

## Study on denim dress designs in apparel industry for sustainability and cost-effectiveness

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### KEY WORDS

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### ABSTRACT

Denim is considered a versatile fabric due to its subsequent usage by the population of all ages. However, it also leads to a large amount of fabric wastage in the apparel industry. Therefore, this research explored 13 denim dress designs for women's top wear for fabric efficiency and sustainability. 2D patterns of all selected dress designs were drafted and virtual markers were generated through Garment Gerber Technology (GGT) to investigate the sustainable designs. Results revealed that denim bustier was ranked top with fabric efficiency (89.01%), while denim shirt dress ranked 2nd (88.64%), triple pleat blouse ranked 3rd (87.10%), denim bodysuit ranked 4th (86.88%), western style shirt ranked 5th (86.79%), long sleeve jacket ranked 6th (86.76%), rock and roll jacket ranked 7th (86.74%), light shade jacket ranked 8th (86.58%), fitted denim shirt ranked 9th (86.39%), denim dungaree 10th (86.16%), crop jacket ranked 11th (85.79%), lace-up ranked 12th (85.74%) and oversized jacket ranked 13th (85.59%). Denim bustier was ranked 1st style with minimum fabric consumption (7 meters) and fabric wastage (11%), while oversized jackets and lace-up shirts ranked last with fabric consumption (33 and 39 meters) and fabric wastage (14.41% and 14.26%). ANOVA test *p*-value shows that the results were close to significant. Thus, the research is beneficial to the apparel industry for the execution of sustainable and cost-effective dress designs.

### 1. Introduction

Textile apparel industry has been facing complex and demanding challenges including resources, waste, time, workforce conditions and income inequality [1]. This is due to the consumption and disposable of fast abrupt fashion of textile and apparels [2]. Moreover,

an artistic intention of the designers primarily addresses the aesthetics of the garment and usually not considering the preciousness of the materials used which often led to the ridiculous changes in the archival value of the garments among different brands [3]. Thus, recognition and incorporation of dress cut

lines not only the passionate, amateurs, enticing fashion creation but also exponentially influences for material consumption [4-6]. Therefore, textile and apparel fashion companies have many apprehensions for the use of appropriate garment designs because they affect not only to the fashion creativity but also the material usage, waste and cost [7].

Denim fashion and styles, including short shirts, unisex long T-shirts, skirts, bags, shoes, jeans, short pants, trousers, sleeveless jackets, piper jackets, cross over skirts, caps etc., have been involved in vast design ideas, innovations, displays and manufacturing in apparel industries [8-10]. Levi's Strauss created the very first cotton denim fabric and invented the first blue jeans with a pair of pockets fastened with copper rivets for hardworking workers [11]. In 1934, Lady Levi's, the first pair of blue jeans for ladies, were released by Levi Strauss and Co. [12]. In 1950's, James and Marlon introduced jeans as rock and roll flair and boot cut style (first jeans with zippers) that became iconic for celebrities and fashionistas [13]. Since then, it has been acknowledged by people of every age exclusively among youngsters and teens due to its unique fashion features, a classic and modernized core look in fashion and styles [14]. New styles kept on emerging with time, meanwhile denim dungaree was designed and manufactured which added some chic in girls and ladies' wardrobe. In 1960's, light shade tight fitted full sleeve denim jacket was apprehended having front with double pockets and more buttons. These were mostly garb with high waist pants and skirts [15].

In 1970's, light and dark shade denim flared jackets with two pockets at front were dressed with flared pants and mid length shirts. 1980s was renowned for same colour of oversized denim jacket and flared pants however the jackets were super trendy with bigger size pockets and buttons. In 1990's, light shade single colour fitted jackets with big pockets and full sleeves dressed with miniskirts and shorts were chic in women wardrobe [15]. According to Mary, from the start of the twentieth century, the trick to the survival of fashion-focused businesses have been creatively captured the ethos, or spirit of the times, and translated its impact into distinctive, contemporary, and desirable products [16]. In 2000, through the advanced body shape analysis in women's, the top wear denim garments became more fitted and wore with flared pants. Later these were transformed into long full sleeved ripped jackets with single pocket and belt in front. These were attired with skinny jeans and skirts [15]. 2012 was revered with long over-sized ripped denim jackets having big four pockets at front with prominent buttons and wore with all types of jeans, pants and skirts etc. Furthermore, sleeves and fronts

were embellished with embroidery or embroider patches for funky girls [17]. In 2017, denim tie-up crop style shirt and relaxed fit jacket with small pockets was highly trendy and wore with narrow pants, high waist pants and skinny tights [18]. Recently, Dean and Dan transformed and presented long shirt having classic collar with long cuffed sleeves and small buttons. The modified design of shirt had front pockets with flaps and buttons. The shirt was regular fit which was paired with mini curved skirt [15]. The product was purely made by denim with layered and maxi prints. In 2019, Melanie Carrico developed a different cut line, named as bat-wing denim dress, with the idea of manipulating the typical seams of dress with modern cut line. The dress was created with the help of digital cutting pattern techniques [19].

The above all discussion and references addressed have observed that the designing and manufacturing of garments (basic to highly fashion) by ideological designers have rebellion against material consumption. They only focused to the artistic or aesthetic luxury products that attract critical attention to consumer values. However, lack of focus to symbolic material consumption is significant with respect to the design cut lines which is a challenging art for designer of garments. Therefore, this research work has studied different dress designs used in previous different eras in denim top wears for women by the designers. Flat patterns of thirteen garment designs of women top wears were drafted according to the medium size of the Paynter's and transformed into virtual patterns through the digitize machine. The drafted 2D patterns were converted to pattern markers through garment technology software. The material consumption, efficiencies, wastage, and costing were evaluated. ANOVA test method was also used for the evaluation of significance level in the selected variables. This research work has achieved United Nation Sustainable Development Goals (UNSDG 8, UNSDG 9, UNSDG 12).

## **2. Experimental Work**

### *2.1 Selection of Garment Designs*

Thirteen denim women top wears with different garment cut design lines were selected for the evaluation of fabric efficiency, consumption, wastage and cost effectiveness. Fig. 1 has shown the selected cut design lines with front view of the garments. The denim garments with different designs were, triple pleat blouse (1880), denim dungaree (1943), over-sized shirt (1950), denim body suits (1958), light

shade jacket (1960), rock and roll jacket (1962), western style shirt (1970), fitted denim shirt (2000), long sleeve jacket (2010), denim shirt dress (2012), denim bustier (2013), lace-up shirt (2012), and crop jacket (2014). The styles were classified into three groups; group 1 had style named as denim dungaree (style number 2), group 2 included the styles i.e.,

bustier and denim body suit (style number 4 and 12). All the other styles were categorized in group 3 because of close similar styles and cut lines. Fig. 1 shows the frontal view of selected garment styles from era 1880-2014. Adobe Photoshop 2022 was used to create all garment styles.



**Fig. 1.** Selected Denim Trendy Top Wear Styles from Era 1880-2014

### 2.2 Selection of Body Garment Size

The Paynter’s is a manufacturing company of denim jackets. It’s standard size measurements of medium size of women top wear garments were selected [20]. Table 1 has shown the detailed standard measurements of medium size of women’s top wear [20].

### 2.3 Selection of Denim Fabric and its Characteristics

Denim woven fabric with 2/1 Z twill weave was provided by the Sapphire Pvt Ltd, Lahore, Pakistan. The dyed fabric colour was matched with “Indigo Whisper’s” colour pallets and was remarked as ‘MULBERRY DREAM’. The width of the denim fabric was 147 cm with composition of 98% cotton and 2% Elastane. The finished weight of the fabric was 6.4 ounces/square yard and possessed 20% stretch in it.

### 2.4 Tool, Equipment and Methods

A pattern making tool kit (including Japanese ruler, French curves, tracing wheel, set square, notch cutter,

etc.) was used for designing the manual flat patterns of selected garments having different cut lines on a cardboard sheet. The size measurements of all the patterns were kept according to the Paynter’s medium standard size measurements of women top wear garments. The shrinkage percentage (introduced during the flat pattern making technique to include the after-wash effect in the size of manufactured garments) was kept constant for all the designs since the same denim fabric was used. These all patterns were digitized and transformed into virtual/digital patterns in the Garment Gerber Technology Computer Software (Accumark 9). The pattern markers were prepared with the technology software while keeping the 20 number of product pieces in each single marker for all the styles. Gerber AccuNest was used for nesting of markers. Usage of this software caused the minimum chances of error and maximized the accuracy in patterns thus leading to the efficient utilization of materials (fabrics) [21]. Fig. 2 has shown the tool kit and transform the flat patterns into virtual digital patterns.

**Table 1**

Paynter's standard size chart for women denim jacket [20]

Sr.#	Description	Measurements/Medium Size (cm)	Tolerance	
			(-)	(+)
1	Neck	41	1	1
2	Across Shoulder: Shoulder to shoulder measurement	47	1	1
3	Breast: Pit-to-pit measurement	51.5	1	1
4	Waist width	49	1	1
5	Body length	60.5	1	1
6	Sleeve length including cuff	56.5	1	1



(i) Tool kit



(ii). Flat Pattern



(iii). Transformation



(iv). 2D pattern

**Fig. 2.** Transformation of Manual Flat Pattern to 2D Virtual Pattern

























Table 2 has shown the front view and back view of the selected garments with different design cut lines on virtual model. These garment styles were illustrated through the Adobe Photoshop (version 2022) for the drawing and execution of front panel view and back panel view of the selected garment. In 1880, Triple pleat blouse jacket was created with thick denim fabric [22]. It had three pleats running along centre front on both sides. The jacket had one to two big pockets. It was initially a work wear for labour, farmers and miners. Denim Dungaree design was developed in 1943 and became very popular especially for workers and their protective characteristics. It is overall garment with top portion attached to bottom. The shoulders have straps. The top portion is also called a bib which has pocket on chest level. A pair of pockets are also attached with pants. Oversized (upsized/ boxy shirt) has exaggerated shoulders, long length sleeves, and wide look. The sleeves have cuffs. This shirt gives a wider and boxy look to wearer. The denim body suits (body fitted dress) are created according to shape of body. The garment is consisting of panels. The silhouette is very smart which gives a slim look to body. The body suits can be made with variety of fabric and considered as bold style garment.

The light shade denim jacket (slim fit jacket) is made-up of light tone of denim fabric processed through various washing treatments. The jacket has two chest

pockets and more button at frontal opening. The jacket has panels, full sleeves and gives a fitted look. Rock and Roll jacket (Statement jacket) style is a fashionable jacket with a very stylish look. The jacket has a stylish cut line with big buttons on front and pockets on chest. Collar is of normal size. The jacket is worn on t-shirts or tops with accessories. Western style denim (cowboy style) shirt is inspired by cowboy shirt, have collar, pockets on chest and full sleeves. It is paired with wide legged trousers. Fitted denim shirt (Slim fit) is produced as smart shape garment with collar and cuffs. It is paired with contrasting jeans or trouser. Long sleeves jacket has V-shaped seams on both sides. The collar, cuffs and pockets are present. The sleeves are exaggerated as compared to typical length. The length of the denim dress shirt (loose fit) is up-to hips level, it gives a boxy look because of denim fabric, it is better to wear as fitted dress or wear with belt. Lace-up denim shirt is with slim shape. The shirt has laces for opening and closing purpose. Denim bustier is short body length denim garment starting from bust level and tight fitted silhouette. It may have different designs and style. It can be with or without shoulder straps. Crop jacket (short body jacket) has smart shape and short length. The buttons and pockets are also short. It is very appealing and stylish among youngsters. It can be worn on a shirt and paired with bell bottom for a chic look.

**Table 2**

Denim garment designs on virtual model with front, and back view

Description	Garment Design	Front View	Back View
<p><u>1. Triple pleats blouse (1880):</u> The design has triple pleats along the front. Design enhanced with a single patched chest pocket and a silver buckle tied at the lower back. It was short and boxy to facilitate body movement.</p>			
<p><u>2. Denim Dungaree (1943):</u> Sturdy work wear was designed for workers and farmers. Initially the Dungaree lacked the bib and shoulder straps. Later in the design, the bib and pants were combined.</p>			
<p><u>3. Oversized shirt (1950):</u> Jacket with wide comfy look. It has full sleeves with increased length of bodice. Overall look of garment was boxy and upsize with rounded button and exaggerated shoulders. It was paired with high waist pants.</p>			
<p><u>4. Denim body suit (1958):</u> The garment was produced by following the body shape, is slim-fitted fashion garment. Initially it was constructed as loose fit garment and worn with gusset between the legs. Later on, it was adopted as elite fashion garment.</p>			
<p><u>5. Light shade jacket (1960):</u> The jacket with two front chest pockets, full sleeves, slim fit and V-seams at both side of opening. This jacket came with a new cut line known as Levi's trucker jacket. The light shade color of jacket was quite popular among youngster.</p>			
<p><u>6. Rock and Roll jacket (1962):</u> This jacket has normal size collar, with big round button, V-seams, pair of pockets at chest and side pockets, also called the bold style. It was paired with t-shirts and accessories.</p>			
<p><u>7. Western style shirt (1970):</u> A cowboy inspired shirt with fitted silhouette and pockets at front with front and back yoke. The cut line was mixture of traditional Mexican shirts and combats shirts used in civil war of America. The cut line was modified with decorative yokes, piping and embellishment.</p>			
<p><u>8. Fitted denim shirt (2000's):</u> Simple western style appearance and unnecessary details were removed. A simple cut line with smart shape shirt was in trend with front opening, pockets at chest and new style of yoke. The seams were straight and buttons were of smaller size.</p>			

9. Long sleeve jacket (2010): The Levi's trucker jacket was modified with long length sleeves than normal size, some ripping effect and single or double pockets. The jacket was paired with skinny jeans and skirts.



10. Denim shirt dress (2012): The shirt has long length, opening at front, without seams, have cuffs and a pair of pockets at chest. The look of dress was wide. The shirt was stylized with skirts.



11. Lace-up denim shirt (2012): The variation was made in shirt dress. The style has advancements with smart fit look and laces for opening and closing of shirt and longer shirt length than normal size. The cut line gives a stylist look to wearer and paired with straight pants.



12. Denim bustier (2013): The cropped shaped garment was initially made as under garment but later on, the celebrities layered the bustier over the garments for a chic style.



13. Crop jacket (2014): The jacket has short length with small size pocket and small buttons. The jacket available in light and dark shade was worn with all types of vests, casual t-shirts, narrow pants etc.



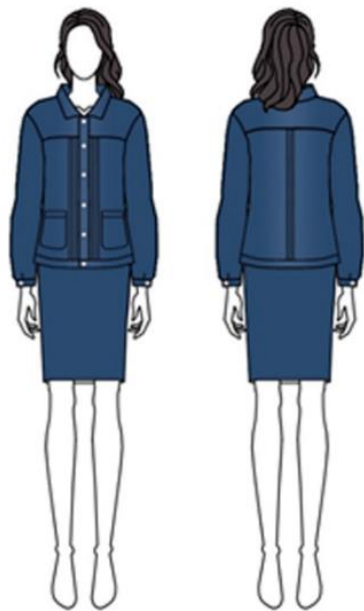
### 3. Result and Discussion

Thirteen garments with different design cut lines were selected for the measurements of the four variables, i.e., fabric consumption, fabric efficiency, fabric loss and cost effectiveness. While the factors like fabric width, shrinkage, and number of pieces in each marker were kept constant. The number of garments in each pattern marker were kept 20 pieces. The length of the pattern marker varied according to the style of the garment and hence the fabric utilization and the losses or waste of fabric quantity also varied.

#### 3.1 Fabric Consumption Results of Triple Pleats Blouse Design

Fig. 3 shows the triple pleat blouse cut lines along with 2D patterns and the marker of 20 garment pieces. All the garments' cut panels were nested with maximum efficiency of the marker and fabric, i.e., minimizing wastage or fabric losses. The results in the figure

described that the fabric efficiency achieved in this garment style was 87.10% with fabric consumption of 28 meters (2800cm). 12.90% area of the marker wasted the fabric. The silhouette of the garment was straight, the fabric was utilized in collar, bodice, sleeves and pockets. The results indicated that 1.4-meter (1400cm) fabric was used for each single triple pleat blouse jacket including the wastage or losses. 20 pieces of this style consumed 28 meters (2800 cm) fabric with wastage of 3.612 meters (361.2 cm). The fabric utilization in 28 meters (2800 cm) was 24.388 meters (2438.8 cm). Among the styles of group 3, the fabric in triple pleat blouse was consumed more due to three pleats. Therefore, as the number of pleats increased or reduced in the style it would affect the fabric utilization or fabric efficiency and fabric losses. This style was ranked 3rd with fabric utilization (87.10%) and fabric wastage (12.9%). Moreover, it was ranked 4th in fabric consumed (marker length) and thus in cost-effectiveness.



3D illustration of triple pleats blouse



2D Pattern of triple pleats blouse



Marker of triple pleats blouse

Fig. 3. Triple Pleat Blouse Cut Lines with 2D Patterns and the Marker

### 3.2 Fabric Consumption Results of Dungaree Design

Fig. 4 shows the Denim Dungaree style cut lines along with 2D patterns and the marker of 20 garment pieces. The results in the figure described that the fabric efficiency achieved in this garment style was 86.16% with fabric consumption (marker length) of 35 meters (3500cm). 13.84% area of the fabric (marker) wasted the fabric. This indicated that 1.75-meter fabric was used for each single dungaree including the wastage or losses. 20 pieces of the style consumed 35 meters (3500cm) of fabric with wastage of 4.84 meters (484.4cm). The total fabric utilization in 35 meters (3500cm) was 30.156 meters (3015.6 cm). The fabric was consumed more due to big size bib, shoulder straps, bottom wear, waist belt, and pockets. However, changing the style of bib, frontal pocket, straps and bottom wear, the fabric efficiency, and fabric consumption was affected. In group 1, denim dungaree consumed more fabric due to its combined pant. However, among all 13 styles, the style was ranked 10<sup>th</sup> in fabric utilization (86.16%) and wastage (13.84%). The style ranked 6<sup>th</sup> in cost-effectiveness and fabric consumption (marker length).

### 3.3 Fabric Consumption Results of Oversized Top Design

Fig. 5 shows the oversized top cut lines along with 2D patterns and the marker of 20 garment pieces marker. The result depicted that the fabric efficiency achieved in this style was 85.59%, with fabric consumption (marker length) 33 meters (3300cm). The fabric loss in this garment styles was 14.41%. This indicated that 1.65-meter (165 cm) fabric was consumed for each single over-sized top including the wastage or losses. 20 pieces of oversized top consumed 33 meters (3300cm) of fabric with wastage of 4.75 meters (475 cm). The total fabric utilization in 33 meters (3300 cm) was 28.2447 meters (2824.47 cm). Among styles of groups 3, the more fabric consumption for this style was due to exaggerated length of sleeves, shoulders, and bodice. However, increasing/decreasing the garment's pieces' length would directly affect the fabric consumption/utilization. This style was ranked as least efficient (85.59%) style with maximum wastage (14.41%) of fabric. According to the fabric consumption, and cost-effectiveness, the style was ranked 9<sup>th</sup>.

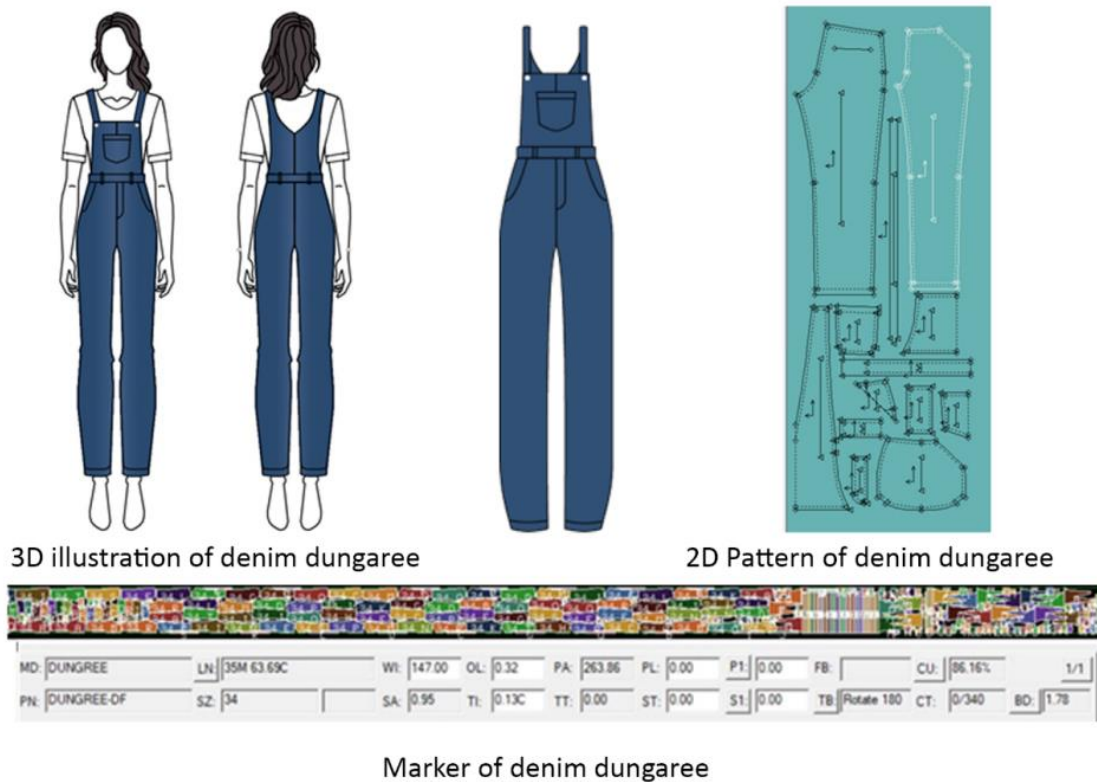


Fig. 4. Dungaree Design Cut Lines with 2D Patterns and the Marker

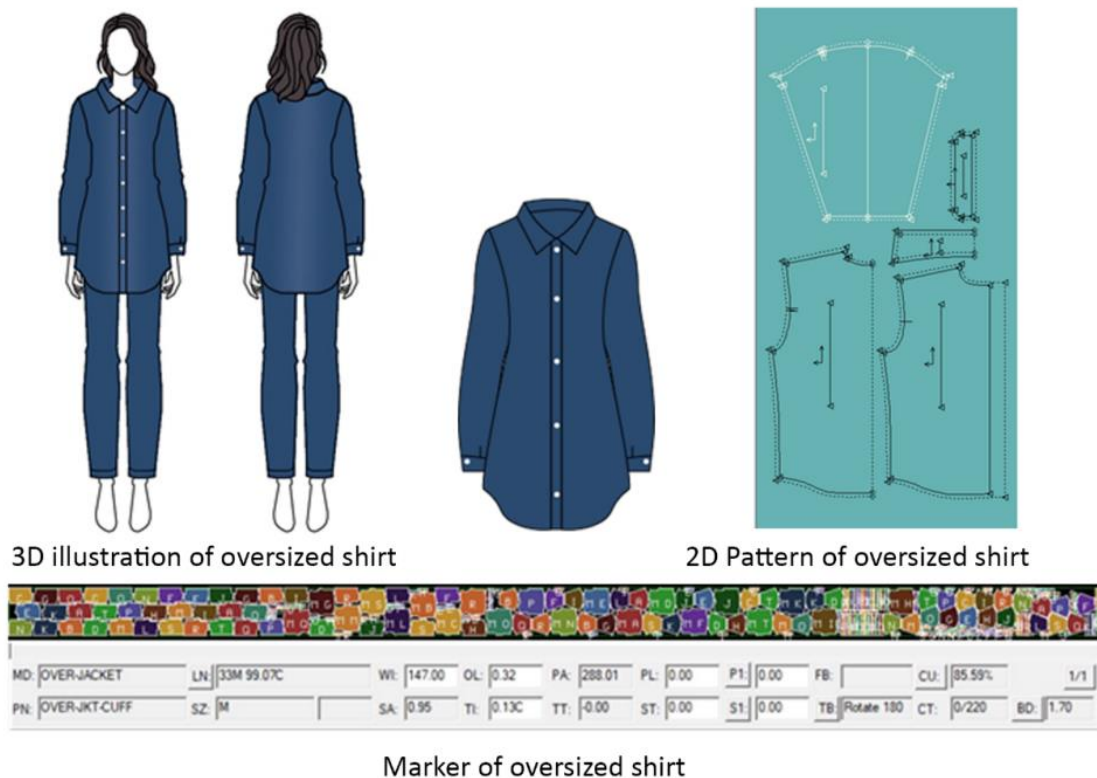


Fig. 5. Oversized Top Cut Lines with 2D Patterns and the Marker

### 3.4 Fabric Consumption Results of Denim Body Suit Design

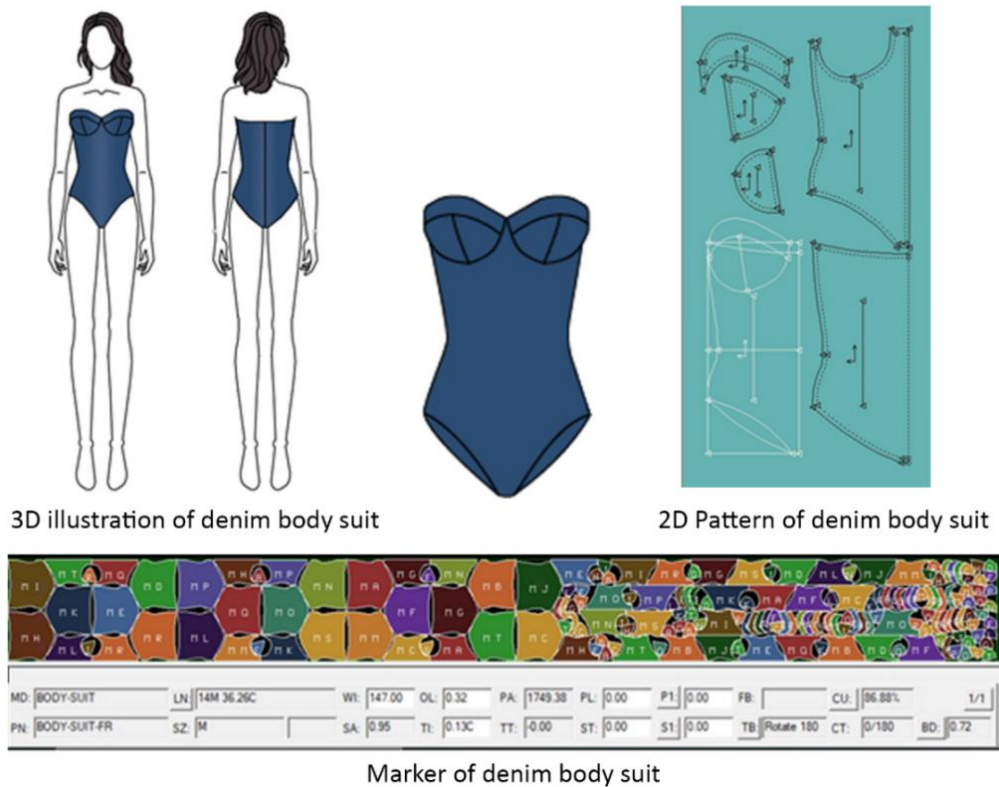
Fig. 6 has shown the Denim body suit style cut lines along with 2D patterns and the marker of 20 garment pieces. The results declared that the fabric efficiency in denim body suit achieved was 86.88% with fabric consumption (marker length) 14 meters (1400 cm). The fabric loss in this garment styles was 13.12%

which depicted that 0.7 meter (70 cm) of fabric was consumed for each single denim body suit including the wastage or loss. 20 pieces of denim body suit consumed 14 meters (1400 cm) with fabric wastage of 1.84 meters (184 cm). The total fabric utilization in 14 meters (1400 cm) was 12.1632 meters (1216.32cm). The fabric was consumed less due to fitted cut line and absence of neckline and sleeves. In this way, fabric efficiency was high as compared to other styles of



group 1 and 3, and fabric wastage was minimum. In group 2, the style used more fabric length than denim bustier for the reason of exaggerated length of dress. Therefore, changing the cut line and designing the neckline and sleeves in different styles would affect

the fabric efficiency and consumption. Among all the 13 styles, this style was ranked 4<sup>th</sup> in the fabric efficiency (86.88%) and fabric wastage (13.12%). The style ranked 2<sup>nd</sup> in cost effectiveness due to less fabric consumed (marker length).



**Fig. 6.** Body Suit Style Cut Lines with 2D Patterns and the Marker

### 3.5 Fabric Consumption Results of Light Shade Jacket Design

Fig. 7 shows the light shade jacket cut lines along with 2D patterns and the marker of 20 garment pieces. According to marker results of this style, fabric efficiency in this style achieved was 86.58% with fabric consumption (marker length) of 29 meters (2900cm). The fabric wastage in this garment styles achieved was 13.42% which indicated that 1.45 meters (145cm) of fabric was consumed in single light shade jacket including wastage or loss. 20 pieces of light shade jacket consumed 29 meters (2900 cm) with fabric wastage of 3.89 meters (389 cm). The total fabric utilization in 29 meters (2900 cm) was 25.1082 meters (2510.82 cm). Among styles of group 3, the fabric was consumed more due to size of chest pockets, v-seams, front and back yoke and straight jacket shape. Therefore, as the size of pocket increased or reduced, jacket silhouette is changed in the style, it would affect the fabric efficiency and fabric consumption. In group 3, this style consumed less fabric as compared to style number 2,5,7,8 and 9. More efficient with less wastage of fabric. Light shade jacket style was placed 8<sup>th</sup> in the fabric efficiency. The style placed 5<sup>th</sup> in cost-effectiveness and fabric

consumption among all styles. (86.58%) and fabric wastage (13.42%).

### 3.6 Fabric Consumption Results of Rock and Roll Jacket Design

Fig. 8 shows the Rock and Roll jacket cut lines along with 2D patterns and the marker of 20 garment pieces. The results showed that the fabric efficiency in this style achieved was 86.74% with fabric consumption (marker length) of 28 meters (2800 cm). The fabric (marker) wastage in this garment style was 13.26%, which showed that 1.4 meter (14cm) was consumed in single Rock and Roll jacket including wastage or loss. 20 jackets consumed 28 meters (2800 cm) with fabric wastage of 3.7128 meters (3712.8 cm). The total fabric utilization in 28 meters (2800 cm) was 24.2872 meters (2428.72 cm). Among styles of group 3, the less fabric (marker length) wastage as compared to light shade jacket was due to normal size of collar and pocket flaps. Therefore, changing the size of collar and pocket would increase/decrease the fabric efficiency and fabric consumption. This style consumed less fabric length (marker length), more efficient and less fabric wastage. Rock and Roll jacket style was ranked 7<sup>th</sup> in the fabric efficiency (86.74%) and fabric wastage

(13.26%). According to fabric length consumed (marker length used), the style was positioned at 5th

among all 13 styles. The similar position was observed in cost-effectiveness.

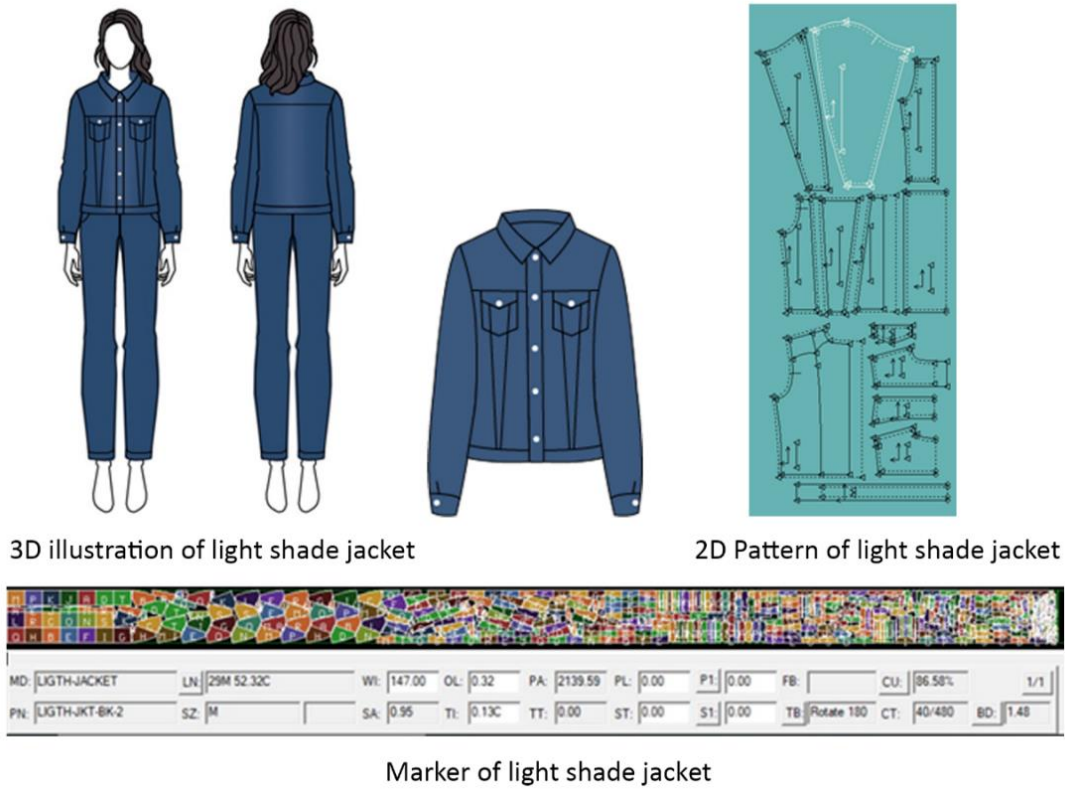


Fig. 7. Light shade jacket Cut Lines with 2D Patterns and the Marker

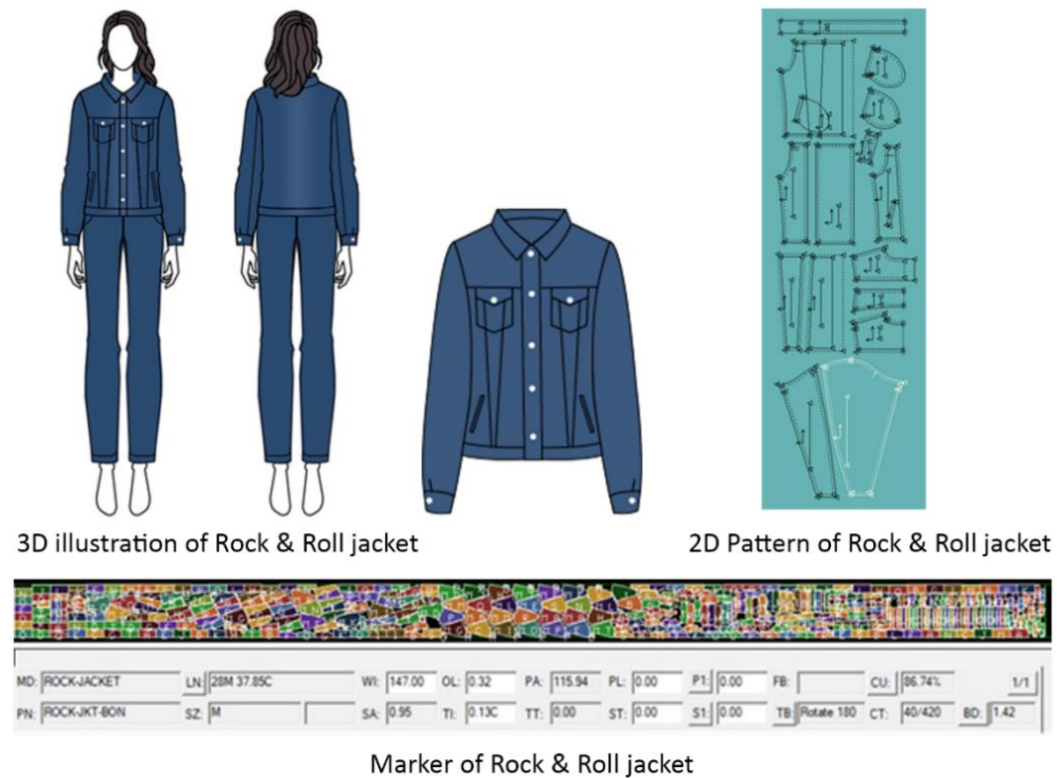


Fig. 8. Rock and Roll Jacket Cut Lines with 2D Patterns and the Marker

### 3.7 Fabric Consumption Results of Western-Style Shirt Design

Fig. 9 shows the western style shirt cut lines along with 2D patterns and the marker of 20 garment pieces.

The fabric efficiency of western style shirt achieved was 86.79% with fabric consumption (marker length) of 31 meters (3100 cm). The fabric (marker) wastage in this garment styles were 13.21%. This indicated that

1.55 meters (155cm) of fabric was consumed in single western style shirt including wastage or loss. 20 pieces of western style shirt consumed 31 meters (3100 cm) with fabric wastage of 4.09 meters (409 cm). The total fabric utilization in 31 meters (3100 cm) was 26.9049 meters (2690.49cm). Among all the styles of group 3, the more fabric consumption was due to small size collar, slim-fit silhouette, straight yoke, and absence of v-seams. Therefore, increase or decrease in size of yoke and fitting can increase or decrease the fabric efficiency and consumption. The western style shirt consumed more fabric length, more efficient with minimum wastage of fabric (marker). Among all styles of group 1,2 and 3, this style was ranked as 5th efficient style with maximum fabric efficiency (86.79%) and fabric wastage (13.21%) whereas according to fabric consumption (marker length) and cost-effectiveness, it ranked 7th.

### 3.8 Fabric Consumption Results of Fitted Denim Shirt Design

Fig. 10 has displayed the fitted denim shirt cut lines along with 2D patterns and the marker of 20 garment

pieces. Results of this garment style has shown fabric efficiency achieved which was 86.39% with fabric consumption (marker length) 29 meters (2900 cm). The fabric (marker) wastage in this garment styles were 13.61%. This means that 1.45 meter (145 cm) of fabric was used in single fitted denim shirt including the wastage or losses. 20 pieces of fitted denim shirt consumed 29 meters (2900 cm) with fabric wastage (marker loss) of 3.9469 meters (394.69 cm). The total fabric utilization in 29 meters (2900 cm) was 25.0531 meters (2505.31cm). This style was categorized in group 3, and more fabric (marker length) wastage as compared to western style shirt and denim shirt dress was due to stylized yoke, specific size of pockets, and suspended panels of shirt which were absent in western style shirt and shirt dress. Therefore, a change in design of yoke, pockets and panels could increase or decrease the fabric efficiency and consumption. This style was ranked 9th in fabric efficiency (86.39%) and fabric wastage (13.61%), among all styles. The style was positioned 5th in fabric consumption and cost-effectiveness.

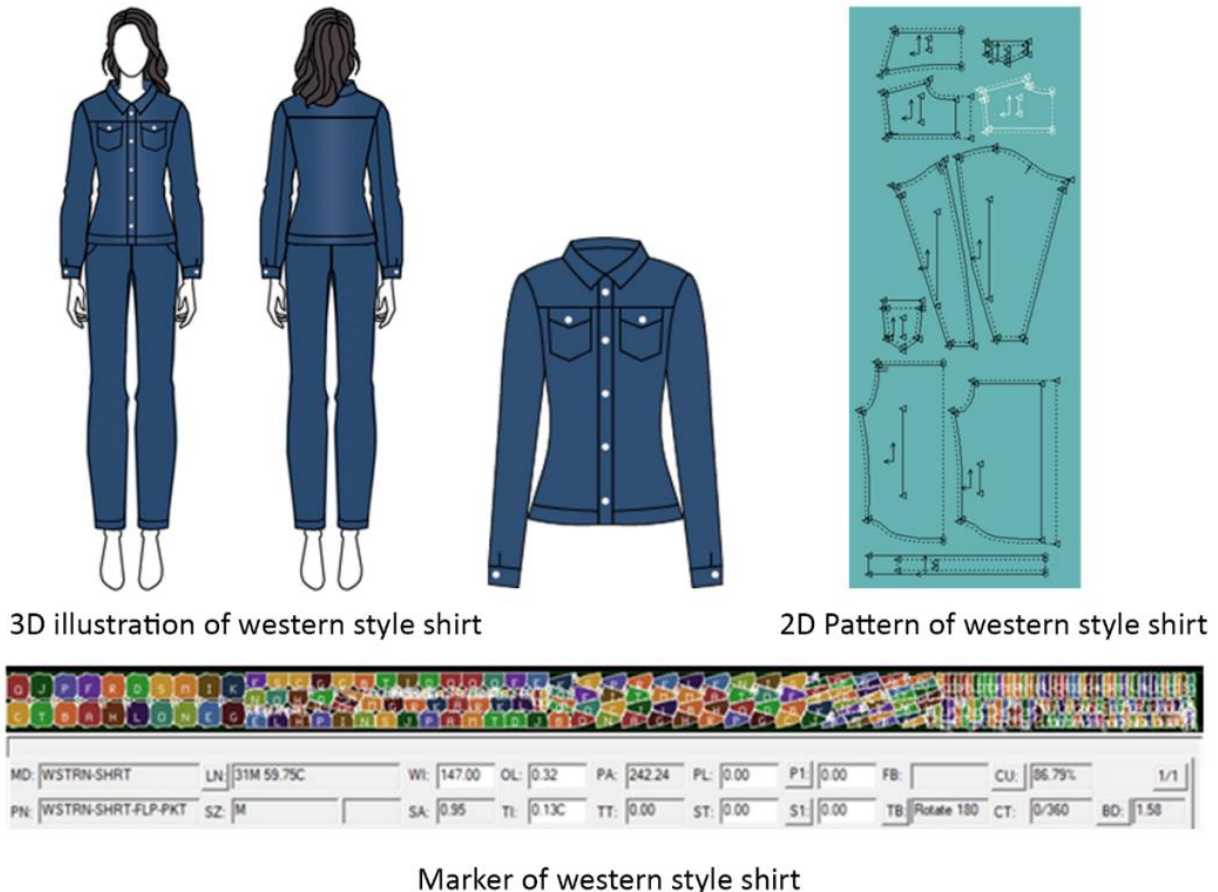
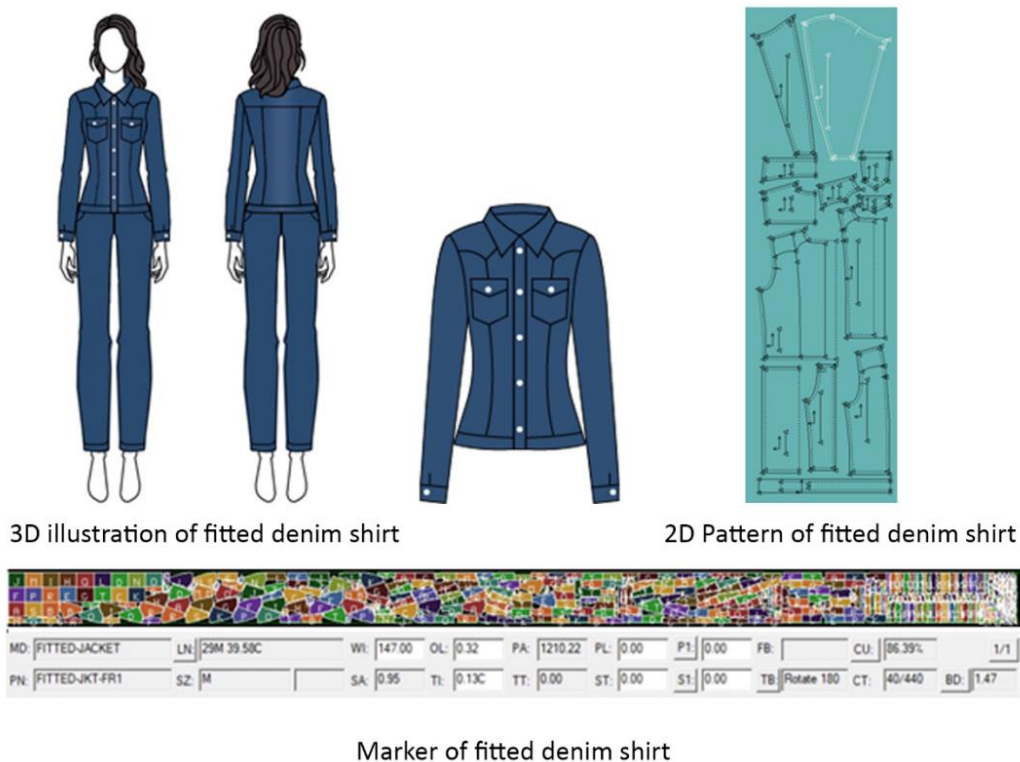


Fig. 9. Western Style Shirt Cut Lines with 2D Patterns and the Marker



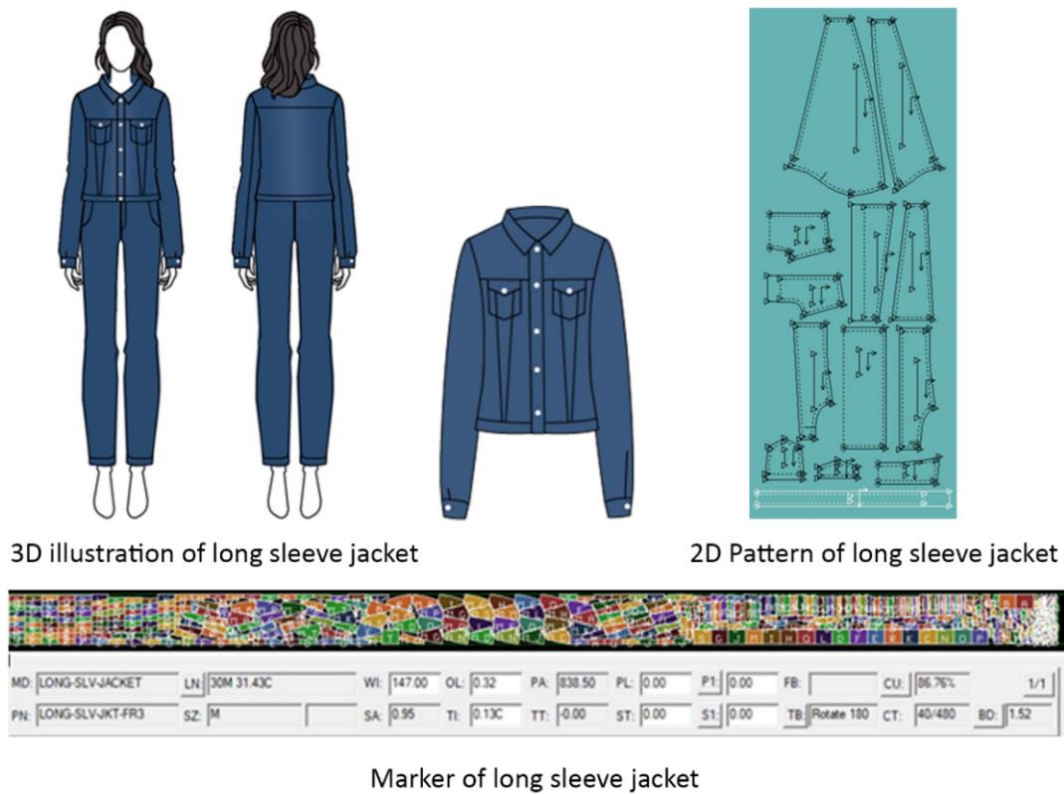
**Fig .10.** Fitted Denim Shirt Cut Lines with 2D Patterns and the Marker

### 3.9 Fabric Consumption Results of Long Sleeve Jacket Design

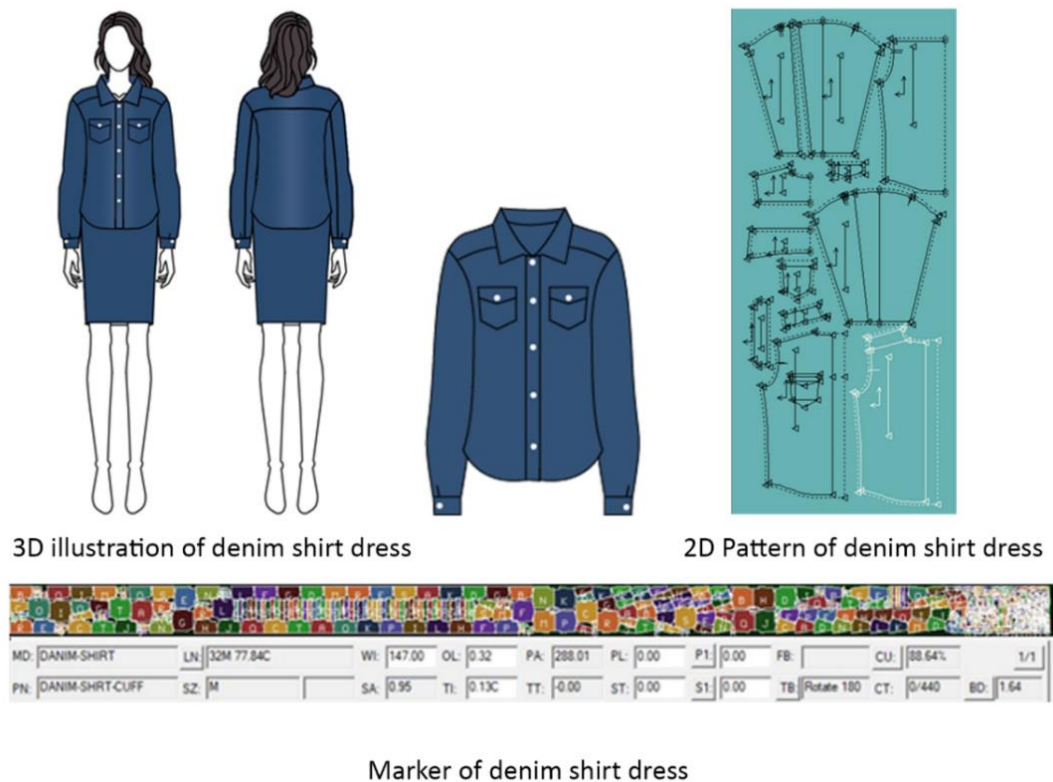
Fig. 11 has displayed the long sleeve jacket cut lines along with 2D patterns and the marker of 20 garment pieces. The fabric efficiency in this garment style achieved was 86.76% with fabric consumption (marker length) 30 meters (3000 cm). The fabric waste was calculated as 13.24% which showed that 1.5-meter (150 cm) fabric was consumed in each long sleeve jacket including the fabric wastage or losses. 20 pieces of long sleeve jacket consumed 30 meters (3000 cm) with fabric (marker length) wastage of 3.97200 meters (397.2) cm. The total fabric utilization in 30 meters (3000 cm) was 26.028 meters (2602.8cm). The style consumed more fabric as compared to denim bustier and body suit due to collar, sleeves, cuffs and pocket. Among group 3, the fabric length (marker length) of long sleeve jacket was higher than denim fitted shirt, rock n roll jacket, and light shade jacket due to straight cut line of yoke, sleeves and overall shape of jacket which caused marker to efficiently use fabric and waste less fabric. However, change in length of yoke, sleeves and bodice can affect the fabric efficiency and fabric consumption. Long sleeve jacket consumed more fabric, more efficient and less fabric wastage. Among all the styles, it was ranked 6th in fabric efficiency, fabric consumption and cost-effectiveness and 8th in fabric loss.

### 3.10 Fabric Consumption Results of Denim Shirt Dress Design

Fig. 12 has displayed the denim shirt dress cut lines along with 2D patterns and the marker of 20 garment pieces. The results have shown that the fabric efficiency in this garment style achieved was 88.64% with fabric consumption (marker length) 32 meters (3200 cm). The fabric waste (marker loss) examined was 11.36%. This showed that 1.6-meter (160 cm) fabric was consumed in single denim shirt dress including fabric wastage or loss. 20 pieces of shirt dress consumed 32 meters (3200 cm) with fabric (marker) wastage of 3.6352 meters (336.52 cm). The total fabric utilization of 20 pieces of denim shirt dress was calculated as 28.3648 meters (2836.48 cm). The greater fabric length as compared to other styles of group 3 was due to straight cut line of garment style, pockets and lack of V-shaped panels in cut line. However, increase or decrease in pocket style or panels would affect the fabric efficiency and fabric consumption. The style was fitted, without seams, having small pockets caused the efficient fabric (marker) results. The style used greater length of fabric (maker length), was more efficient in fabric efficiency and minimum fabric wastage. The style was ranked 2nd efficient among all styles with maximum fabric utilization (88.64%) and 2nd highest in marker efficiency with minimum fabric wastage (11.36%), while according to fabric consumption (marker length) used and cost-effectiveness, this style was ranked 8th.



**Fig. 11.** Marker of Long Sleeve Jacket with 2D pattern and the Marker



**Fig. 12.** Denim Shirt Dress Cut Lines with 2D Patterns and the Marker

### 3.11 Fabric Consumption Results of Lace-Up Shirt Design

Fig. 13 shows the lace-up shirt cut lines along with 2D patterns and the marker of 20 garment pieces. The fabric (marker) efficiency in this garment style achieved was 85.74% with fabric consumption (marker length) 39 meters (3900 cm). The fabric wastage (marker loss) examined was 14.26%. The

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results indicated that 1.95 meters (195cm) fabric was consumed in single lace-up shirt including fabric wastage or loss. 20 pieces of lace-up shirt consumed 39 meters (3900cm) which fabric (marker) wastage of 5.5614 meters (556.14cm). The total fabric utilization for 20 garment pieces was calculated as 33.4386 meters (3343.86 cm). Among all shirt styles in group 3, the use of more fabric length (marker length) was

due to extended length of shirt. Therefore, the increase or decrease of shirt length would affect the fabric efficiency and consumption. The style consumed greatest fabric (marker) length, was less efficient and less cost-effective. According to fabric efficiency and

fabric wastage, the style was ranked 12th and observed as 2nd least efficient style. According to the fabric consumed and cost-effectiveness, the style was ranked 10th among all the styles.

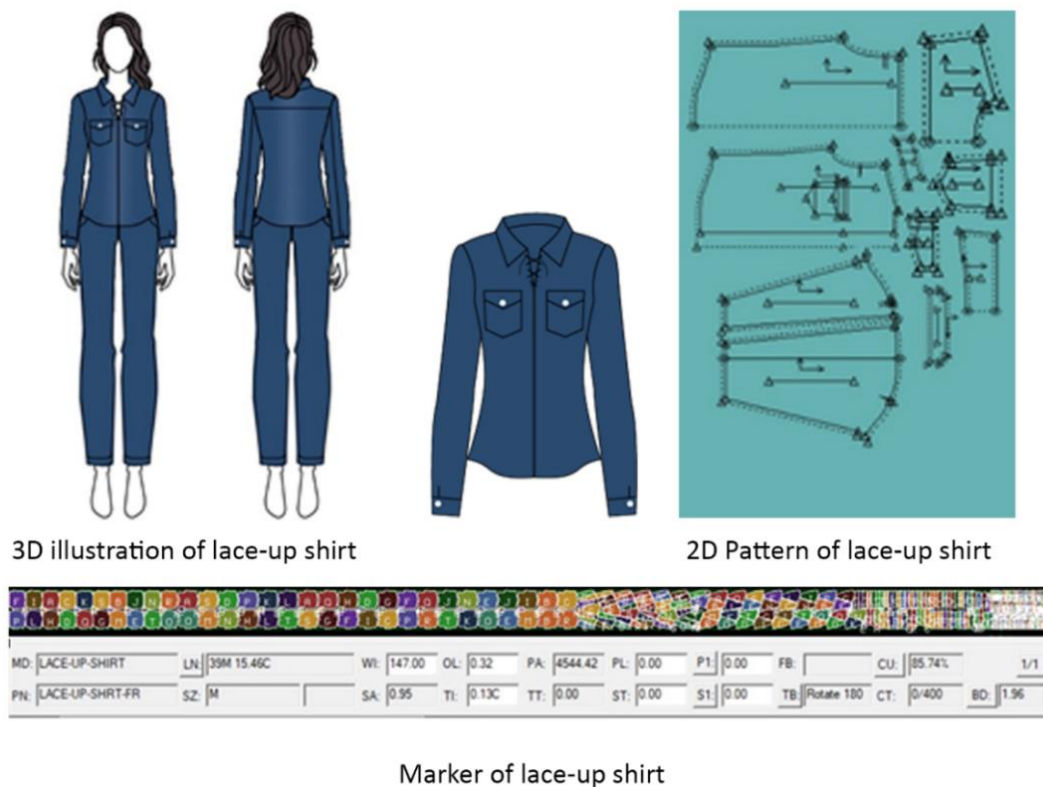


Fig. 13. Lace-Up Shirt Cut Lines with 2D Patterns and the Marker

### 3.12 Fabric Consumption Results of Denim Bustier Design

Fig. 14 has shown the denim bustier cut lines along with 2D patterns and the marker of 20 garment pieces. The highest value of fabric (marker) efficiency among all garment styles was achieved in this garment style with value 89.01%, within fabric consumption (marker length) 7 meters (700cm). The fabric wastage (marker loss) was examined 10.99% which means that 0.35 meter (35cm) of fabric was used for single bustier which included the fabric wastage or losses. 20 pieces of denim bustier consumed 7 meters (700cm) of fabric (marker length) with fabric wastage (marker loss) of 0.7693 meters (76.93cm). The total fabric utilization in 7 meters (700 cm) was 6.2307 meters (623.07 cm). The less fabric length (marker length) used among all the garment styles was due to short length of garment and absence of sleeves. In group 2, unlike denim body suit, the bustier lack the bottom panels around the legs, therefore its marker produced highly efficient results. Denim bustier consumed lesser fabric length (marker length), was highly efficient and efficient in fabric wastage. Therefore, increase or decrease in the length of garment would affect the fabric efficiency and

fabric consumption. Denim bustier style was ranked 1st position in all factors i.e., fabric efficiency (89.01%), minimum fabric wastage (10.99 %), minimum fabric consumption and therefore most cost-effectiveness.

### 3.13 Fabric Consumption Results of Crop Jacket Design

Fig. 15 has shown the crop jacket cut lines along with 2D patterns and the marker of 20 garment pieces. The results have shown that the fabric (marker) efficiency in this garment style achieved was 85.79% with fabric consumption (marker length) 26 meters (2600cm). The fabric wastage (marker loss) was calculated 14.21% which showed that 1.3 meter (130cm) of fabric was consumed in single crop jacket including the wastage or losses. 20 pieces of crop jacket consumed 26 meters (2600cm) with fabric wastage of 4.1209 meters (412.09cm). The total fabric utilization in 26 meters (2600 cm) was 22.3054 meters (2230.54cm). The less use of fabric length (marker length) as compared to other styles of group 3 was due to short length of jacket and small size of pockets. However, the use of more fabric length than denim bustier and body suit was due to collar, sleeves and

cuffs, yokes and v-seams. Crop jacket consumed more fabric, less efficient with greater fabric wastage. Therefore, increase and decrease of length in style would affect the fabric efficiency and fabric consumption. Crop jacket style was ranked 11th in

fabric efficiency (85.79%) with greater fabric wastage (14.21%). Therefore, this style was considered least efficient. However, in fabric consumption and cost-effectiveness it ranked 3rd.

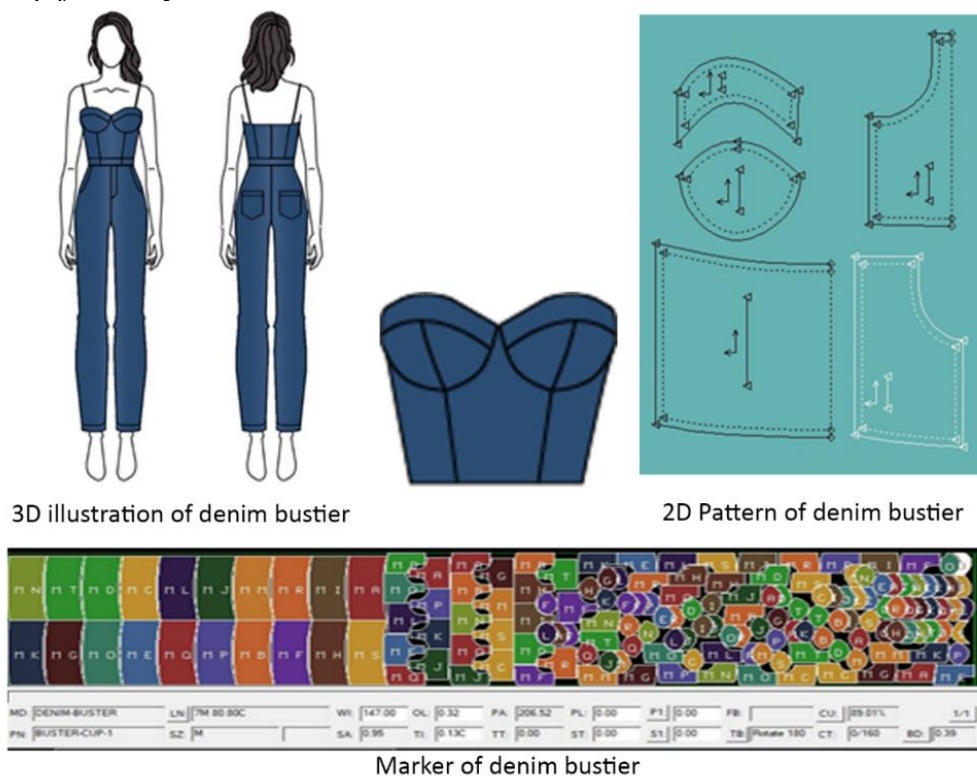


Fig. 14. Denim Bustier Cut Lines with 2D Patterns and the Marker

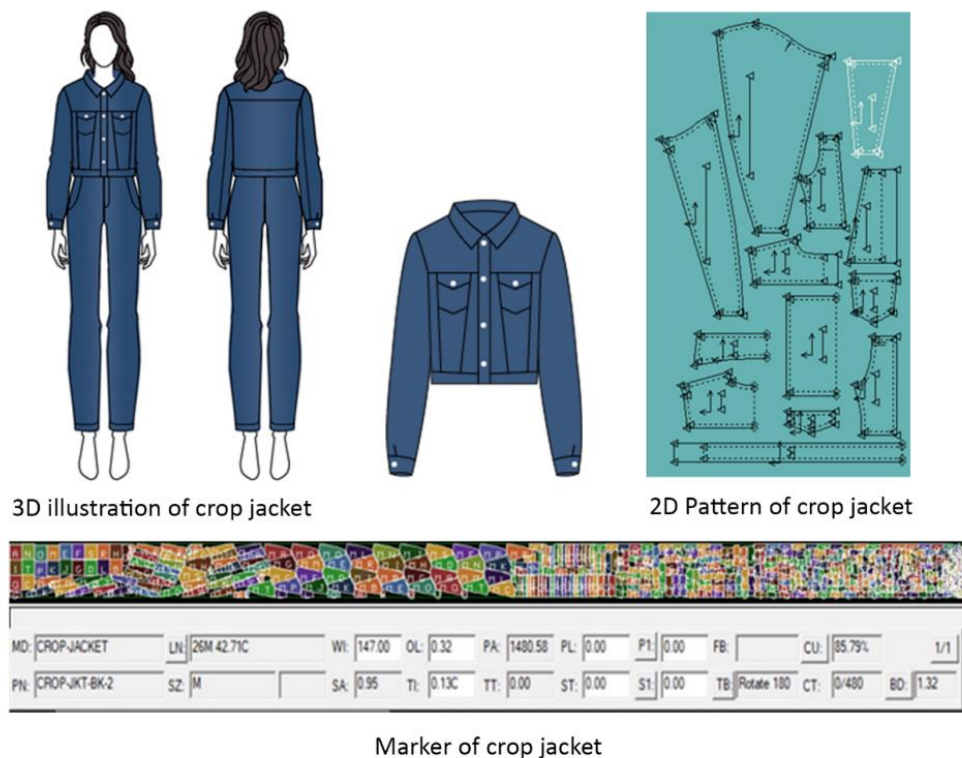


Fig. 15. Crop Jacket Cut Lines with 2D Patterns and the Marker

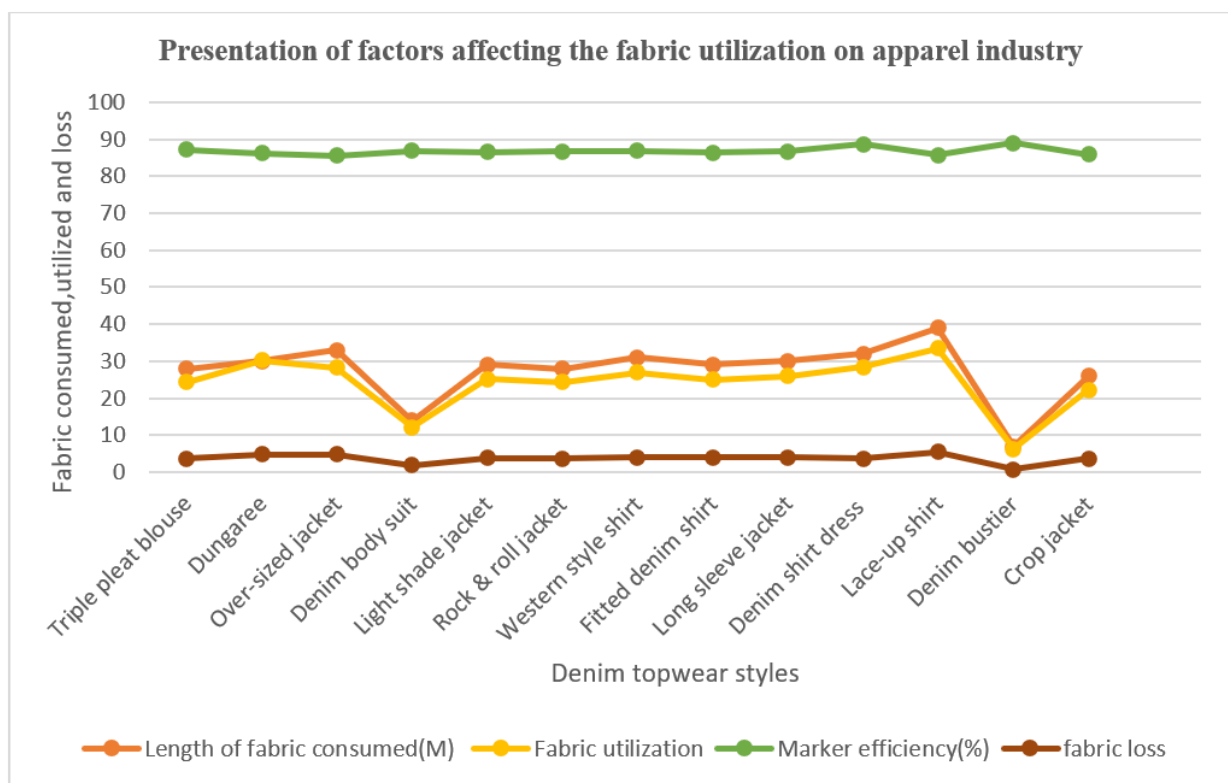
Table 3 showed the garment styles with values of factors affecting the fabric utilization in apparel industries. The styles were mentioned according to

their respective groups with values of fabric consumption, fabric efficiency, fabric utilization, fabric loss and cost-effectiveness.

**Table 3**

Garment styles with calculated values of dependent variables

	Style No.	Denim top wears style	Fabric Consumption (m)	Fabric efficiency (%)	Fabric utilization (m)	Fabric loss (m)	Cost Effectiveness
Group 1	1	Dungaree (1943)	35(10 <sup>th</sup> )	86.16(10 <sup>th</sup> )	30.156	4.844(12 <sup>th</sup> )	6 <sup>th</sup>
Group 2	2	Denim bustier (2013)	7(1 <sup>st</sup> )	89.01(1 <sup>st</sup> )	6.2307	0.7693(1 <sup>st</sup> )	1 <sup>st</sup>
	3	Denim body suit (1958)	14(2 <sup>nd</sup> )	86.88(4 <sup>th</sup> )	12.1632	1.8368(2 <sup>nd</sup> )	2 <sup>nd</sup>
Group 3	4	Triple pleat blouse (1880)	28(4 <sup>th</sup> )	87.10(3 <sup>rd</sup> )	24.388	3.612(4 <sup>th</sup> )	4 <sup>th</sup>
	5	Over-sized jacket (1950)	33(9 <sup>th</sup> )	85.59(13 <sup>th</sup> )	28.2447	4.7553(11 <sup>th</sup> )	9 <sup>th</sup>
	6	Light shade jacket (1960)	29(5 <sup>th</sup> )	86.58(8 <sup>th</sup> )	25.1082	3.8918(6 <sup>th</sup> )	5 <sup>th</sup>
	7	Rock and roll jacket (1962)	28(4 <sup>th</sup> )	86.74(7 <sup>th</sup> )	24.2872	3.7128(5 <sup>th</sup> )	4 <sup>th</sup>
	8	Western style shirt (1970)	31(7 <sup>th</sup> )	86.79(5 <sup>th</sup> )	26.9049	4.0951(9 <sup>th</sup> )	7 <sup>th</sup>
	9	Fitted denim shirt (2000's)	29(5 <sup>th</sup> )	86.39(9 <sup>th</sup> )	25.0531	3.9469(7 <sup>th</sup> )	5 <sup>th</sup>
	10	Long sleeve jacket (2010)	30(6 <sup>th</sup> )	86.76(6 <sup>th</sup> )	26.028	3.972(8 <sup>th</sup> )	6 <sup>th</sup>
	11	Denim shirt dress (2012)	32(8 <sup>th</sup> )	88.64(2 <sup>nd</sup> )	28.3648	3.6352(4 <sup>th</sup> )	8 <sup>th</sup>
	12	Lace-up shirt (2012)	39(11 <sup>th</sup> )	85.74(12 <sup>th</sup> )	33.4386	5.5614(13 <sup>th</sup> )	10 <sup>th</sup>
	13	Crop jacket (2014)	26(3 <sup>rd</sup> )	85.79(11 <sup>th</sup> )	22.3054	3.6946 (10 <sup>th</sup> )	3 <sup>rd</sup>



**Fig. 16.** Factors Affecting the Fabric Performance in Apparel Industry

Fig. 16 shows the diagram of all styles with respect to fabric length consumed, fabric utilization, fabric loss and marker efficiency. The orange line indicated

the fabric length consumed, i.e., highest fabric consumption was achieved in lace-up shirt (39 meters) whereas least fabric consumed in denim bustier (7



meters) and denim bodysuit (14 meters). Similarly, the green colour line specified the marker efficiency exhibited highest points for denim bustier and denim shirt dress i.e., displayed highest fabric efficiency values respectively. The graph also showed fabric utilization of all styles and maximum fabric was utilized in denim bustier (6.2307 meters) and denim body suit (12.1632 meters) while minimum fabric was utilized in lace-up shirt (33.4386 meters). The line for fabric loss indicated higher fabric loss was achieved in lace-up shirt (5.5614 meters) whereas minimum fabric

loss was achieved in denim bustier (0.7693 meters). For statistical results, one-way ANOVA test was performed to compare the significant results of all style's fabric consumption. All the fabric lengths were divided into two groups for comparison. The variance in group 1 and 2 was 172.2381 and 20.90476 respectively. The value of SS between groups were 423.5 while within groups were 1158.857. The results of ANOVA test showed the value of  $p$  as 0.058 which means the results were close to the significant.

**Table 4**

ANOVA test to compare the result of fabric consumption in all top wear styles

Anova: Single Factor						
SUMMARY						
Groups	Count	Sum	Average	Variance		
Group 1	7	142	20.28571	172.2381		
Group 2	7	219	31.28571	20.90476		
ANOVA						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	423.5	1	423.5	4.385355	0.058148	4.747225
Within Groups	1158.857	12	96.57143			
Total	1582.357	13				

#### 4. Conclusion

The research work was conducted to study the fabric consumption, fabric efficiency, fabric loss and cost-effectiveness of thirteen different denim top wear styles (triple blouse jacket, dungaree, over-sized shirt, body suit, light shade jacket, rock n roll jacket, western style shirt, fitted shirt, long sleeve shirt, denim shirt dress, lace-up shirt, denim bustier and crop jacket) on 2/1 Z twill weave denim fabric having composition of 98% cotton and 2% Elastane, in apparel industry. The results obtained through the experimental work can be summarized as below:

(1) Fabric consumption (marker length), fabric efficiency (marker efficiency), fabric loss and cost-effectiveness are dependent variables. Their values vary according to different garment style.

(2) According to the fabric (marker) efficiency, denim bustier has higher fabric efficiency (89.01%) with fabric consumption of 7 meters and minimum fabric loss (marker loss) of 10.99%. This style was 1st cost-effective style among all the styles. Over-sized jacket has least fabric efficiency among all styles with value 85.59%. The fabric loss in this style was 14.41%. Denim shirt dress was ranked second with respect to fabric efficiency (88.64%) with fabric consumption of 32 meters. The fabric loss was 11.36%.

(3) According to the fabric consumption (marker length) for all styles, denim bustier was ranked 1st style with minimum fabric consumption with fabric length 7 meters among all the styles. Similarly, denim body suit was ranked 2nd with fabric length 14 meters, over-sized shirt and lace-up shirt were graded least efficient style since consumed 33 meters and 39 meters fabric.

(4) In ANOVA test, the fabric consumption of all styles was compared. The value of  $p$  in ANOVA shows that the results are close to the significant.

The above research work suggested that the selection of efficient styles in the apparel industries can reduce the overall production cost in such a way that these efficient styles would optimize fabric utilization and cause minimum fabric waste. The top three styles i.e., denim bustier, denim body suit and triple pleat blouse with fabric efficiencies 89.01%, 86.88 % and 87.10% suggested that the apparel industries can select the efficient styles for production of garments, sustainability and cost effectiveness.

#### 5. Acknowledgment

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