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Research the influence of the T-shirt body structure and marker performance

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ABSTRACT: *Fabric consumption is an important factor in establishing the costs and prices of garments. The product's price depends on the cost of materials, including fabric. Fabric consumption depends on many factors such as quantity, style, and product size. This study presents the results of determining the difference between the body structure and the marker performance. The T-T-shirt is designed with different body structures felt on 5 different fabric widths. MarkerMaking V6R2 software is used to create and measure T-shirt markers from which to determine fabric standards for a product. R software was used to define 17 mathematical models on the relationship between marker efficiency, fabric width, and detailed shape on the T-shirt body. This contributes to helping garment manufacturers and traders choose the appropriate product structure, saving fabric costs in industrial garment production.*

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I. INTRODUCTION

In industrial garments, many factors related to cutting production costs are concerned such as labor costs, materials, fixed costs... Among them, spreading and cutting fabric, and increasing marker efficiency are always respected. Many studies have been carried out to build optimal performance for garment products. Increase marker efficiency by combining sizes and changing part dimensions during T-shirt marker [1]. Increase fabric usage efficiency during the marker process thanks to coordinating sizes and arranging details of men's T-shirts on the appropriate fabric width [2]. Building a cutting plan with the number of fabric layers and the aspect ratio has a clear influence on the marker performance [3]. The marker efficiency is determined based on the marker map results when the fabric width and marker length are known [4]. However, the marker results depend largely on the product shape, structure, number of products on the marker, fabric width, fabric surface effects, cutting table elimination method... [5]. Different forms of pattern markers in industrial garments also bring different marker performance [8]. Calculation software calculates material consumption set for FOB orders [9]. Studies have been carried out on certain product categories. Each garment is structured by many different shapes of details, so learning about the relationship between the structure of the details and marker performance is necessary. Therefore, this study determines the relationship between the shape of the body of the T-shirt with the fabric consumption and the marker performance, thereby providing a mathematical model that allows calculating specific fabric performance for each structural shape. T-shirt body and fabric width. This is an important factor that contributes to shortening the time to calculate fabric consumption when needing to order fabric and allocate fabric for production, providing recommendations for choosing the appropriate fabric width for the product design, and helping to save costs input costs and lower product costs in industrial garments

II. RESEARCH METHODS

2.1. Object and scope of the study

Product: Select a T-shirt with 17 body shape structures in Figure 1, the sleeves, and collar are fixed and used to create a marker. This is a popular and common product in life and is a traditional product in many garment businesses.

Fabric: The fabric used for the study is the fabric commonly used to make T-shirts. The T-shirt is made of 5 different fabric widths of 1m; 1.2m; 1.4m; 1.5m and 1.6m.

2.2. Methods

In this study, the initial T-shirt used to design the sample was T-shirt A1. After that, T-shirt model A1 was designed to change the detailed body shape to T-shirt designs from A2 to A17 (Figure 1). The study of the influence of body structure and shape on marker performance is measured by observed variables. These observed variables are the fabric width, the 17 T-shirts have different body structure shapes, the number of details on the T-shirt, and the fabric standards are determined through the form of a marker. Coding for observed variables is shown in Table 1.

Figure 1. Image of 17 T-shirts

Table 1. Coding of observed variables

No	Observed variables	Code
1	T-shirts with different shapes and details on the body	Style
2	Fabric Width	Width
3	Fabric consumption for a product	Cons
4	Number of details on the T-shirt	Panels
5	Marker performance	Eff

2.2.1. Marker, calculating fabric consumption and marker efficiency

Parameters of the angle marker include Marker length, marker efficiency (Eff), and marker width (Width). Use MakerMaking V6R2 software to create markers. Each T-shirt shape has 3 sizes are S, M, and L which marked on a marker.

The fabric consumption of a product (Cons) for each marker is determined by the formula (1a), and the marker efficiency (Eff) is determined by the formula (1b).

Cons = Length of marker/ number of products on the marker (m/product) (1a)

Eff = (Used fabric area / Original fabric area) x 100 (%) (1b)

2.2.2. Determine the relationship between marker efficiency and fabric width, number of details on the T-shirt and fabric consumption

To determine the relationship between marker efficiency and fabric width, the number of details on the T-shirt, and fabric consumption, use a multivariate linear regression model with a matrix form as follows:

$$Eff = X\beta + \varepsilon \qquad (2)$$

In which, Eff is a vector of marker matrix efficiency values.

Where R software is used to determine the relationship between marker efficiency and fabric width, number of details on the T-shirt, and fabric consumption; Use the *cbind* function to consider the correlation of pairs of input variables; Use the summary command to view results ensuring high reliability and accuracy.

To consider the impact of each input variable on the variation of marker perception performance, use the LMG method to determine the coefficient of determination R^2 of the model for each input variable. LMG is the abbreviation of the three statisticians who came up with this index: Lindermann, Merenda, Gold. This is a new and good measure used by many statisticians. Use the *calc.relimp* function and the *boot.relimp* function in R to determine the coefficient of determination R^2 of the model for each input variable [10].

When the T-shirt is felt on different fabric widths, the marker efficiency changes. The model describes this consumption change as follows:

$$Eff_i = y_i = c_i + d_i*Width + e_i \qquad (2)$$

In which: i is the serial number of the marker (i = 1,2,3,4,5,6)

y_i is the marker efficiency for the i^{th} T-shirt

c_i is the marker efficiency for the original T-shirt. In this study, the original T-shirt is A1

di is the change in marker efficiency for the i^{th} T-shirt

e_i is the noise level during the measurement and calculation process

To consider the change in marker matrix performance for a T-shirt when there are also factors related to the shape of details on the T-shirt's body, we have:

$$c_i = C_0 + C_1*Style + u \qquad (3)$$

In which, C_0 is the average marker performance between marker sessions

C_1 is the difference in average marker performance between marker sessions

u reflects the difference between the c_i marker performance and the average marker performance ($C_0 + C_1*Style$)

$$d_i = D_0 + D_1*Style + v \qquad (4)$$

In which, D_0 is the change in average marker performance between marker sessions

D1 is the change in average marker performance difference between marker sessions

v reflects the difference between d_i and ($D_0 + D_1*Style$)

Combining model (2) and equations (3), and (4) we have a model to study the influence of the shape of details on the body of a T-shirt on the marker efficiency in a systematic way when marker on different fabric widths as follows:

$$Eff_i = y_i = C_0 + C_1*Style + u + (D_0 + D_1*Style + v)*Width + e_i$$

$$Eff_i = y_i = (C_0 + C_1*Style + D_0*Width + D_1*Style*Width) + (u + v*Width + e_i) \qquad (5)$$

From the mixed influence model (5), the relationship between the marker efficiency (Eff) and the width of the fabric (Width), and the shape of the details on the body of the T-shirt are determined (Style). Use the *lmer* function to review and estimate the parameters in the model. The *lmer* function has two main parts in the model: the fixed effect part, which is a parameter, and the random effect part because it reflects the variance; Use the summary command to view results ensuring high reliability and accuracy [10].

III. RESULTS AND DISCUSSION

3.1. Marker results and marker performance

Using 85 markers, each shape marker has 3 products with sizes S, M, and L, each shape marker is on different fabric widths of 1m, 1.2m, 1.4m, 1.5m, and 1.6m. The results are marker magically as shown in Table 2.

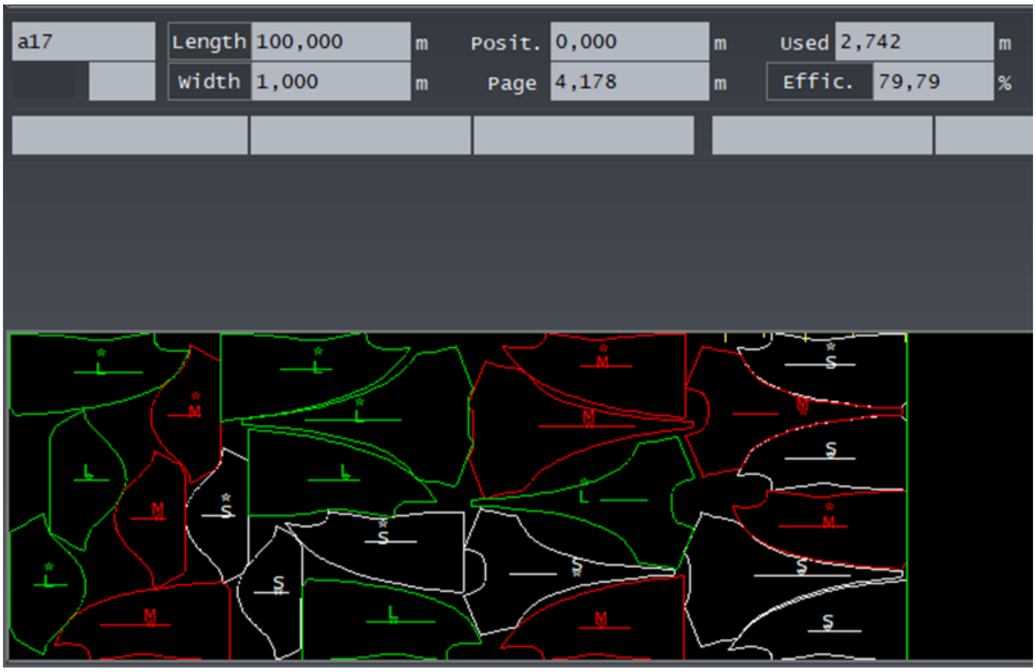

Figure 2. Marker of T-shirt A17 size S, M, L with fabric width 1m

Table 2. Schematic marker results

ID	Style	Panels	Width	Effect	Cons	Size	ID	Style	Panels	Width	Effect	Cons	Size
1	A1	7	1	84.01	0.820	SML	44	A9	7	1.5	82.22	0.563	SML
2	A1	7	1.2	84.63	0.678	SML	45	A9	7	1.6	81.59	0.532	SML
3	A1	7	1.4	86.54	0.569	SML	46	A10	7	1	80.91	0.846	SML
4	A1	7	1.5	86.04	0.534	SML	47	A10	7	1.2	78.67	0.725	SML
5	A1	7	1.6	84.6	0.509	SML	48	A10	7	1.4	84.33	0.580	SML
6	A2	7	1	82.32	0.838	SML	49	A10	7	1.5	82.55	0.553	SML
7	A2	7	1.2	83.07	0.700	SML	50	A10	7	1.6	82.03	0.521	SML
8	A2	7	1.4	83.76	0.588	SML	51	A11	9	1	81.77	0.890	SML
9	A2	7	1.5	81.68	0.563	SML	52	A11	9	1.2	79.76	0.761	SML
10	A2	7	1.6	83.17	0.518	SML	53	A11	9	1.4	81.77	0.636	SML
11	A3	7	1	80.6	0.857	SML	54	A11	9	1.5	82.9	0.586	SML
12	A3	7	1.2	82.7	0.696	SML	55	A11	9	1.6	82.1	0.554	SML
13	A3	7	1.4	82.55	0.596	SML	56	A12	9	1	81.83	0.858	SML
14	A3	7	1.5	82.3	0.561	SML	57	A12	9	1.2	78.37	0.747	SML
15	A3	7	1.6	82.26	0.525	SML	58	A12	9	1.4	84.48	0.594	SML
16	A4	9	1	82.9	0.526	SML	59	A12	9	1.5	82.48	0.568	SML
17	A4	9	1.2	83.4	0.436	SML	60	A12	9	1.6	82.62	0.531	SML
18	A4	9	1.4	84.1	0.371	SML	61	A13	9	1	83.78	0.866	SML
19	A4	9	1.5	83.46	0.349	SML	62	A13	9	1.2	81.59	0.741	SML
20	A4	9	1.6	83.3	0.327	SML	63	A13	9	1.4	80.22	0.646	SML
21	A5	7	1	81.07	0.851	SML	64	A13	9	1.5	84.55	0.572	SML
22	A5	7	1.2	81.33	0.707	SML	65	A13	9	1.6	82.55	0.549	SML
23	A5	7	1.4	84.07	0.586	SML	66	A14	9	1	82.58	0.887	SML
24	A5	7	1.5	82.11	0.560	SML	67	A14	9	1.2	82.47	0.740	SML
25	A5	7	1.6	82.92	0.520	SML	68	A14	9	1.4	81.17	0.645	SML
26	A6	9	1	83.68	0.827	SML	69	A14	9	1.5	84.86	0.575	SML
27	A6	9	1.2	82.2	0.671	SML	70	A14	9	1.6	83.24	0.550	SML
28	A6	9	1.4	87.17	0.567	SML	71	A15	9	1	81.81	0.907	SML
29	A6	9	1.5	84.4	0.546	SML	72	A15	9	1.2	83.08	0.773	SML
30	A6	9	1.6	86.63	0.499	SML	73	A15	9	1.4	80.93	0.655	SML
31	A7	7	1	81.93	0.853	SML	74	A15	9	1.5	83.3	0.594	SML
32	A7	7	1.2	82.31	0.707	SML	75	A15	9	1.6	83.93	0.552	SML

33	A7	7	1.4	83.91	0.595	SML	76	A16	13	1	81.6	0.903	SML
34	A7	7	1.5	83.16	0.560	SML	77	A16	13	1.2	82.08	0.813	SML
35	A7	7	1.6	82.81	0.527	SML	78	A16	13	1.4	83.36	0.631	SML
36	A8	7	1	81.24	0.921	SML	79	A16	13	1.5	82.15	0.598	SML
37	A8	7	1.2	82.7	0.754	SML	80	A16	13	1.6	81.99	0.562	SML
38	A8	7	1.4	84.03	0.636	SML	81	A17	9	1	79.79	0.914	SML
39	A8	7	1.5	81.86	0.610	SML	82	A17	9	1.2	79.818	0.756	SML
40	A8	7	1.6	83.07	0.563	SML	83	A17	9	1.4	79.61	0.654	SML
41	A9	7	1	81.24	0.854	SML	84	A17	9	1.5	81.21	0.599	SML
42	A9	7	1.2	82.07	0.705	SML	85	A17	9	1.6	81.7	0.558	SML
43	A9	7	1.4	83.73	0.592	SML	44	A9	7	1.5	82.22	0.563	SML
							45	A9	7	1.6	81.59	0.532	SML

3.1.1. Correlation between pairs of input data

The input data are the detailed quantity of the T-shirt (Panels), fabric width (Width), and consumption for 1 product (Cons). These variables are correlated as follows:

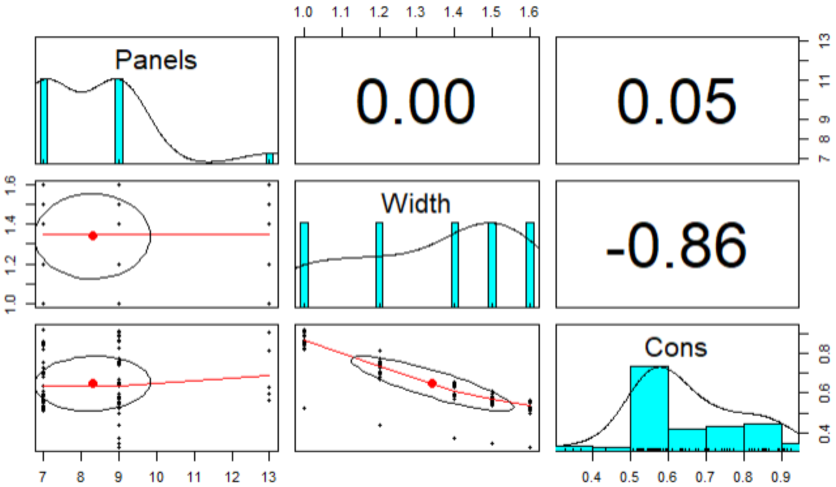

Figure 3. Correlation chart between pairs of input data

When considering the correlation between pairs of input data with the participation of all 3 variables, the results on the correlation chart show that there is no value of the correlation coefficient r greater than or equal to 0.95 are input variables that are independent of each other. Therefore, it is possible to consider and search for separate relationships between output variables and input variables.

3.1.2. Relationship between input data and output values Efficiency Graph (Eff)

The data is processed using R software to consider the linear relationship between input variables: Number of shirt details (Panels), Fabric width (Width), and Consumption for 1 product (Cons) with the value of output marker efficiency (Eff). The results show that there exists a multivariate relationship between Eff and input variables as follows:

$$\textbf{Eff} = \textbf{90.1} - \textbf{0.04*Panels} - \textbf{7.43*Cons} - \textbf{1.73*Width} \qquad (3)$$

The model has a coefficient of determination $R^2 = 0.208$; p-value: $< 0.0003 < 0.05$ has statistical significance. Thus, the variation of input values Width, Size, and Eff explains 20.8 % of the variation in map marker performance (Eff) within the study range. This model allows us to estimate the efficiency of the marker when knowing the width of the fabric, the number of details on the T-shirt, and the fabric consumption for 1 product.

Model (3) is a model that shows the correlation between input variables: Number of T-shirt details (Panels), Fabric width (Width), and Consumption for a product (Cons) with the value of the input. Output the Efficiency Marker (Eff). The regression coefficients in the model show that the marker efficiency (Eff) will increase when reducing the width of the fabric (Width) and keeping the standard and number of details on the T-shirt constant. When the value of the input variable Width decreases by 1 unit and the consumption and number of details on the T-shirt do not change, the efficiency of the marker for the T-shirt will increase by 1.73 units within the research scope.

The marker efficiency model (Eff) depends on 3 input variables: Number of T-shirt details (Panels), Fabric width (Width), and Fabric consumption for 1 product (Cons). The model shows the impact of all three variables on the variation of marker performance through the coefficient of determination R^2. Use the *calc. limp* function and the *boot. limp* function in R to determine the model's coefficient of determination R^2 for each input variable. The following results:

The coefficient of determination R^2 of the number of T-shirt details (Panels) is 0.004.

The determination coefficient R^2 of fabric consumption for 1 product (Cons) is 0.148.

The coefficient of determination R^2 of Fabric Width is 0.056.

Thus, the variation of input values of fabric consumption for a product explains 14.8%, the number of T-shirt details explains 0.4%, and the fabric width explains 5%, 6 % variation in marker efficiency (Eff) for T-shirt products within the study range. This result shows that the fabric consumption for a product has the most influence on the change in marker performance.

3.2. The results determine the relationship between the marker performance and the fabric width and detailed shape on the T-shirt body.

Because the input variables in the multivariate linear regression model in model (2) may not fully explain the variation in marker performance, it is necessary to consider the influence of variation in the shape of the plots. details on the T-shirt body and fabric width to the marker matric performance.

To evaluate the influence of detailed shape on the body of the T-shirt on the performance of feeling the T-shirt pattern on different fabric widths, it is necessary to consider the performance of each T-shirt when feeling the pattern on different fabric widths.

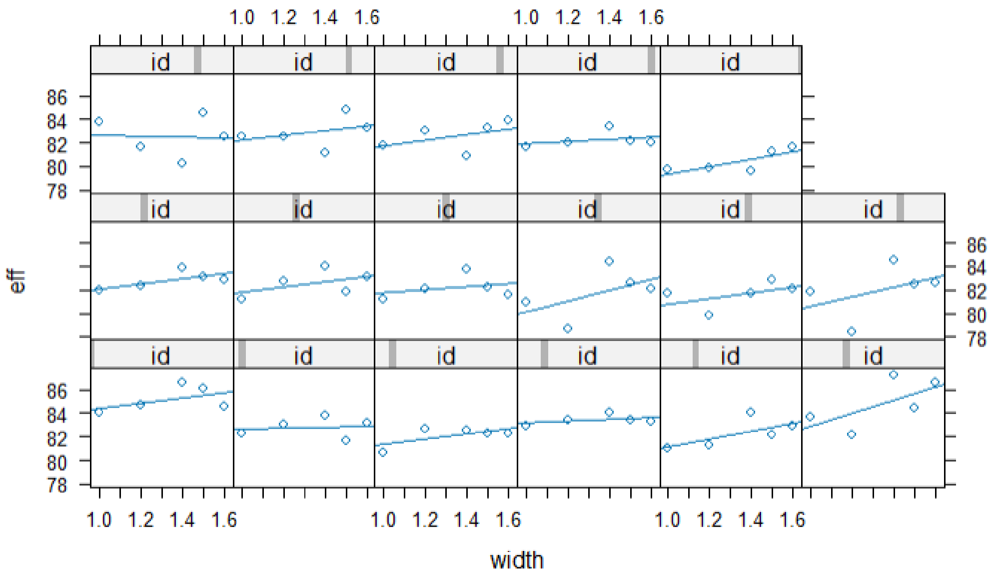

Figure 4. Efficiency for each T-shirt when marking samples on different fabric widths

Figure 4 shows that the marker efficiency of each T-shirt with different detailed shapes on the T-shirt body tends to increase as the fabric width increases. The degree of increase in marker efficiency as fabric width increases also vary between T-shirts.

To consider the relationship of the detailed shape on the T-shirt body to the map marker performance when the T-shirt sample is marked on different fabric widths, this article uses a mixed influence model in R software.

Consider the case of a T-shirt A1 that changes the shape and details to a T-shirt A2 and the design shown on the marker has a fabric width that changes in 5 types of sizes. According to model (5), taking into account the factor of changing the shape of the details in the model:

$$Eff_i = y_i = (C_0 + C_1*Style + D_0*Width + D_1*Style*Width) + (u + v*Width + e_i) \quad (5)$$

In which, C_0 is the average marker performance between marker sessions

C_1 is the difference in average marker performance between marker sessions

u reflects the difference between the c_i marker performance and the average marker performance ($C_0 + C_1*Style$)

D_0 is the average change in marker performance between marker sessions

D_1 is the change in average marker performance difference between marker sessions v reflects the difference between d_i and (D_0 + D_1*Style)

e_i reflects the variation in marker performance per T-shirt

Therefore, after data analysis, model (5) becomes:

$$\text{Eff } y_2 = 81.8 + 0.2*\text{Style} + 4.3*\text{Width} – 1.9*\text{Style}*\text{Width}$$

During data processing, the study called Style = 1 for T-shirt A1 and Style = 2 for T-shirt A2, Width has 5 values of 1m; 1.2m; 1.4m; 1.5m, and 1.6m. Result:

The model that describes the fluctuation of the marker performance for T-shirt A1 is:

$$\text{Eff }_{A1} = 82 + 2.4*\text{Width} \quad \text{với } e_2^2 = 0{,}0006 \qquad (5*A1)$$

The model that describes the fluctuation of the marker performance for T-shirt A2 is:

$$\text{Eff }_{A2} = 82.2+ 0.5*\text{Width} \quad \text{với } e_2^2 = 0{,}0006 \qquad (5*A2)$$

Model (5*) has e^2 = 0.0006, which is a modest but still significant reduction in measurement noise. The estimates calculated in the model (5*A1) or (5*A2) are considered accurate and reliable.

From model (5*A2), it is possible to determine the rough marker efficiency for T-shirts A2 with any type of fabric, and also from the (5*A1) model, it is possible to determine the rough marker efficiency clothes for T-shirts A1 with any type of fabric within the scope of research.

******* Doing the same with the transformation from any T-shirt with the shape of one body detail to a T-shirt with the shape of other body details according to model (5) will result in a model that determines the performance of the marker for each type of T-shirt is as shown in Table 3.

Table 3. Results of the marker performance model for each T-shirt with different shapes and details on the body.

No	Coding T-shirt	The model determines the schematic marker performance for the T-shirt
1	T-shirt A1	Eff A1 = 82 + 2.4*Width
2	T-shirt A2	Eff A2 = 82.2+ 0.5*Width
3	T-shirt A3	Eff A3 = 79 + 2.2*Width
4	T-shirt A4	Eff A4 = 82.6 + 0.8*Width
5	T-shirt A5	Eff A5 = 77.4 + 3.5*Width
6	T-shirt A6	Eff A6 = 77.3 + 5.7*Width
7	T-shirt A7	Eff A7 = 80.1 + 2.2*Width
8	T-shirt A8	Eff A8 = 79.4 + 2.4*Width
9	T-shirt A9	Eff A9 = 80.5 + 1.3*Width
10	T-shirt A10	Eff A10 = 75.5 + 4.7*Width
11	T-shirt A11	Eff A11 = 78.6 + 2.3*Width
12	T-shirt A12	Eff A12 = 76.4 + 4.2*Width
13	T-shirt A13	Eff A13 = 83.1 – 0.5*Width
14	T-shirt A14	Eff A14 = 80.1 + 2.1*Width
15	T-shirt A15	Eff A15 = 79.5 + 2.5*Width
16	T-shirt A16	Eff A16 = 80.9 + 0.9*Width
17	T-shirt A17	Eff A17 = 76.3 + 3*Width

The models in Table 3 show that the marker efficiency for different T-shirts is different and proportional to the fabric width (except for T-shirts A13), the marker efficiency for T-shirts will increase as the fabric width increases and vice versa. With a T-shirt A1, when the fabric width increases by 1 unit, the marker efficiency for the T-shirts will increase by 2.4 units.

The models in Table 3 also show that the level of fluctuation in marker performance for T-shirts when marker samples on different fabric widths are very different, in which, the level of fluctuation in marker performance of T-shirts A6 is very different is the largest 5.7 levels when the fabric width changes; T-shirt A2 has a fluctuation level of marker performance as small as 0.5 levels.

From the models in Table 3, it can choose the fabric width for the marker to help save fabric and increase the efficiency of the marker in production. High marker efficiency helps reduce fabric costs, increase profits, reduce waste, and contribute to environmental protection.

IV. CONCLUSION

The marker efficiency of each T-shirt with different detailed shapes on the T-shirt body tends to increase as the fabric width increases. The degree of increase in marker efficiency as fabric width increases also varies between T-shirts.

There exists a multivariate relationship between marker efficiency (Eff) and the input variables number of T-shirt details (Panels), Fabric width (Width), and Consumption for 1 product (Cons) as follows:

$$\textbf{Eff = 90.1 – 0.04*Panels – 7.43*Cons – 1.73*Width} \qquad \textbf{(3)}$$

$R^2 = 0.208$; p-value: $< 0.0003 < 0.05$

This model allows us to estimate the efficiency of the marker when knowing the width of the fabric, the number of details on the T-shirt, and the fabric consumption for 1 product. Building 17 models (table 3) shows that the efficiency of the marker is proportional to the width of the fabric.

From there, it can choose the appropriate fabric width for the marker to help save fabric and increase the efficiency of the marker in production. High marker efficiency helps reduce fabric costs, increase profits, reduce waste, and contribute to environmental protection.

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