On Relationship Between Fit And Garment Sizing Parameters

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Abstract— **The problem of fit in the garment industry is a recurrent one as several attempts to resolve it appear not to have yielded satisfactory result. One of the reasons for this problem may probably have to do with the issue of relationship between fit and garment sizing parameters. The aim of this study is to investigate the possible relationships that may exist between fit and garment sizing parameters which may be useful for developing better garment sizing system. Garment sizing parameters were identified using information from literature and interaction with tailors. Fit was defined in terms of these identified sizing parameters. A response surface function of garment fit was formulated in terms of these parameters using regression analysis in order to determine the level of relationship between fit and the parameters. Garment-related anthropometric data for 500 randomly selected male customers who use trousers in Nigeria obtained from literature were used for analysis. The degree of contributions of each parameter to fit was examined using t-test at p=0.05. Results from the analysis of the application of response surface function showed that tolerance, number of dimensions, customer population and number of sizes and their three way interactions have positive relationship with fit while their two way and four way interactions have negative relationships. Furthermore, the results of the hypotheses and t-test indicate that all the parameters contributed significantly to garment fit. The values of these parameters should be appropriately determined in order to design an effective and efficient garment sizing system.**

Keywords— Garment; Fit; tolerance; number of dimensions; regression coefficient

I. INTRODUCTION

Fit problem in the garment industry is a recurrent issue in the literature. It has been observed that it is a difficult concept to research and analyse as the relationship between body and clothing is complex and often ambiguous [1]. There have been several studies addressing fit problem adopting diverse approaches. Reference [2] observed that these approaches can be classified into general, statistical and optimisation. The general approach includes individual craftsmen perspective to solving clothing problems i.e. fitting to individual. After tailors have measured many customers over time, set of patterns were gradually developed into sizing catalogue to make clothes for people with similar body shapes [3]. Reference [4] and [5] described steps involved in sizing systems to comprise among others, selecting appropriate body anthropometric data, select key dimensions and establish number of each size necessary to outfit the intended users' population. Some statistical approaches are decision tree techniques [6]; statistical model for developing body size charts for garment manufacture in India [7]; a two stage cluster analysis to develop sizing system for Taiwanese elementary and high school students [8]. Also, [9] used Fuzzy clustering methodology (FCM) to develop a size chart for different styles of trousers worn by Nigeria male population while [10] used support vector clustering (SVC) with genetic algorithm (GA) models to improve the upper garment size system for military uniforms in Taiwan. Studies such as [11]; [12]; [13]; [14] can be categorised as optimisation. All these authors attempted to improve garment sizing system. When a sizing system is perfect, then each customer in the population will be fully satisfied with the garments, otherwise, there will be too many complains because of misfits [2]

For a comprehensive analysis of the relationship between fit and garment sizing parameters, a close form mathematical function expressing garment fit in terms of these parameters might be necessary and this was attempted by [15]. However, the study appeared not to have examined the level of contributions of each of these parameters to fit. One of the possible reasons why it has become difficult to obtain a satisfactory garment sizing system yet, may perhaps be due to the lack of complete understanding about the relationship between fit and certain parameters that may be contributing to cloth fitting. The knowledge of this relationship may be a very valuable analytical instrument. Most authors [12]; [13]; [14] among others appeared to have based determination of sizing system on the correlation between one or two key body dimensions with other dimensions. This seems not to have captured all the essential parameters. This study intends to examine more parameters and their possible contributions to garment fit.

II. METHODOLOGY

Reference [15] identified garment sizing variables and parameters to include tolerance, number of dimensions, customer population and number of sizes and came out with a mathematical function that relates degree of fit with these parameters as indicated in "1".

$$V(h_\alpha) = f(g_\alpha, q;\ t, m, N) = {[h_1 + h_{2+} \dots h_\alpha + \cdots h_q]}/{q} \quad (1)$$

Where;
g_α = a set of customers in size α
q = number of sizes
t = tolerance
m = number of dimensions
N = customers' population

The degree of fit was expressed as a function of number of dimensions (*m*), customer population (*N*), tolerance (*t*) and the number of required size (*q*) as well a set of customers (g_α) in size α.
These variables and parameters are defined as follows. Number of dimensions: Number of distinct dimensions that can be identified for a particular garment
Tolerance: The numerical value that a designer can add or subtract from the value of a particular dimension without hindering the fit of a garment to a set of customers
Customer population: The number of potential customers that a garment could be designed or produced for.
Number of sizes: The possible number of sizes that could be produced so that every potential customer in a given population could find a suitable size

A. *Relationship between Fit and Garment Sizing Parameters*

The expressions "1" has defined fit in terms of the number of garment-related anthropometric dimensions of customers (m); customer population (N); garment sizing tolerance (t); and number of garment sizes (q). These are the garment sizing parameters whose relationships to garment fit require investigation. If there is significant relationship between customer fit and or any of these entire garment sizing parameters, then the information obtained may be further explored as possible clues for developing better garment sizing systems.

To investigate the extent of contributions or otherwise of a set of variables/parameters (independent variables) to the dependent variable (system fit), a response surface equation may be useful. The concept of response surface involves a dependent variable 'Y' called response variable and several independent or controlled variables x1, x2......xn. If all these variables are assumed to be measurable, the response surface according to [16] can be expressed as:

$$Y = f(x_1, x_2, \dots, x_n) \quad (2)$$

The equation Y = f (x_1, x_2......x_n) is a general form of polynomial function. The specific type of polynomial function depends on the degree of contribution of the variables individually and collectively.

For this study,

Let $\hat{Y}_i$ be the estimated value (response) of garment fit with respect to changes in tolerance (X_1), number of dimensions (X_2), customer population (X_3), number of sizes (X_4) and all their respective interactions.

Thus:

$$\hat{Y}_i = b_0 + b_1x_{1i} + b_2x_{2i} + b_3x_{3i} + b_4x_{4i} + b_{12}x_{1i}x_{2i} + b_{13}x_{1i}x_{3i} + b_{14}x_{1i}x_{4i} + b_{23}x_{2i}x_{3i} + b_{24}x_{2i}x_{4i} + b_{34}x_{3i}x_{4i} + b_{123}x_{1i}x_{2i}x_{3i} + b_{124}x_{1i}x_{2i}x_{4i} + b_{134}x_{1i}x_{3i}x_{4i} + b_{234}x_{2i}x_{3i}x_{4i} + b_{1234}x_{1i}x_{2i}x_{3i}x_{4i} \quad (3)$$

Where b_p is the parameters of the p^{th} term and its combinations of the response function.

Thus: for 1-way interaction p = *0, 1, 2, 3 and 4*

For 2-way interaction, p = 12, 13, 14, 23, 24, 34

For 3-way interaction, p = 123, 124, 134, 234,

For 4-way interaction, p = 1234

Also, let the observed response be Y_i and the error term be (e_i) where

$$e_i = Y_i - \hat{Y}_i \quad (4)$$

Taking the square of the error:

$$e_i^2 = \left(Y_i - \hat{Y}_i\right)^2 \quad (5)$$

For '*n*' data points the sum of squares of the errors (*E*) is given by the equation

$$E = \sum_{i=1}^{n} e_i^2 = \sum_{i=1}^{n}\left(Y_i - \hat{Y}_i\right)^2 \quad (6)$$

That is:

$$E = \sum_{i=1}^{n}\left[Y_i - \begin{pmatrix} b_0 + b_1x_{1i} + b_2x_{2i} + b_3x_{3i} + b_4x_{4i} + b_{12}x_{1i}x_{2i} \\ +b_{13}x_{1i}x_{3i} + b_{14}x_{1i}x_{4i} + b_{23}x_{2i}x_{3i} + b_{24}x_{2i}x_{4i} + b_{34}x_{3i}x_{4i} \\ +b_{123}x_{1i}x_{2i}x_{3i} + b_{124}x_{1i}x_{2i}x_{4i} + b_{134}x_{1i}x_{3i}x_{4i} \\ +b_{234}x_{2i}x_{3i}x_{4i} + b_{1234}x_{1i}x_{2i}x_{3i}x_{4i} \end{pmatrix}\right]^2 \quad (7)$$

Applying the least square principle to estimate the value of the parameters of the response function, the partial derivatives of "6" were taken and set to zero.

Thus,

$$\frac{\partial E}{\partial b_0} = -2\sum_{i=1}^{n}[Y_i - (b_0 + b_1x_{1i} + b_2x_{2i} + b_3x_{3i} + b_4x_{4i} + b_{12}x_{1i}x_{2i} + b_{13}x_{1i}x_{3i} + b_{14}x_{1i}x_{4i} + b_{23}x_{2i}x_{3i} + b_{24}x_{2i}x_{4i} + b_{34}x_{3i}x_{4i} + b_{123}x_{1i}x_{2i}x_{3i} + b_{124}x_{1i}x_{2i}x_{4i} + b_{134}x_{1i}x_{3i}x_{4i} + b_{234}x_{2i}x_{3i}x_{4i} + b_{1234}x_{1i}x_{2i}x_{3i}x_{4i})] = 0 \quad (8)$$

Considered over all the parameters of equation "7", sixteen other normal equations would be derived.

If the parameters of "3" are estimated, it is possible to identify those variables that would significantly contribute to degree of fit or not. Reference [16] noted that the parameters b_0, b_1, b_2, b_3, ..., b_{1234}, the regression coefficients are the relative measures of contributions to customer garment fit (Y) by either the associated sizing parameters/variables or their combination. Hence a value of zero for any of the parameters suggests that the associated parameter does not contribute to fit in a garment sizing process. It contributes, otherwise. Thus, the hypotheses stated in Table I are used to identify the set of parameters/variables or interactions with significant contribution to garment fit.

TABLE I. SET OF HYPOTHESES TO TEST PARAMETERS AND VARIABLES WITH CONTRIBUTIONS TO FIT

Parameters/Variables	Hypotheses	Interpretations
Tolerance (X_1)	$b_1 = 0$	Tolerance does not contribute to Garment fit
	$b_1 \neq 0$	Tolerance contributes to Garment fit
Number of Dimensions (X_2)	$b_2 = 0$	Number of dimensions does not contribute to Garment fit
	$b_2 \neq 0$	Number of dimensions contributes to Garment fit
Customer population (X_3)	$b_3 = 0$	Customer population does not contribute to Garment fit
	$b_3 \neq 0$	Customer population contributes to Garment fit
Number of Sizes (X_4)	$b_4 = 0$	Number of Sizes does not contribute to Garment fit
	$b_4 \neq 0$	Number of Sizes contributes to Garment fit
Tolerance (X_1), Number of Dimensions (X_2)	$b_{12} = 0$	Tolerance interacting with Number of dimensions does not contribute to Garment fit
	$b_{12} \neq 0$	Tolerance interacting with Number of dimensions contributes to Garment fit
Tolerance (X_1), Customer Population (X_3)	$b_{13} = 0$	Tolerance interacting with Customer population does not contribute to Garment fit
	$b_{13} \neq 0$	Tolerance interacting with Customer population contributes to Garment fit
Tolerance (X_1), Number of Sizes (X4)	$b_{14} = 0$	Tolerance level interacting with Number of sizes does not contribute to Garment fit
	$b_{14} \neq 0$	Tolerance level interacting with Number of sizes contributes to Garment fit
Number of Dimensions (X_2), Customer Population (X_3)	$b_{23} = 0$	Number of Dimensions interacting with Customer population does not contribute to Garment fit
	$b_{23} \neq 0$	Number of Dimensions interacting with Customer population contributes to Garment fit
Number of Dimensions (X_2), Number of sizes (X_4)	$b_{24} = 0$	Number of Dimensions interacting with Number of Sizes does not contribute to Garment fit
	$b_{24} \neq 0$	Number of Dimensions interacting with Number of Sizes contributes to Garment fit
Customer Population (X_3), Number of sizes (X_4)	$b_{34} = 0$	Customer population interacting with Number of sizes does not contribute to Garment fit
	$b_{34} \neq 0$	Customer population interacting with Number of sizes contributes to Garment fit
Tolerance (X_1), Number of Dimensions (X_2), Customer Population (X_3)	$b_{123} = 0$	Tolerance, Number of dimensions and Customer population interacting does not contribute to Garment fit
	$b_{123} \neq 0$	Tolerance, Number of dimensions and Customer population interacting contribute to Garment fit
Tolerance (X_1), Number of Dimensions (X_2), Number of sizes (X_4)	$b_{124} = 0$	Tolerance, Number of Dimensions interacting with Number of Sizes does not contribute to Garment fit
	$b_{124} \neq 0$	Tolerance, Number of Dimensions interacting with Number of Sizes contribute to Garment fit
Tolerance (X_1), Customer Population (X_3), Number of	$b_{134} = 0$	Tolerance, Customer population interacting with Number of sizes does not contribute to Garment fit

sizes (X_4)	$b_{134} \neq 0$	Tolerance, Customer population interacting with Number of sizes contributes to Garment fit
Number of Dimensions (X_2), Customer Population (X_3), Number of sizes (X_4)	$b_{234} = 0$	Number of Dimensions, Customer population interacting with Number of sizes does not contribute to Garment fit
	$b_{234} \neq 0$	Number of Dimensions, Customer population interacting with Number of sizes contributes to Garment fit
Tolerance (X_1), Number of Dimensions (X_2), Customer Population (X_3), Number of sizes (X_4)	$b_{1234} = 0$	Tolerance, Number of Dimensions, Customer population interacting with Number of sizes does not contribute to Garment fit
	$b_{1234} \neq 0$	Tolerance, Number of Dimensions, Customer population interacting with Number of sizes contributes to Garment fit

Each of these hypotheses may be tested using the following Student's t-test statistics at ($p < 0.05$).

$$t_{bi} = \frac{b_i}{SE} \quad (9)$$

Where b_i is parameter being investigated; SE is the standard error of estimates given as:

$$SE = \sqrt{\sum_{i=1}^{n} (Y_i - \hat{Y}_i)^2 / n-1} \quad (10)$$

To investigate this relationship of fit with the garment parameters, a typical trouser used by male population in Nigeria was selected. It has the following features:

(i) Five different dimensions- length, hip, waist, thigh and bottom girth

(ii) Tolerance of 5.08, 10.08, 15.08 and 20.08cm

(iii) Customer population that the trouser can be designed for.

(iv) The number of sizes that would satisfy customer population

A sample of 500 customers whose relevant anthropometric data to trousers collected by Kolawole (2016) were grouped into sizes so that 'best' possible degree of fit could be attained. This data which has 500 male customers was collected by [2], 100 of the data is shown in Table II as space limitation would not permit the whole data being shown. However, the descriptive analysis of the data is summarised in Table III. In the process of grouping, the identified parameters were varied and fit determined to ascertain how parameters related to fit.

Tolerance (t) was at 4 levels, number of dimensions (m) 5 levels, customers population at 9 levels (*i.e.,* 100, 150, 200…………450 and 500) to obtain the required number of sizes and fit. The procedure for solving for fit and the corresponding required number of sizes was as described by [2].

A regression analysis relating tolerance (t), number of dimensions (m), customer population (N) and number of sizes (q) to garment fit, $V(q;t,m,N)$, was carried out using the multivariate linear function stated in "3". The associated normal equations of "3" were solved using R- statistical Software in a personal computer (HP model G6.1). The resulting curve parameter values and statistical test of the hypotheses stated in Table I using the t-statistics in "9" were determined.

III. Results and Discussions

When tolerance (t) was set at four (4) levels; Number of dimensions (m), five (5) levels; customer population (N), nine (9) levels and Number of sizes (q), nineteen (19) levels; a sets of garment sizing solution Tables emerged which have values for fit and corresponding number of sizes. A sample of this solution set is shown in Table IV. From Table IV, fit values vary with changes in parameters. For example, when tolerance was set at 5.08cm with 5 dimensions and customer population of 500, number of sizes vary from 2 to 20, fit values range from 84.15% for 2 sizes, 89.52% for 3 sizes, 92.22% for 4 sizes……….98.41% for 19 sizes and 98.1% for 20 sizes. The best "fit possible" was when number of sizes was 19 and fit was 98.41%. Other results for fit with different combinations of parameters and variables are indicated in Table IV when customer population was 500. For limitation of space, Tables of results for when customer population were 100, 150, 200, 250, 300, 350, 400 and 450 could not be shown, but results summarised in Table V where the "best fit possible" and corresponding number of sizes (in brackets) are indicated.

From the analysis of the regression equations relating tolerance (t), number of dimensions (m), customer population (N) and number of sizes (q) to garment fit, $V(q;t,m,N)$, using the multivariate linear function together with associated normal equations and the statistical test of hypotheses stated in Table I using t-statistics; the results showed that the garment sizing parameters: tolerance, customer population and the variable, number of sizes relate strongly to garment fit as indicated by the curve's coefficient of determination value of 98.7%. This is also evident in the hypotheses' test results, all the parameter values and the variable appear to have significant contributions to garment fit. This is also true with their respective interactions. This may be interpreted to mean that, given tailoring-related anthropometric dimensions of a known population of customers, some systematic changes in each of the values of the parameters/variable (tolerance, number of dimensions, customer population and number of sizes) and their respective interactions may bring about satisfactory garment sizing system. These findings are further expressed in "11" and Table IV

$$Y = 6.336X_1 + 27.7X_2 + 0.2009X_3 + 6.864X_4 - 1.999X_1X_2 - 0.0139X_1X_3 - 0.4548X_1X_4 - 0.05837X_2X_3 - 2.045X_2X_4 - 0.01492X_3X_4 + 0.004323X_1X_2X_3 + 0.1426X_1X_2X_4 + 0.00103X_1X_3X_4 + 0.004446X_2X_3X_4 - 0.00032X_1X_2X_3X_4 \quad (11)$$

From "11", the values of the coefficients of X_1, X_2, X_3 and X_4 represent the contributions of tolerance, number of dimensions, customer population and number of sizes respectively. It is apparent from "11" and the result of t-tests of Table IV that all garment sizing parameters/variables and their respective interactions contribute significantly to garment fit.

Considering the coefficients of the terms in "11", it appears that tolerance (X_1), number of dimensions (X_2), customer population (X_3) and number of sizes (X_4) exhibited positive contributions to garment fit with number of dimensions contributing the highest proportion. Most of the two-way interacting parameters exhibit negative values, suggesting that depending on the use of correlation of one or two key body dimensions to other dimensions in order to come up with a garment sizing may not yield satisfactory garment sizes. This perhaps may be responsible for the garment misfits that are being experienced in clothing by customers with most of the current sizing systems. In view of this, it may be necessary to take a holistic consideration of all necessary parameters and variables while attempting to develop a sizing system.

IV. Conclusion

This study was conducted to investigate the possible relationship between garment sizing parameters and fit. The results indicate that tolerance, number of dimensions on a garment, customers population and number of sizes have strong relationships to fit. From the outcome of tests of hypotheses, all the parameters make significant contributions to fit. In view of these, all garment sizing parameters may have to be taken into consideration in order to obtain a satisfactory sizing system.

TABLE II. GARMENT RELATED ANTHROPOMETRIC DATA FOR TROUSERS

Customer	Length(cm)	Waist(cm)	Thigh(cm)	Hip(cm)	Bottom girth(cm)
1	107.95	76.2	71.12	101.6	45.72
2	99.06	86.36	73.66	105.41	44.45
3	105.41	83.82	73.66	100.33	44.45
4	106.68	83.82	71.12	97.79	45.72
5	106.68	78.74	73.66	96.52	45.72
6	106.68	78.74	68.58	99.06	45.72
7	116.84	86.36	73.66	102.87	45.72
8	114.3	101.6	76.2	110.49	45.72
9	104.14	78.74	69.85	97.79	44.45
10	105.41	80.01	69.85	100.33	45.72
11	109.22	80.01	71.12	100.33	45.72
12	101.6	77.47	73.66	97.79	45.72
13	104.14	93.98	73.66	107.95	45.72
14	110.49	81.28	69.85	96.52	45.72
15	105.41	81.28	71.12	96.52	45.72
16	102.87	76.2	69.85	95.25	45.72
17	99.06	85.09	71.12	95.25	45.72
18	110.49	78.74	71.12	96.52	45.72
19	99.06	74.93	68.58	93.98	44.45
20	100.33	76.2	68.58	95.25	43.18
21	106.68	81.28	69.85	97.79	45.72
22	104.14	74.93	68.58	93.98	45.72
23	99.06	87.63	71.12	93.98	45.72
24	109.22	71.12	69.85	95.25	45.72
25	116.84	81.28	69.85	100.33	45.72
26	104.14	78.74	68.58	96.52	45.72
27	107.95	81.28	72.39	97.79	46.99

Customer	Length(cm)	Waist(cm)	Thigh(cm)	Hip(cm)	Bottom girth(cm)
28	107.95	78.74	71.12	100.33	45.72
29	100.33	73.66	69.85	96.52	43.18
30	104.14	82.55	71.12	99.06	45.72
31	102.87	72.39	68.58	95.25	44.45
32	110.49	77.47	71.12	101.6	45.72
33	101.6	73.66	69.85	95.25	44.45
34	104.14	85.09	69.85	97.79	45.72
35	101.6	83.82	69.85	93.98	45.72
36	104.14	83.82	73.66	102.87	45.72
37	101.6	77.47	69.85	100.33	45.72
38	109.22	78.74	71.12	100.33	45.72
39	114.3	86.36	73.66	101.6	45.72
40	105.41	78.74	68.58	101.6	45.72
41	111.76	78.74	69.85	100.33	45.72
42	105.41	81.28	71.12	100.33	45.72
43	111.76	78.74	69.85	97.79	45.72
44	105.41	81.28	71.12	100.33	45.72
45	113.03	92.71	71.12	105.41	45.72
46	109.22	91.44	71.12	107.95	45.72
47	106.68	86.36	71.12	97.79	45.72
48	106.68	81.28	69.85	97.79	45.72
49	101.6	76.2	76.2	101.6	43.18
50	104.14	78.74	71.12	99.06	43.18
51	96.52	71.12	73.66	96.52	43.18
52	109.22	74.93	71.12	96.52	43.18
53	104.14	76.2	63.5	93.98	40.64
54	110.49	81.28	76.2	99.06	43.18
55	104.14	81.28	66.04	96.52	38.1
56	109.22	91.44	76.2	109.22	43.18
57	106.68	72.39	71.12	99.06	43.18
58	114.3	88.9	76.2	106.68	43.18
59	109.22	83.82	76.2	101.6	43.18
60	106.68	76.2	71.12	96.52	40.64
61	104.14	78.74	71.12	99.06	43.18
62	101.6	76.2	71.12	99.06	43.18
63	104.14	85.09	71.12	106.68	43.18
64	109.22	78.74	71.12	101.6	40.64
65	101.6	68.58	71.12	101.6	40.64
66	109.22	85.09	73.66	101.6	45.72
67	106.68	73.66	73.66	96.52	43.18
68	107.95	78.74	73.66	96.52	43.18
69	109.22	78.74	66.04	99.06	38.1
70	111.76	73.66	66.04	99.06	38.1
71	104.14	71.12	71.12	96.52	40.64
72	104.14	76.2	73.66	96.52	40.64
73	106.68	78.74	76.2	101.6	45.72
74	99.06	71.12	73.66	101.6	43.18
75	109.22	76.2	73.66	96.52	43.18
76	106.68	73.66	71.12	101.6	40.64
77	109.22	73.66	71.12	99.06	40.64
78	109.22	81.28	71.12	101.6	43.18
79	106.68	76.2	71.12	96.52	45.72
80	109.22	78.74	68.58	99.06	45.72
81	97.79	71.12	66.04	96.52	40.64
82	111.76	77.47	71.12	99.06	45.72
83	100.33	71.12	68.58	96.52	43.18
84	106.68	78.74	68.58	99.06	40.64
85	114.3	80.01	81.28	106.68	45.72

Customer	Length(cm)	Waist(cm)	Thigh(cm)	Hip(cm)	Bottom girth(cm)
86	110.49	82.55	71.12	99.06	43.18
87	116.84	80.01	71.12	101.6	45.72
88	101.6	73.66	71.12	96.52	43.18
89	111.76	77.47	78.74	96.52	45.72
90	106.68	81.28	71.12	99.06	40.64
91	106.68	78.74	73.66	96.52	43.18
92	100.33	74.93	71.12	96.52	40.64
93	104.14	78.74	73.66	96.52	43.18
94	101.6	76.2	73.66	99.06	43.18
95	106.68	76.2	76.2	99.06	43.18
96	106.68	78.74	76.2	101.6	40.64
97	104.14	78.74	76.2	101.6	43.18
98	114.3	92.71	76.2	111.76	45.72
99	104.14	74.93	76.2	101.6	43.18
100	106.68	69.85	71.12	96.52	40.64

Source: Kolawole (2016)

TABLE III. SUMMARY OF GARMENT RELATED ANTHROPOMETRIC DATA FOR TROUSERS

Body Dimension	Maximum (cm)	Minimum (cm)	Mean (cm)	Standard Deviation
Length	119.38	93.98	105.02	4.71
Waist	114.3	68.58	82.26	7.48
Thigh	99.06	58.42	70.84	3.82
Hip	121.92	68.58	96.98	6.17
Bottom girth	55.88	38.1	45.02	2.12

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TABLE IV. FIT WITH RESPECT TO SIZING PARAMETERS/VARIABLES AT N= 500

Customer Population	Tolerance	No of Dimensions	Number of Sizes																		
			2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
500	5.08	1	43	69.16	79.78	85.09	87.93	90.99	92.73	94.06	95.12	95.76	96.34	96.53	97.52	97.19	97.58	98.02	98.25	98.53	98.65
		2	36.53	52.74	77.58	71	74.86	77.85	80.54	82.8	84.88	86.4	90.42	91.22	92.1	92.67	93.36	92.24	92.77	93.64	94.17
		3	60.11	72.09	85.15	82.25	85.36	87.33	88.53	90.16	91	91.84	92.74	93.43	94.06	94.4	94.51	95.19	92.54	93.17	93.57
		4	72.59	81.17	88.94	88.27	90.36	91.44	92.17	93.48	93.85	94.4	95.08	95.61	96.1	96.25	95.89	96.65	92.37	93.01	93.41
		5	84.15	89.52	92.22	93.8	94.9	95.65	94.83	96.13	96.95	95.56	96.9	97.14	97.46	91.36	97.2	98.01	97.93	98.41	98.1
	10.08	1	69.33	81.01	85.93	91.6	93.74	94.93	95.49	96.58	96.91	97.37	98.17	98.14	98.49	98.44	98.12	98.68	95.78	96.11	96.36
		2	56.85	71.93	82.14	85.59	88.75	90.83	91.85	93.26	94.07	94.81	95.83	95.96	96.46	96.59	96.74	97.22	95.95	96.27	96.52
		3	50.59	67.17	80.52	85.21	88.17	90.2	91.44	92.72	93.64	94.45	95.28	95.49	96.02	96.28	96.56	96.94	96.48	96.79	97.09
		4	82.43	95.37	97.78	98.07	98.88	99.05	99.25	99.28	99.43	94.86	95.37	95.74	96.06	96.3	96.59	96.76	96.93	97.07	97.17
		5	91.36	94.49	95.03	96.08	96.86	97.8	98.06	98.43	98.37	98.72	98.74	98.94	98.99	99.01	99.12	93.31	99.32	99.34	99.38
	15.08	1	66.97	87.95	94.92	98.3	99.1	99.24	99.56	99.8	99.84	99.9	99.91	99.95	99.96	99.97	99.99	99.99	99.99	100	99.93
		2	59.21	77.67	89.05	96.71	97.56	98.06	98.59	98.98	99.17	99.44	99.49	99.68	99.73	99.76	99.79	99.83	99.85	99.91	99.84
		3	55.04	73.15	87.56	95.38	96.36	97.09	97.57	97.99	98.32	98.67	98.81	99.08	99.21	99.36	99.45	99.51	99.55	99.66	99.61
		4	75.25	84.81	93.28	97.07	97.62	98.11	98.42	98.7	93.86	94.48	94.98	95.42	95.81	96.18	96.46	96.69	96.88	97.09	97.23
		5	96.74	97.99	98.48	98.83	98.76	98.96	86.8	99.47	89.46	90.53	91.33	92.05	92.61	93.15	93.59	93.91	94.31	94.6	94.95
	20.08	1	99.87	99.95	99.97	99.98	100	100	100	100	90	90.91	91.67	92.31	92.86	100	100	100	100	100	100
		2	73.74	91.86	97.07	99.77	99.81	99.86	99.89	99.94	99.94	99.96	99.96	99.97	99.97	100	100	100	100	100	100
		3	64.1	79.69	90.36	97.99	98.33	98.59	98.77	98.99	99.12	99.32	99.42	99.42	99.51	99.54	99.62	99.65	99.75	99.67	99.77
		4	79.52	88.91	95.12	98.98	99.2	99.32	93.18	93.96	94.54	95.03	95.48	95.76	96.12	96.46	96.69	96.77	96.96	97.09	97.39

TABLE V. OPTIMAL FIT VALUE AND OPTIMAL NUMBER OF SIZES IN RELATION TO TOLERANCE, NUMBER OF DIMENSIONS AND CUSTOMERS POPULATION (NUMBER OF SIZES IN BRACKET

TOLERANCE	No of Dimensions	Customers Population								
		100	150	200	250	300	350	400	450	500
5.08	1	100 (12)	100 (9)	100 (9)	100 (9)	100 (12)	99.99 (13)	99.98 (12)	99.98 (14)	99.89 (12)
	2	98.86 (20)	97.9 (20)	98.17 (20)	97.4 (20)	97.3 (20)	96.89 (20)	96.98 (20)	95.7 (16)	95.8 (16)
	3	97.05 (20)	96.78 (20)	94.48 (20)	94.77 (20)	94.98 (16)	94.77 (20)	94.65 (18)	94.89 (20)	94.62 (20)
	4	96.23 (20)	94.83 (20)	94.72 (20)	94.14 (20)	93.88 (20)	93.76 (20)	93.52 (20)	93.33 (20)	93.1 (20)
	5	99.31 (18)	98.99 (19)	98.69 (17)	98.69 (19)	98.13 (14)	98.7 (20)	98.69 (20)	98.52 (19)	98.41 (19)
10.08	1	100 (14)	100 (13)	100 (19)	100 (13)	100 (14)	99.89 (13)	98.97 (13)	99.77 (19)	99.89 (14)
	2	100 (16)	99.98 (20)	99.85 (20)	99.3 (20)	99.47 (20)	99.2 (20)	99.01 (20)	98.99 (20)	98.81 (20)
	3	99.63 (20)	99.74 (20)	99.61 (20)	98.72 (16)	98.59 (10)	98.53 (20)	98.22 (19)	97.64 (20)	97.43 (16)
	4	99.28 (20)	98.83 (19)	98.43 (20)	97.98 (20)	97.66 (20)	97.41 (20)	97.18 (20)	96.94 (20)	96.6 (20)
	5	99.97 (11)	100 (20)	99.62 (19)	99.49 (17)	98.87 (10)	99.06 (16)	99.36 (19)	99.21 (17)	99.38 (20)
15.08	1	100 (10)	100 (11)	100 (15)	100 (15)	100 (11)	100 (15)	100 (17)	100 (16)	100 (15)
	2	100 (13)	100 (18)	100 (15)	100 (15)	100 (20)	100 (20)	99.93 (16)	99.89 (16)	99.84 (20)
	3	99.78 (20)	99.82 (20)	100 (18)	99.92 (16)	99.82 (19)	99.87 (20)	99.44 (20)	99.44 (20)	99.32 (20)
	4	100 (18)	100 (20)	99.88 (20)	99.84 (20)	99.54 (20)	99.25 (20)	99.24 (20)	99.23 (20)	99.22 (20)
	5	100 (14)	99.7 (07)	99.84 (10)	99.5 (07)	99.71 (09)	99.77 (13)	99.75 (12)	99.74 (13)	99.47 (09)
20.08	1	100 (05)	100 (08)	100 (08)	100 (08)	100 (13)	100 (10)	100 (08)	100 (10)	100 (14)
	2	100 (06)	100 (13)	100 (07)	100 (16)	100 (15)	100 (20)	99.98 (20)	99.96 (20)	99.96 (20)
	3	100 (09)	100 (12)	100 (19)	99.99 (19)	99.99 (18)	99.99 (18)	99.65 (20)	99.7 (20)	99.77 (20)
	4	100 (12)	100 (17)	99.99 (19)	99.98 (17)	99.82 (20)	99.63 (17)	99.63 (20)	99.62 (10)	99.61 (20)
	5	100 (04)	100 (14)	98.69 (19)	98.69 (19)	96.2 (14)	98.7 (20)	99.78 (06)	99.9 (08)	99.94 (11)

TABLE VI. RESULTS OF HYPOTHESES TESTING OF CONTRIBUTIONS OF GARMENT SIZING PARAMETERS

Component Identity	Associated Curve parameter	Estimated Parameter Value	Std. error	t-value	p-values	Remark
Tolerance	b_1	6.336	0.1758	36.03	0.0001	Significant
No of Dimensions	b_2	27.7	0.7663	36.15	0.0001	Significant
customer population	b_3	0.2009	0.007214	27.85	0.0001	Significant
No of sizes	b_4	6.864	0.2162	31.75	0.0001	Significant
Tolerance, No of Dimensions	b_{12}	-1.999	0.07348	-27.21	0.0001	Significant
Tolerance, customer population	b_{13}	-0.0139	0.000721	-19.29	0.0001	Significant
Tolerance, No of sizes	b_{14}	-0.4548	0.02027	-22.44	0.0001	Significant
No of Dimensions, customer population	b_{23}	-0.05837	0.003062	-19.06	0.0001	Significant
No of Dimensions, No of sizes	b_{24}	-2.045	0.08583	-23.83	0.0001	Significant
Customer population, No of sizes	b_{34}	-0.01492	0.000845	-17.65	0.0001	Significant
Tolerance, No of Dimensions, customer, customer population	b_{123}	0.004323	0.00026	16.62	0.0001	Significant
Tolerance, No of Dimensions, No of sizes	b_{124}	0.1426	0.007147	19.96	0.0001	Significant
Tolerance, customer population, No of sizes	b_{134}	0.00103	7.12E-05	14.47	0.0001	Significant
No of Dimensions, customer population, No of sizes	b_{234}	0.004446	0.000299	14.85	0.0001	Significant
Tolerance, No of Dimensions, customer population, No of sizes	b_{1234}	-0.00032	2.39E-05	-13.41	0.0001	Significant

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