of dresses were directly obtained in this work, while Tsuru et al. [18] obtained this after processing the data using cluster analysis. This shows that using form factors that represent ratios is a better option than using "raw" measurements. Compared to MSD, PCA applies dimensionality reduction, variance maximization to include significant differences, and noise filtering for clear clustering. Its multivariate approach – considering multiple variables simultaneously – uncovers complex relationships and interactions that MSD may miss entirely. In addition, PCA allows interpretability through the visualization of the main components, which supports an intuitive understanding of the data structure itself, whereas MSD lacks this. Additionally, PCA's scalability and flexibility put it at the forefront of various datasets and analyses, thereby expanding its applicability compared to MSD, a dimensionality reduction technique whose uses tend to be extremely limited. In this way, PCA provides a solid framework for grouping objects, captures the underlying variations in the data, and improves clarity throughout the analysis so that it remains reliable.

Qin et al. [18] studied variations in the silhouette of women's jackets and found that waist, length, and

hems are important design elements in consumers' perceptions of fashion. Our research contributes to their findings by better categorizing silhouettes, examining different types of silhouettes, and proposing new silhouettes that further advance knowledge of consumer preferences and perceptions in fashion design. Hadija et al. [19] used qualitative methods that examined the shapes and construction details of the garments in-depth, providing valuable insights into the fit and performance of the garments. However, our approach complements this by using qualitative analysis supported by quantitative analysis for statistical validity and comprehensive trend analysis, thus addressing the potential limitations of purely qualitative methods. Nie et al. [22] quantified the factors affecting X-shape, including waist, chest, hem, hip, and shoulder measurements; However, more knowledge is needed about how these factors influence clothing choices. This deeper analysis was done in this work.

CONCLUSIONS

An analysis of fashion trends for the subglacial decade shows that there are silhouettes that cannot be assigned to any of the most comprehensive of the studied classifications, the 12-silhouette classification. Some of these silhouettes are extremely asymmetrical, which again contradicts the idea of silhouette representation. However, these silhouettes can be presented as a combination of several existing silhouettes, for example, a straight and A-shaped silhouette or a fitted and colourful silhouette. Therefore, the classification of the twelve silhouettes can be supplemented by another combined silhouette. The presented author's analysis distinguishes several types of combined silhouettes, including symmetrical, asymmetrical, multifaceted, transforming and mixtures of the basic silhouettes. Such detailed categorization will help meet consumers' growing needs for originality and memorable designs in their clothing. In women's clothing silhouettes, the trend is developing to create designs that are non-standard but have a great visual impact.

The results obtained in this development help to improve the knowledge and classification of silhouettes for dresses and skirts, allowing us to identify specific, highly distinguishable groups and establish new silhouettes. Dress silhouettes are divided into four groups, each located in a different quadrant of the PCA diagram: modern X-shaped silhouettes in the first quadrant; A- and I-shaped silhouettes in the second and third quadrants for traditional and minimalist styles, respectively; and finally, the X and Y shaped silhouettes occupy the fourth quadrant. Three groups of skirts can be quickly identified: the first and fourth quadrants with innovative, flexible designs; structured, formal designs in the second quadrant; and classic, conservative silhouettes in the third quadrant.

Compared to previous research, our study offers a more sophisticated classification system and new silhouettes that reveal additional insights into consumer preferences. Our mixed silhouette approach combines in-depth qualitative and quantitative analysis for statistical validity and comprehensive trend analysis. This article explores proportion-based form factors to provide an efficient method for classifying silhouettes – a system that better solves the grouping problems of previous studies and provides a clearer understanding of dress and skirt design trends.

The results obtained in this study are suitable for practical application. Through better categorization and the development of new silhouettes, designers can make clothing more presentable and fashionable so that they are closer to consumer tastes and thus improve fashion. Clear delineation of silhouettes forms the basis for how designers can effectively implement the visual and functional impact of different clothing styles. This is particularly valuable when designing specialized collections to meet consumers' diverse needs for specific, unique and memorable clothing.

Furthermore, identifying combined silhouettes and studying them for functional aspects, air circulation and thermal comfort would be helpful in developing a much more comfortable and practical garment. Fashion brands can use these insights to improve garment fit and performance, reduce returns and increase customer satisfaction. The results achieved in this development allow retailers to better organize goods in shop windows and make it easier for consumers to find suitable clothing according to their tastes and shape preferences. Personalization can increase sales and improve customer satisfaction throughout the entire shopping experience.

The limitations of the current work are recruiting dress and skirt silhouettes that do not truly represent the global market. The sample size cannot capture this enormous diversity of consumer perceptions and preference variables. Additionally, reliance on certain analytics technologies may impact applicability for some designers and brands. Such future studies should be expanded to a wider range of garments with greater sample diversity, followed by extensive consumer surveys to identify perceptions with demographic-specific knowledge. Combining new technologies such as AI and machine learning to further fine-tune silhouette analysis; Exploring functional and sustainable elements of silhouettes for improved material utilization, garment durability and sustainable environmental impact.

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