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INFLUENCE OF WOVEN FABRIC WIDTH AND HUMAN BODY TYPES ON THE FABRIC EFFICIENCIES IN THE APPAREL MANUFACTURING

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Abstract:

In the apparel manufacturing, the fabric is the single largest element in the cost of the garment. Therefore, effectual fabric consumption causes a reduction in cost and exertions. The purpose of this research is to study the effects of fabric width on the efficiency of marker (cutting) plans. Fabric consumption is in four types for human body shapes, that is, triangle, oval, square, and circle, in both genders to control the fabric utilization. Two clothing styles, fitted trousers and fitted shirts, are manufactured in an apparel manufacturing industry. The marker plans produced through Garment Gerber Technology software are accomplished in 36 different fabric widths (independent variables). The evaluation of dependent variables, that is, marker efficiency, marker loss, and fabric consumption efficiency relevant to four body shapes in variable fabric widths is analyzed for both women and men. The statistical analysis indicates that there is a linear relationship between marker efficiency and fabric width (sig <0.05). The regression analysis (p-value) between dependent variables and predictor variables (body types and fabric width) is also statistically significant. Also, the result implies that markers are more productive with larger fabric widths in all styles in both genders.

Keywords:

Apparel manufacturing, body shapes, fabric width, fabric efficiency, marker

1. Introduction

In the apparel manufacturing, fabric efficiency is the percentage of the total fabric actually utilized in the garment component parts [1]. The fabric utilization and its cost difference in the total product cost depend on the item and production situation [2]. However, it is the single largest element in the total cost of the garment product [3]. Therefore, an improvement in fabric utilization results in many savings [4]. For instance, a saving of two million dollars per year was achieved through a 0.1% improvement in fabric utilization [5]. Thus, companies have substantial apprehensions in fabric consumption reduction through effectual resource utilization [6]. To control the fabric efficiencies, fabric widths and human body shapes are particularly imperious, since minute variations in pattern shapes led to the enormous consumption of fabric [7]. The efficient fabric consumption and controlling its cost have remained an unresolved issue in the apparel industries.

The body shapes with the dissimilarity in dimensions and morphological appearances are generalized into few figure types (triangle, square, oval, and circle) [8]. Additionally, the body shape classifications, both in women and men, play a deceive role in the fabric consumption and always contribute to the issue of production cost in the fabric cutting-room of an apparel firm [9]. This often occurs with reiterated similar garment style production orders, nevertheless proceeding with different body shapes. The significant part of fabric consumption is caused during the making of marker cutting plans that are based on a technical drawing of pattern and markers (a two-dimensional placement of a set of pattern pieces on a rectangular fabric lay) [10]. Since the fabric is cut based on the pattern marker, marker losses and marker efficiencies have an imperative role in fabric consumption [11].

Marker loss is the wastage (fabric wastage) which consists of those proportions (non-useable areas) of the marker that do not become the part of garment components in the rectangular sheet [12]. Marker loss (wastage) is measured according to the marker area and the value of maker efficiency [1]. Marker efficiency is the percentage of the total area actually used in the garment component parts [13]. Higher the marker efficiency, lower the marker loss and vice versa [14]. There have been several studies [15–22] accomplished with the aim of improving fabric consumptions. However, with the different effect of fabric widths and human body shapes, there is a lack of research analysis on marker losses and wastages through marker cutting plans.

The approach proposed in this study is to investigate the effect of different fabric widths in the preparation of marker plans for fabric consumption in different human body shapes. In this scope, fabric widths and body types are deliberated as independent (predictors) variables, whereas marker efficiencies, marker losses, and fabric consumption efficiencies are considered as dependent variables. Fabric widths and body shapes (pattern shapes) are substantial criteria affecting the fabric efficiency. The results are also statistically verified and validated through the neural network. This study will make the apparel industries better decision-making and more cost-effective.

2. Materials and Methods

2.1. Materials and equipment

Four different human body shapes, in both genders, that is, women and men, were chosen as shown in Figure 1 (different body shapes with similar size). In Figure 2, the technical features of the fitted shirt and trouser manufactured for these body shapes are shown. In Figures A1 and A2 in Appendix, the patterns of the fitted shirt and fitted trouser are shown. These graded patterns were used for drawing marker plans for fabric cutting. 100% cotton woven fabrics (construction parameters of trouser fabric: 66 x 36/10 x 10: 50 to 85, whereas construction parameters of shirt fabric were 100 x 80/40 x 40: 50 to 85), with shrinkage 2% in warp and weft, were selected.

The research was consummated on close-fitted (following the body curves, outlining the figure) garment styles, that is, trousers and shirts, for both women and men. The tools and equipment used in this research were pattern-making kit, paper roll, Minitab 17, and Garment Gerber Technology (GGT; V10.351) software for making graded patterns and marker cutting plans.

2.2 Experimental work

The experimental work was performed in the fabric cutting-room of an apparel firm. The work was conducted in the early hours of the day (morning between 9 AM and 12 PM) to avoid mental tiredness in the individuals since earlier research revealed that individuals were efficient in the dawn and non-efficient at the time of sunset [24,25]. The fabric cutting-room temperature was kept at 25°C. The study was accomplished with close-fitted garments, that is, trousers and shirts, for women and men. The garment styles (shown in Figure 2) were selected for the assessment of fabric utilization comparative to each body shape in 36 different fabric widths, 127–216 cm (50–85 inches).

Figure 3 has shown the conceptual model of the impact of body shapes and fabric widths on the efficiencies. These two critical impacting components in the conceptual model have an influence on marker and fabric efficiencies due to the variation of pattern shapes and fabric widths. Since body types have the key impact on product development in the traditional apparel manufacturing approaches, they have a substantial effect on the textile material (fabric) consumptions.

The triangle body was considered as a reference shape in our experiments because, in the world of fashion beauty and fitness, triangle-shaped body is also considered as an ideal (highest symmetry) and best in all situations [26]. The anthropometric measurements of an ideal triangle female body were 91.5 cm (36 inches) bust, 66 cm (26 inches) waist, and 91.5 cm (36 inches) hips and ideal triangle male body measurements

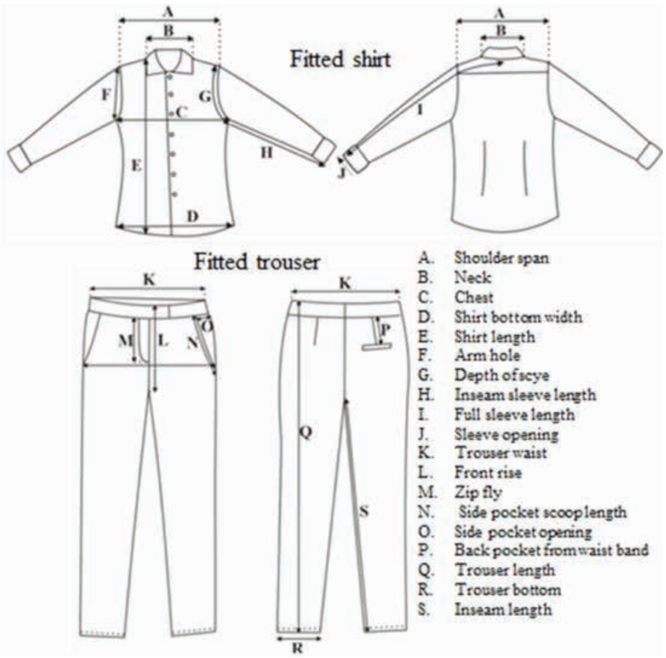

Figure 2. Technical features of the fitted shirt and fitted trouser.

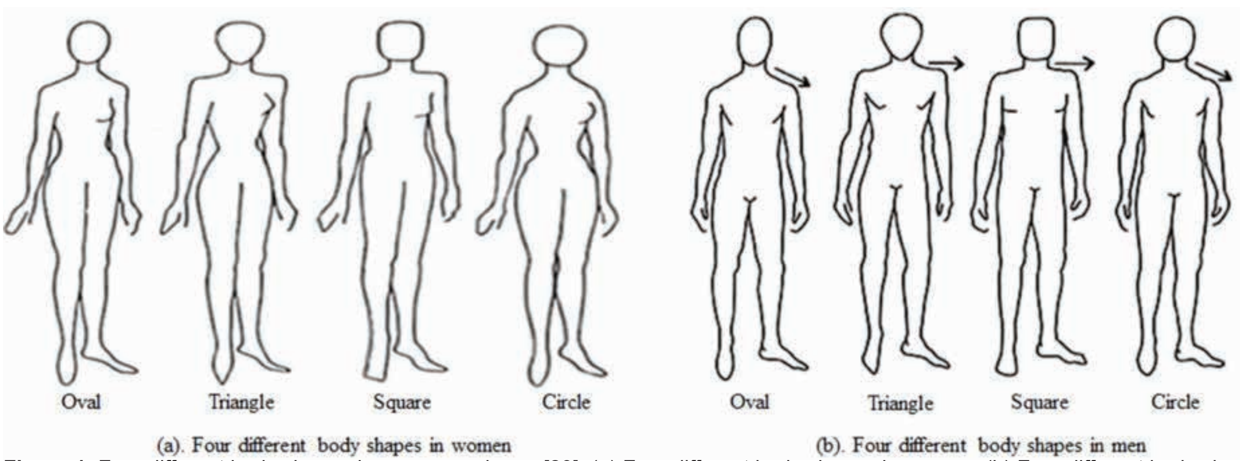

Figure 1. Four different body shapes in women and men [23]. (a) Four different body shapes in women. (b) Four different body shapes in men.

were 96.5 cm (38 inches) chest, 81.3 cm (32 inches) waist, and 99 cm (39 inches) hips [27]. Proportional grading skills among corresponding sizes, such as extra small (XS), small (S), medium (M), large (L), and extra large (XL), were applied by subtraction and addition of one measurement from another as per rule of ASTM D5585-95 standard (shown in Table A1 for women and Table A2 for men in Appendix). The medium size (M), also named "Size 12" in the garment industry, is commonly used for grading [28]. The female triangle body drop (waist girth minus bust girth) was kept –25 cm and male triangle body drop (waist girth minus chest girth) was kept –15 cm.

Fitted patterns of trousers and shirts were drawn and cut conventionally in both genders to have the optimal relationship between the body shape and the cloth measurements, that is, accomplished on close fitted (following the body curves, outlining the figure). The similar method was applied to other body shapes, that is, oval, circle, and square in both styles for women and men. The size ratios (XS:S:M:L:XL; 1:1:1:1:1) for cutting order were kept constant in all body shapes to explore the effects on clothing efficiencies. In total, 160 patterns (each shape and five sizes) were prepared before the marker making process in both styles of women and men. The garment pieces were cut optimally in markers (lay) relative to each shape, which contained all the sizes (XS, S, M, L and XL) in an equal quantity. Moreover, the pattern markers were accomplished through the GGT software for the evaluation of fabric consumption and efficiencies. Figure 4 has shown the pattern markers of trouser and shirt against the given styles of a female triangle body shape as for an example. The pattern marker efficiency values are detailed in Tables A3 and A4 in Appendix for both styles of women and men.

To verify the dissimilarities in the fabric efficiencies at different fabric widths in two different styles, fitted trousers and fitted shirts, in four different body shapes of women and men, the results were observed by factors including marker efficiency, marker loss, and fabric consumption efficiency. The factors, such as fabric construction, fabric widths, four different body shapes, fabric shrinkage, the total number of pattern pieces of each shape, the total number of patterns in each marker (number of cut-able pieces), and number of fabric plies, were kept constant. The analysis of variance (ANOVA) and correlation were applied to determine the level of significance of difference and the predictive relationship between the variables.

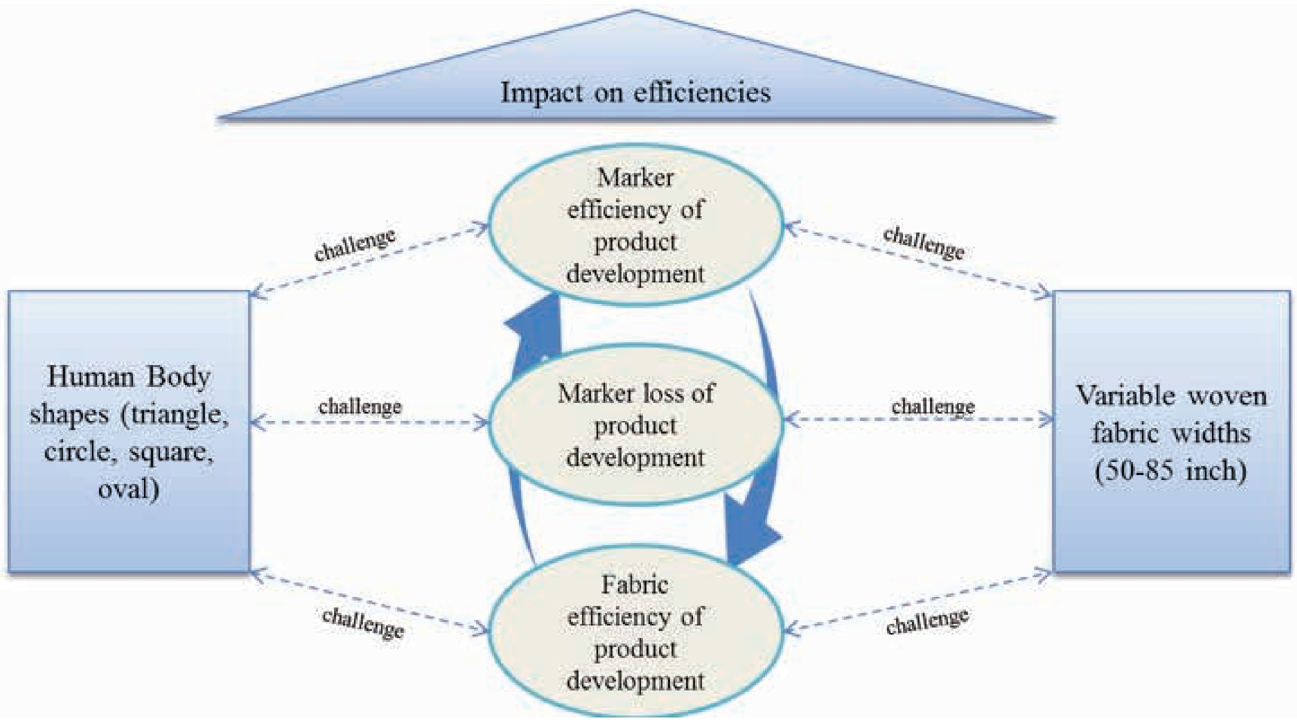

Figure 3. A conceptual model of the impact of body shapes and fabric widths on efficiencies.

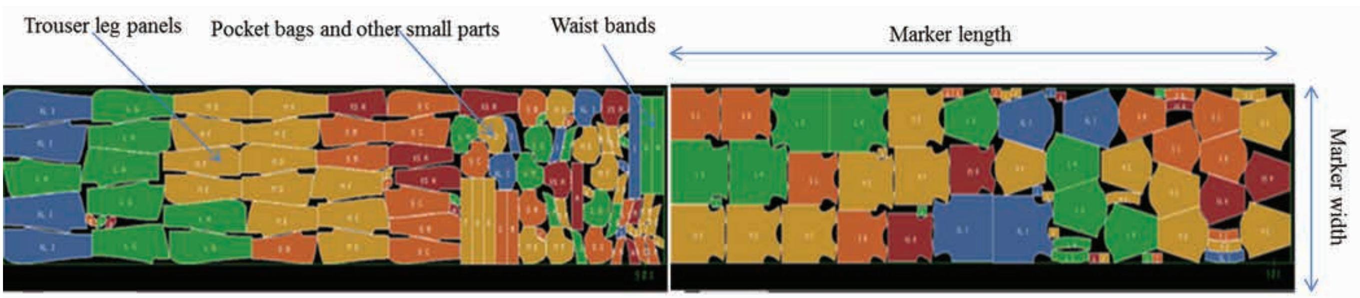

Figure 4. Fitted trouser marker and fitted shirt marker of female triangle body.

Moreover, the statistical consequences were validated through neural network analysis.

3. Results and discussion

3.1 The result of marker efficiency (%)

The marker is a diagram of a precise arrangement of garment patterns. Marker efficiency is the percentage of the total area actually used in the placement of the garment patterns. Tables A3 and A4 in Appendix have compiled the results of marker efficiency generated through GGT software at 36 different fabric widths. It was accomplished by analyzing ideal fabric width appropriate for maximum utilization of fabric for a specific shape. Figure 5 has shown the fitted trouser and fitted shirt marker efficiencies (variations in a bar graph) of four body shapes both in women and men at different fabric widths. The figure illustrates that the general trend in the marker efficiency increases with the increase in fabric widths in all body shapes both in women and men.

3.1.1. The result of marker efficiency of fitted trouser in both genders

In Figure 5(a), in women fitted trouser, the triangle-shaped body has the most marker efficiency (89.4%) at 193 cm (76 inches) fabric width, the circle shape has (89.7%) at 210.8 cm (83 inches), the oval shape has the most marker efficiency (89.8%) at 213.4 cm (84 inches) fabric width, and the square-shaped body has (89.8%) at 213.4 cm (84 inches) fabric width. Thus, in manufacturing the women fitted trouser, triangle-shaped body was the best type since it consumed the fabric efficiently with smaller fabric width. While in men fitted trouser, that is, in Figure 5(b), the triangle-shaped body was found most efficient (89.3%) at 213.4 cm (84 inches) width, the circle-shaped body

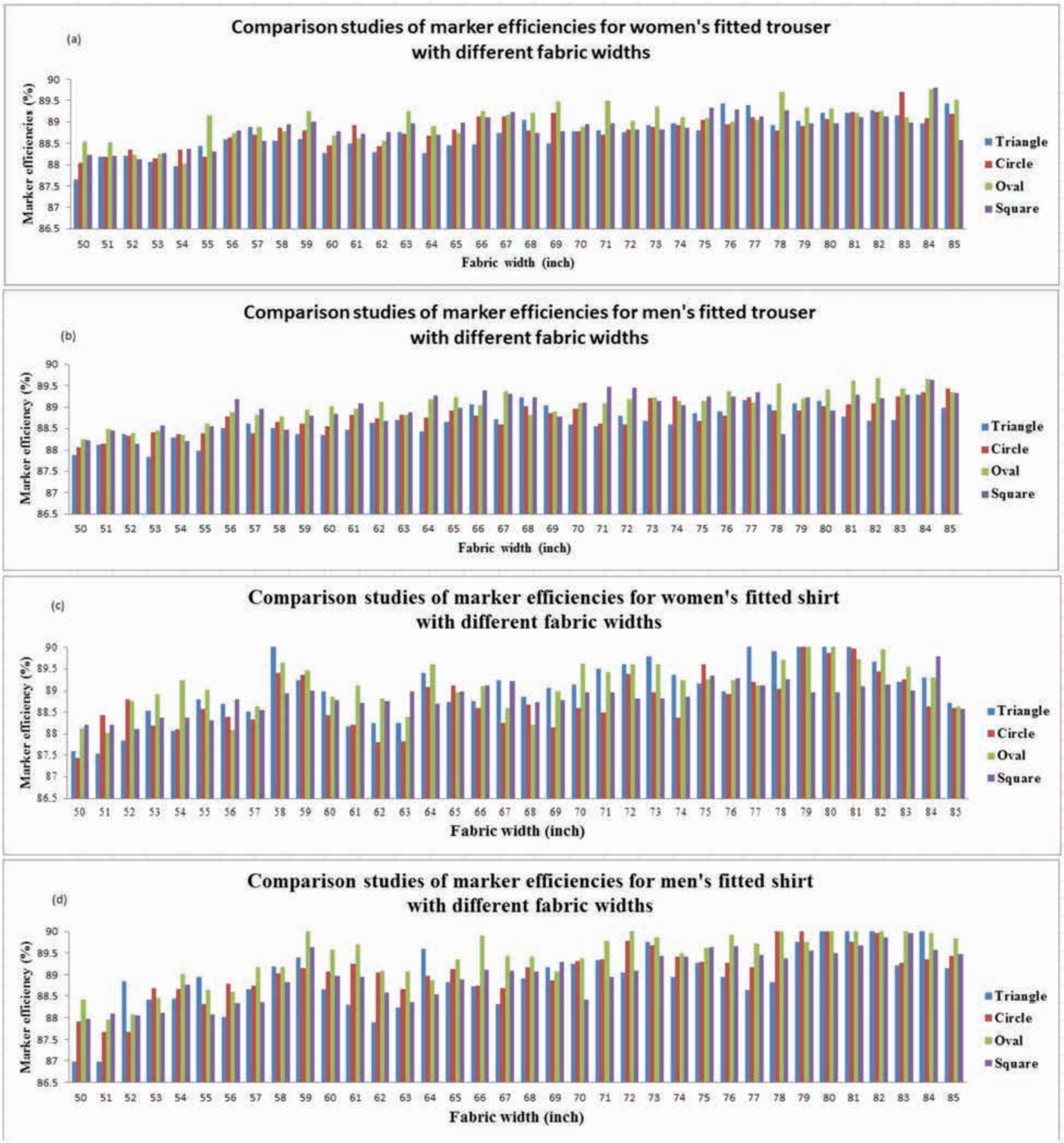

Figure 5. Fitted trouser and shirt marker efficiencies of women and men at different fabric width.

was the most efficient (89.4%) at 216 cm (85 inches), the oval-shaped was the most efficient (89.66%) at 213.4 cm (84 inches), and the square-shaped body was the most efficient (89.64%) at 213.4 cm (84 inches) fabric width. Thus mostly, the fabric width 213.4 cm (84 inches) has conveyed the best and maximum marker efficiency results in fitted trouser. In men fitted trouser manufacturing, the oval-shaped body is the best type. Also, the results revealed that women fitted trousers have more marker efficiency comparatively to men fitted trousers. Women fitted trouser markers were more efficient with less fabric utilization. This was due to the confined magnitude of women as compared with the capacious magnitude of men. Therefore, women fitted trouser markers were cost-effective as well.

3.1.2. The result of marker efficiency of the fitted shirt in both genders

Figure 5(c) has shown the women fitted shirt marker efficiency results. The triangle-shaped body has the most marker efficiency (90.33%) at 205.7 cm (81 inches) fabric width, the circle-shaped body has the most marker efficiency (90.03%) at 200.7 cm (79 inches) fabric width, the oval-shaped body has the most marker efficiency (90.7%) at 203 cm (80 inches) fabric width, and square-shaped body has the most efficiency (89.34%) at 190.5 cm (75 inches) fabric width. Thus in women fitted shirt, the fabric width ranges from 200.7 to 205.7 cm has provided the best and maximum marker efficiency results in most of the body shapes. Additionally, in manufacturing the women fitted shirt, square-shaped body was the best type as it has good results with minimum fabric width utilization. In Figure 5(d), in men's shirt marker, the triangle-shaped body was the most efficient (90.1%) at 205.7 cm (81 inches) fabric width, the circle-shaped body was the most efficient (90.8%) at 203 cm (80 inches) fabric width, the oval-shaped body was the most efficient (90.8%) at 205.7 cm (81 inches) fabric width, and the square-shaped body was the most efficient (90%) at 210.82 cm (83 inches) fabric width. Hence, in men's fitted shirt, the fabric width ranged from 203 to 205.7 cm has provided the best and maximum marker efficiency outcomes. In manufacturing the men fitted shirt, circle-shaped body was the best type. Also, the results revealed that the women fitted shirt has less marker efficiency in comparison to men fitted shirt. The reason was due to the more voluptuous of the breast in women body shapes. Therefore, in the case of men fitted shirt, the markers were more efficient and cost-effective than the women fitted shirt markers.

Figure 5 also depicted that trouser markers were less efficient than shirt markers. The reason was the number of panels involved in the shirt that could be adjusted in between the gaps of the pattern markers. Therefore, in the shirt manufacturing, the fabric utilization was efficient and cost-effective. The results have also revealed that companies, which are in the provision of using fabrics with 147 cm (58 inches) width as for instance, are operating in lesser marker efficiencies and thus in-effective in cost while the companies operating with larger fabric width have more effective results.

3.2. The result of marker loss (%)

Marker loss is the wastage that consists of non-useable areas of the marker. It does not become the part of garment patterns in the rectangular marker sheet. Marker wastage is measured according to the marker area and the value of maker efficiency. Thus, higher the marker efficiency, lower the marker loss and vice versa. The mathematical expression stated as follows:

$$\text{Marker loss} \propto \frac{1}{\text{Marker efficiency}} \qquad (1)$$

In the fitted trouser markers, the fabric width at 213.4 cm (84 inches) has proven the minimum marker losses. Similarly, in the case of the fitted shirt, the minimum marker loss was at 200.7–205.7 cm fabric width in women's wears and 203–205.7 cm fabric width in men's wear. The consequences indicated the general trend in the marker loss decreased with the increase in fabric widths in all body shapes both in women and men. Thus, higher the marker efficiency, lower the marker loss and vice versa.

3.3. The result of fabric consumption efficiency (%)

Fabric consumption efficiency is the percentage of the total area actually used in the garment component parts. Fabric consumption efficiency depends on marker efficiency. Higher the marker efficiency, higher the fabric efficiency and lower the marker (fabric) loss. The mathematical expression stated as follows:

$$\text{Marker efficeincy} \propto \text{Fabric consumption efficiency} \qquad (2)$$

In women fitted trouser, the triangle-shaped body has the most fabric consumption efficiency (86.7%) at 193 cm (76 inches) fabric width, the circle-shaped has (86.4%) at 210.8 cm (83 inches), the oval-shaped has the most fabric efficiency (87%) at 213.4 cm (84 inches) fabric width, and the square-shaped body has efficiency (87.03%) at 213.4 cm (84 inches) fabric width. Thus, in women fitted trouser, triangle-shaped body was the best type since it consumed the fabric efficiently with smaller fabric width. In men fitted trouser, the triangle-shaped body was the most efficient (86.43%) at 213.4 cm (84 inches) fabric width, the circle-shaped body was the most efficient (86.6%) at 216 cm (85 inches), the oval-shaped was the most efficient (86.83%) at 213.4 cm (84 inches), and the square-shaped body was the most efficient (86.8%) at 213.4 cm (84 inches) fabric width. Thus, the oval-shaped body was the best. Among all, the fabric width 213.4 cm (84 inches) has demonstrated the best and maximum fabric efficiency results in fitted trouser.

In women fitted shirt, the triangle-shaped body has the most fabric consumption efficiency (87.6%) at 205.7 cm (81 inches) fabric width, the circle-shaped body has most fabric efficiency (87.25%) at 200.7 cm (79 inches) fabric width, the oval-shaped body has the most marker efficiency (87.9%) at 203 cm (80 inches) fabric width, and square-shaped body has the most efficiency (86.6%) at 190.5 cm (75 inches) fabric width. In men's fitted shirt, the triangle-shaped body has the most fabric efficiency (87.34%) at 205.7 cm (81 inches) fabric width, the circle-shaped body has the most efficiency (87.3%) at 203 cm

(80 inches) fabric width, the oval-shaped body has the most efficiency (88.07%) at 205.7 cm (81 inches) fabric width, and the square-shaped body has the most fabric efficiency (87.2%) at 210.8 cm (83 inches) fabric width. Therefore, in women fitted shirt, the fabric width ranges from 200.7 to 205.7 cm (79–81 inches) and in men's fitted shirt, the fabric width ranges from 203 to 205.7 cm (80–81 inches) has provided the best and maximum fabric efficiency results. The results also revealed that the fabric efficiency depends upon the marker efficiency. However, the fabric consumption efficiency always remained less than the marker efficiency. The reason was the more fabric losses including internal and external losses (selvedge loss, end loss, width loss, etc.).

3.4. Analysis of variance

Table 1 presents the results of one-way analysis between groups for different variables. It was found that there was a statistically significant effect on the marker efficiency, fabric consumption efficiency, and fabric width, given the significant value (<0.05) in the ANOVA table. The regression analysis (*p*-value) between dependent variables (marker efficiency, marker loss, and fabric consumption efficiency) and predictor variables (body types and fabric width) was also statistically significant. Similarly, Tables 2 and 3 have also shown the significant *p* values of all body shapes. However, triangle shape in women fitted trouser (0.858), oval shape in men fitted trouser (0.886), square shape in women fitted shirt (0.714), and circle shape in men fitted shirt (0.880) have a stronger effect due to the higher standardization coefficient beta values as compared to the other body shapes respectively.

Table 1. One-way ANOVA analysis of triangle, circle, oval, and square body shapes

One-way ANOVA analysis		df	Sum of squares	Mean square	F	Significance (p)
Women fitted trouser	ME	3	1.724	0.5747	3.74	0.013
	FCE	3	1.841	0.6138	4	0.009
Men fitted trouser	ME	3	3.488	1.1625	8.59	0.00
	FCE	3	4.038	1.346	9.95	0.00
Women fitted shirt	ME	3	3.317	1.1057	3.15	0.027
	FCE	3	3.654	1.2181	3.47	0.018
Men fitted shirt	ME	3	6.25	2.0835	4.8	0.003
	FCE	3	6.422	2.1405	4.93	0.003
Fabric width	ME	15	21.42	1.4278	5.32	0.00
	FCE	15	21.42	1.4278	5.32	0.00

ME, marker efficiency; FCE, fabric consumption efficiency.

Table 2. Regression analysis between fabric efficiency and fabric width for each body types of women and men in fitted trouser

Statistical analysis	Women fitted trouser				Men fitted trouser			
	Triangle	Circle	Oval	Square	Triangle	Circle	Oval	Square
R square	0.736	0.669	0.558	0.514	0.602	0.721	0.785	0.465
Standardization beta	**0.858**	0.818	0.747	0.717	0.776	0.849	**0.886**	0.682
F statistics	94.821	68.592	43.009	36.022	51.482	88.051	123.942	29.497
p-value	p < 0.000	p < 0.000	p < 0.000	p < 0.000	p < 0.000	p < 0.000	p < 0.000	p < 0.000

Table 3. Regression analysis between fabric efficiency and fabric width for each body types of women and men in fitted shirt

Statistical analysis	Women fitted shirt				Men fitted shirt			
	Triangle	Circle	Oval	Square	Triangle	Circle	Oval	Square
R square	0.492	0.321	0.335	0.510	0.485	0.653	0.676	0.729
Standardization beta	0.702	0.566	0.579	**0.714**	0.696	**0.880**	0.822	0.854
F statistics	32.978	16.055	17.143	35.43	31.972	64.085	70.934	91.343
p-value	p < 0.000	p < 0.000	p < 0.000	p < 0.000	p < 0.000	p < 0.000	p < 0.000	p < 0.000

3.5 Correlation analysis

Table 4 has shown a linear relationship between marker efficiency and fabric width (sig <0.05). Pearson correlation coefficient is 0.858. The results have been similar in fabric consumption efficiency as well. Thus, both have a strong and positive relationship with marker efficiency and fabric consumption efficiency and are affected by the variations in fabric width. There was also sufficient evidence that there exists a linear relationship between both efficiencies and styles of body shapes (sig <0.05). Pearson correlation coefficient ranges from 0.716 to 0.767 in both marker efficiency and fabric consumption efficiency. However, women body shapes have stronger and positive (positive medium) relationship comparative with the men (positive week).

3.6. Neural network analysis

The marker efficiency and the fabric consumption efficiency were further predicted through the fully connected neural network with back propagation (BP). From our observation, this machine learning tool validated and reaffirmed the outcomes of ANOVA table with high prediction accuracy. In practice, our BP network has three layers, that is, an input layer, a hidden layer, and an output layer. The input layer consisted of 36 neurons that represent the features under concern, that is, different fabric widths (50–85 inches). The single hidden layer has 10 neurons and the Sigmoid function was used for nonlinear activation. The output layer contained two neurons for the prediction of maker efficiency and fabric consumption efficiency. The parameters and hyper-parameters settings are presented in Table 5. The cost function was designed in the manner of mean squared error (MSE) to evaluate the difference between the ground truth and the predicted output. We use stochastic gradient descent (SGD) method to minimize the cost.

In Table 6, MSE values obtained from the number of test results, MSE results, and absolute change values have been provided. Closer the absolute error to zero, better the system reflects the truth. *R* square value for training, validation and test datasets were 99.8, 99.7, 99.8, and MSE 0.01372, 0.0157, 0.0142, respectively. The training and validating as a function of epoch was also performed. The network was trained within 10 epochs met the goal of error. The best validation performance was 0.0157 at epoch 7. Hence, we have chosen the strategy of “Early Stop” to learn the best parameters (weights) for the prediction. Thus, the results, as illustrated in Table 6, are satisfactorily reasonable in terms of prediction accuracy.

The research was processed and complied with only two styles (trousers and shirts). For more strengthening the knowledge, there is a need to explore a number of different production orders which would be highly expensive study. This study makes capable the apparel firms which are producing garments for different body shapes of women and men to make their strategies better for competing for different markets in top-wears and bottom-wears. The same experimental analysis should be conducted in more garments to benchmark the approaches, techniques, and production management capabilities.

Table 4. Correlation analysis of variables

Correlation analysis		Fabric width	Women fitted trouser	Men fitted trouser	Women fitted shirt	Men fitted shirt
Marker efficiency (%)	p-value	0.00	0.00	0.00	0.00	0.00
	Correlation coefficient	0.858	0.767	0.723	0.762	0.716
Fabric consumption efficiency (%)	p-value	0.00	0.00	0.00	0.00	0.00
	Correlation coefficient	0.858	0.767	0.723	0.762	0.716
	Correlation	Strong	Not quite strong	Medium	Not quite strong	Medium
	Linear relationship	Positive	Positive medium	Positive weak	Positive medium	Positive weak

Table 5. Neural network parameters

		Item	Parameter
1	Input layer	Normalization Number of neurons	Standard 36
2	Hidden layer	Activation function Number of neurons	Sigmoid 10
3	Output layer	Normalization Number of neurons	Standard 2
4	Weight	Initialization	Random
5	Learning rule	Algorithm	Stochastic gradient descent (SGD)

Table 6. Neural network Analysis

1	**MSE (training)**	**0.01372**
2	MSE (testing)	0.0142
3	R2 (absolute change)	0.9942
4	Validation performance (at epoch 7)	0.0157

4. Conclusion

The objective of this research was to study the effect of different fabric widths on marker efficiencies and fabric consumption efficiencies in correspondence with four different human body shapes, that is, oval, circular, square, and triangular (ideal body) in the apparel industry. Two order styles, fitted trousers and fitted shirts, were selected and transformed on to four body shapes of women and men. The results of the study under discussion can be summarized as follows:

- There is a linear relationship between marker efficiency and fabric width (sig <0.05). The regression analysis (*p*-value) between dependent variables (marker efficiency, marker loss, and fabric consumption efficiency) and predictor variables (four body types in both genders and fabric width) is also statistically significant.
- The markers are more productive with larger fabric widths in all styles in both genders.
- In manufacturing the fitted trousers, the fabric width 213.4 cm has conveyed the best and maximum marker efficiency results in both genders while in the fitted shirt, fabric width ranges from 200.7 to 205.7 cm in women and 203 to 205.7 cm fabric width in men has provided the best and maximum marker efficiency results in most of the body shapes.
- Fabric consumption efficiency depends upon the marker efficiency. However, it always remains less than the marker efficiency.
- Women fitted trouser markers are efficient and cost-effective compared to men fitted trouser markers.
- Women fitted shirt has less marker efficiency as compared to men fitted shirt. Therefore less cost-effective.
- In both genders, shirt markers were more efficient and cost-effective than trouser markers.
- In manufacturing the fitted trousers, triangle-shaped body is the best in women while oval-shaped body in men. In the case of fitted shirts, square-shaped body is the best in women and circle-shaped body is the best in men.

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Conflict of interest

Author has no conflict of interest.

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Appendix

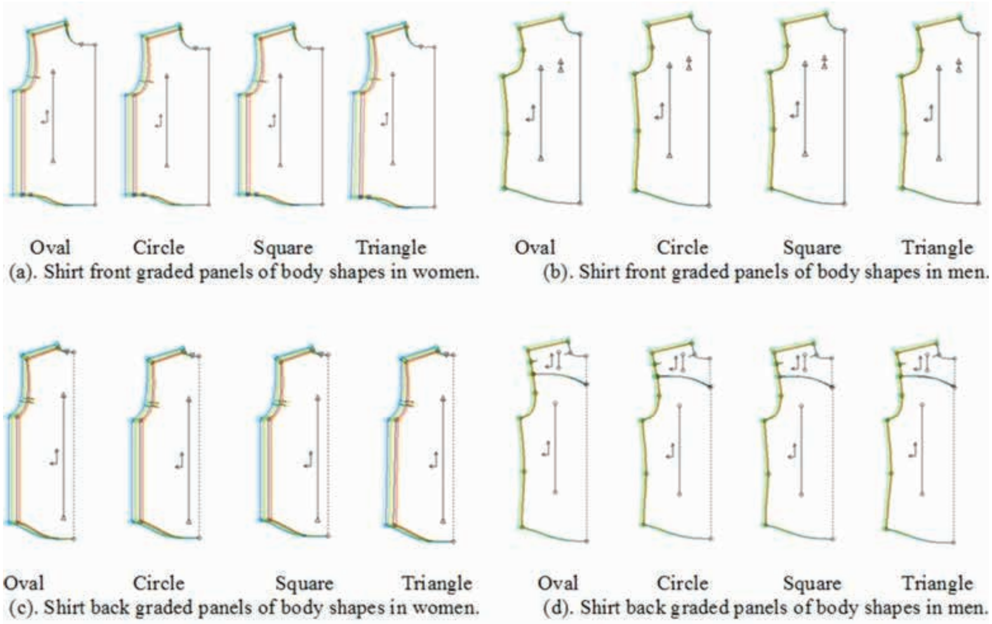

Figure A1. Shirt patterns of four body shapes in women and men [29]. (a) Shirt front graded panels of body shapes in women. (b) Shirt front graded of body shapes in men. (c) Shirt back graded panels of body shapes in women. (d) Shirt back graded panels of body shapes in men.

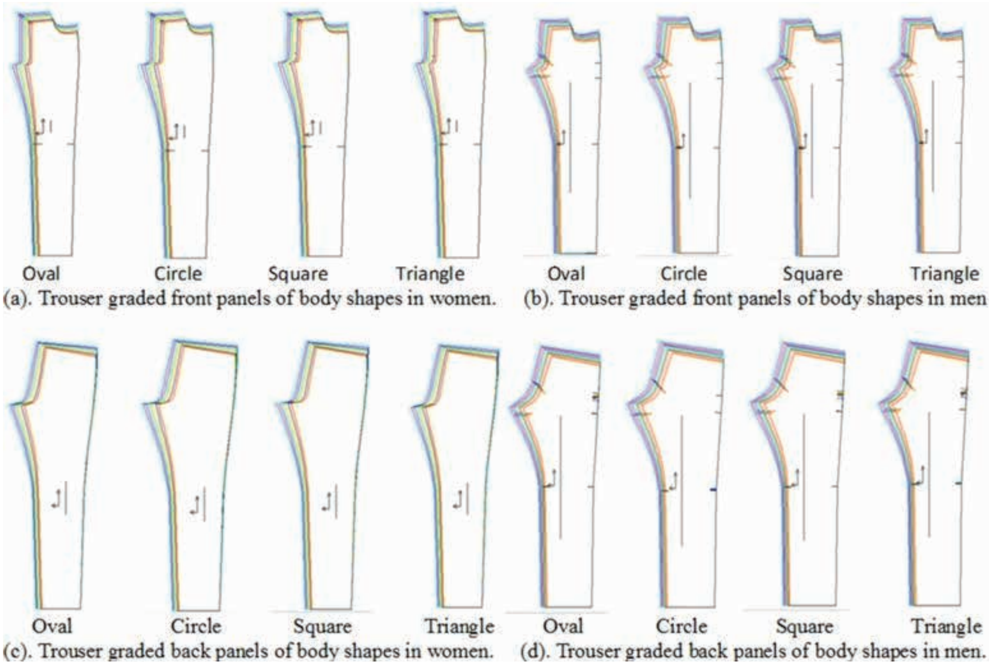

Figure A2. Trouser patterns of four body shapes in women and men. (a) Trouser graded front panels of body shapes in women (b) Trouser graded front panels of body shapes in men. (c) Trouser graded back panels of body shapes in women. (d) Trouser graded back panels of body shapes on men.

Table A1. Graded size chart of an ideal female body

Sr. No	Description	Extra small (XS)	Small (S)	Medium (M)	Large (L)	Extra-large (XL)
	Sizes 2–20	2–4	6–8	10–12	14–16	18–20
1	Bust/chest	30 inch (76 cm)	32 inch (81 cm)	36 inch (91.5 cm)	40 inch (102 cm)	42 inch (107 cm)
2	Waist	20 inch (51 cm)	22 inch (56 cm)	26 inch (66 cm)	30 inch (76 cm)	32 inch (81 cm)
3	Hips	30 inch (76 cm)	32 inch (81 cm)	36 inch (91.5 cm)	40 inch (102 cm)	42 inch (107 cm)
4	Body height	63 inch (157.5 cm)	65.5 inch (164 cm)	68 inch (170 cm)	70.5 inch (176 cm)	73 inch (183 cm)

Table A2. Graded size chart of an ideal male body

Sr. No	Description	Extra-small (XS)	Small (S)	Medium (M)	Large (L)	Extra-large (XL)
	Sizes 2–20	2–4	6–8	10–12	14–16	18–20
1	Chest	32 inch (81 cm)	34 inch (86.5 cm)	38 inch (96.5 cm)	42 inch (107 cm)	44 inch (112 cm)
2	Waist	26 inch (66 cm)	28 inch (71 cm)	32 inch (81 cm)	36 inch (91.5 cm)	38 inch (96.5 cm)
3	Hips	33 inch (84 cm)	35 inch (89 cm)	39 inch (99 cm)	43 inch (109 cm)	45 inch (114 cm)
4	Body height	65.5 inch (164 cm)	67.5 inch (169 cm)	70 inch (178 cm)	72.5 inch (181 cm)	74.5 inch (186 cm)

Table A3. A comparison study of trouser marker efficiencies at 36 different fabric widths

Sr. No	Fabric width (inch)	Women's fitted trouser				Men's fitted trouser			
		Triangle efficiency (%)	Circle efficiency (%)	Oval efficiency (%)	Square efficiency (%)	Triangle efficiency (%)	Circle efficiency (%)	Oval efficiency (%)	Square efficiency (%)
1	50	87.646	88.043	88.54	88.216	87.882	88.054	88.248	88.217
2	51	88.177	88.183	88.507	88.21	88.113	88.136	88.485	88.45
3	52	88.203	88.345	88.23	88.113	88.379	88.327	88.393	88.136
4	53	88.057	88.145	88.252	88.261	87.828	88.4	88.451	88.573
5	54	87.966	88.342	88.025	88.364	88.288	88.368	88.348	88.205
6	55	88.425	88.191	89.144	88.314	87.972	88.396	88.612	88.551
7	56	88.603	88.645	88.729	88.805	88.512	88.777	88.874	89.186
8	57	88.879	88.706	88.876	88.55	88.615	88.381	88.81	88.967
9	58	88.55	88.86	88.785	88.943	88.513	88.666	88.787	88.474
10	59	88.595	88.809	89.252	89.006	88.379	88.613	88.937	88.804
11	60	88.27	88.442	88.671	88.773	88.339	88.561	89.016	88.849
12	61	88.49	88.921	88.608	88.716	88.473	88.823	88.972	89.091
13	62	88.295	88.433	88.557	88.749	88.642	88.728	89.123	88.667
14	63	88.766	88.725	89.254	88.967	88.689	88.829	88.829	88.882
15	64	88.271	88.685	88.911	88.705	88.434	88.751	89.186	89.275
16	65	88.442	88.812	88.744	88.989	88.658	88.918	89.239	88.985
17	66	88.474	89.136	89.24	89.113	89.06	88.798	89.049	89.4
18	67	88.742	89.136	89.171	89.223	88.709	88.586	89.372	89.307
19	68	89.051	88.789	89.207	88.738	89.22	89.027	88.818	89.225
20	69	88.497	89.211	89.483	88.782	89.038	88.856	88.903	88.776
21	70	88.782	88.777	88.887	88.952	88.597	88.96	89.078	89.098
22	71	88.8	88.698	89.499	88.964	88.562	88.606	89.076	89.482
23	72	88.768	88.828	89.018	88.812	88.806	88.604	89.198	89.449
24	73	88.928	88.88	89.348	88.825	88.669	89.208	89.224	89.155
25	74	88.958	88.922	89.101	88.862	88.591	89.243	89.153	89.055
26	75	88.796	89.049	89.096	89.341	88.862	88.676	89.15	89.244
27	76	89.432	88.951	88.996	89.283	88.902	88.798	89.382	89.24
28	77	89.39	89.109	89.051	89.119	89.167	89.221	89.109	89.35
29	78	88.926	88.802	89.71	89.264	89.074	88.929	89.549	88.371
30	79	89.025	88.897	89.332	88.959	89.078	88.912	89.202	89.226
31	80	89.204	89.074	89.302	88.957	89.148	89.02	89.41	88.93
32	81	89.213	89.22	89.201	89.098	88.775	89.067	89.623	89.286
33	82	89.271	89.232	89.258	89.137	88.673	89.085	89.687	89.201
34	83	89.157	89.704	89.101	88.991	88.706	89.254	89.433	89.287
35	84	88.973	89.081	89.756	89.802	89.287	89.346	89.655	89.637
36	85	89.428	89.181	89.518	88.577	88.975	89.433	89.353	89.324

Table A4. A comparison study of shirt marker efficiencies at 36 different fabric widths

		Women's fitted shirt				Men's fitted shirt			
Sr. No	Fabric width (inch)	Triangle efficiency (%)	Circle efficiency (%)	Oval efficiency (%)	Square efficiency (%)	Triangle efficiency (%)	Circle efficiency (%)	Oval efficiency (%)	Square efficiency (%)
1	50	87.591	87.431	88.136	88.216	86.974	87.898	88.424	87.962
2	51	87.537	88.428	88.026	88.21	86.979	87.663	87.939	88.1
3	52	87.842	88.797	88.759	88.113	88.848	87.671	88.062	88.054
4	53	88.525	88.192	88.921	88.361	88.411	88.67	88.45	88.11
5	54	88.057	88.111	89.238	88.364	88.426	88.653	88.997	88.755
6	55	88.794	88.581	89.015	88.314	88.953	88.311	88.647	88.064
7	56	88.705	88.392	88.077	88.805	88.015	88.786	88.591	88.339
8	57	88.506	88.335	88.64	88.55	88.653	88.737	89.164	88.353
9	58	90.041	89.417	89.647	88.943	89.192	89.033	89.158	88.825
10	59	89.247	89.373	89.461	89.006	89.381	89.144	90.154	89.642
11	60	88.974	88.431	88.861	88.773	88.658	89.064	89.569	88.961
12	61	88.169	88.199	89.113	88.716	88.285	89.25	89.703	88.934
13	62	88.249	87.801	88.82	88.749	87.884	89.053	89.076	88.586
14	63	88.246	87.827	88.389	88.976	88.239	88.664	89.061	88.347
15	64	89.417	89.073	89.617	88.705	89.589	88.965	88.867	88.535
16	65	88.744	89.123	88.954	88.989	88.815	89.126	89.347	88.886
17	66	88.763	88.595	89.107	89.113	88.711	88.74	89.906	89.11
18	67	89.243	88.253	88.59	89.223	88.312	88.683	89.436	89.096
19	68	88.855	88.679	88.205	88.738	88.897	89.158	89.403	89.056
20	69	89.057	88.155	88.974	88.782	89.163	88.855	89.074	89.292
21	70	89.134	88.598	89.628	88.952	89.241	89.301	89.365	88.416
22	71	89.512	88.487	89.424	88.964	89.327	89.341	89.786	88.944
23	72	89.602	89.385	89.613	88.812	89.053	89.786	90.033	89.083
24	73	89.784	88.962	89.606	88.825	89.759	89.685	89.859	89.425
25	74	89.373	88.375	89.249	88.862	88.95	89.419	89.499	89.406
26	75	89.156	89.616	89.265	89.341	89.275	89.294	89.613	89.627
27	76	88.978	88.923	89.253	89.283	88.938	89.261	89.917	89.651
28	77	90.089	89.207	89.119	89.119	88.643	89.165	89.712	89.448
29	78	89.907	89.041	89.707	89.264	88.815	90.063	90.152	89.364
30	79	90.078	90.029	90.142	88.959	89.754	90.101	89.763	89.55
31	80	90.194	89.874	90.652	88.957	90.253	90.073	90.157	89.485
32	81	90.329	89.975	89.731	89.098	90.111	89.749	90.827	89.669
33	82	89.669	89.453	89.95	89.137	89.995	89.961	90.616	89.86
34	83	89.208	89.275	89.548	88.991	89.206	89.267	90.487	89.953
35	84	89.313	88.638	89.308	89.802	90.106	89.34	89.953	89.567
36	85	88.724	88.585	88.626	88.577	89.148	89.434	89.828	89.473