

# MODELING THE IMPACT OF MARKER PARAMETERS ON FABRIC CONSUMPTION IN GARMENT MANUFACTURING

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## ABSTRACT

The fabric cost of a garment is closely associated with its fabric consumption. Fabric consumption varies depending on the number of garments and the number of sizes included in a marker, as well as the marker efficiency. This study investigates the effects of the quantity of garments (SP), the quantity of sizes in a marker (SC), and marker efficiency (HS) on fabric consumption, and proposes a method for estimating the fabric consumption of men's shirts. MarkerMaking V6R2 software was used to create patterns, grade them into five sizes, and generate markers for men's shirts on a fabric width of 1.5 m, from which the fabric consumption per garment was determined. The R software was employed to analyze the relationships between fabric consumption and SP, SC, and HS. As a result, a multivariate model describing the relationship between fabric consumption and these three factors was developed. Within the scope of this study, marker efficiency has an impact on the variation in fabric consumption (73%), followed by the garments quantity (21.5%) and the sizes quantity in a marker (3%). The proposed model enables the estimation of fabric consumption based on variations in the quantity of garments, sizes, and marker efficiency, thereby contributing to more efficient fabric utilization in industrial garment manufacturing.

**Keywords:** Marker making, Fabric consumption, Marker efficiency, Garment manufacturing, Modeling.

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## 1. INTRODUCTION

In industrial garment manufacturing, factors related to production cost reduction are reducing fabric expenditure and improving marker efficiency have always been given particular attention.

Researchs have been conducted with the aim of achieving optimal efficiency in garments. Marker efficiency can be improved by combining different sizes

and altering the orientation of pattern panels during shirt marker making [1], computational optimization to identify suitable marker layout solutions for different pattern piece arrangements [2]. Fabric utilization efficiency in the marker-making process can be enhanced through size assortment and appropriate arrangement of men's shirt pattern panels on a given fabric width [3]. The development of cutting plans, including the number of fabric plies and the size ratio in the marker, has a significant influence on marker efficiency [4]. Yeşilpınar et al. [5] proposed a calculation procedure that supports forecasting the amount of fabric required makes it possible to determine fabric consumption with good accuracy in men's shirt manufacturing. Marker efficiency is determined based on the marker-making results, given the fabric width and the marker length [6]. However, the marker-making outcome depends strongly on factors such as pattern shape, garment construction, the number of garments in the marker, fabric width, fabric surface effects, and the cutting table elimination method... [7-9]. Different types of marker-making in industrial garment manufacturing also led to different marker efficiency [10]. Fister et al. [11] proposed a hybrid evolutionary algorithm capable of adaptively generating layouts with high fabric utilization efficiency. Hybrid particle swarm optimization (PSO) algorithms have been used to determine pattern piece arrangements on fabric to improve marker efficiency and reduce material consumption [12]. Yeşilpınar et al. [13] developed software for rapid material requirement estimation for garment orders based on style, measurement, and production conditions. Kalkanç [14] also proposed software for estimating fabric consumption for different bathrobe designs using design and size parameters as input data.

Although many studies have focused on marker optimization, improving fabric utilization efficiency, and developing tools to support fabric requirement calculation, there is still a lack of systematic research

clarifying the relationship between marker-related factors, such as the quantity of sizes in a marker, marker efficiency, and fabric consumption in men’s shirt manufacturing. This is a critical criterion that contributes to shortening the time required for fabric consumption calculation when fabric purchase orders and allocating fabric for production, provides recommendations during cut planning, helps reduce input costs and lower product costs in garment manufacturing.

**2. METHODS**

**2.1. Experimental pattern making, grading, marker making, and fabric consumption calculation**

The study selected a long-sleeve men’s shirt style (Figure 1) as the research object. The garment specifications were used to make patterns and grade into five sizes: S, M, L, XL, and XXL. The patterns of these sizes were then used to create markers on fabric width of 1.5m. This garment is common and widely used in daily life and represents a tradition in many garment manufacturing enterprises.

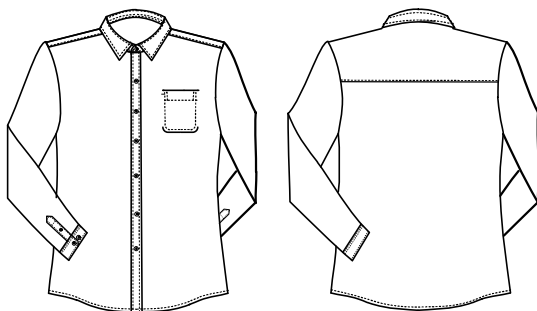


Figure 1. The men’s shirt used in the study

Marker making was carried out with quantities ranging from one to five garments per marker. These garments, in sizes S, M, L, XL, and XXL, were arranged in such a way that the markers did not overlap with one another. Fabric consumption and marker efficiency were determined based on the results obtained from each marker layout.

The study implemented 15 marker types with different numbers of garments and size combinations per marker, without any duplication. In total, 258 markers were generated for this study (Table 1).

Table 1. Quantity of markers

Marker types	SP	SC	Quantity of markers
Marker type 1	1	1	5
Marker type 2	2	1	5
Marker type 3	2	2	10
Marker type 4	3	1	5

Marker type 5	3	2	20
Marker type 6	3	3	10
Marker type 7	4	1	5
Marker type 8	4	2	10
Marker type 9	4	3	30
Marker type 10	4	4	5
Marker type 11	5	1	5
Marker type 12	5	2	67
Marker type 13	5	3	60
Marker type 14	5	4	20
Marker type 15	5	5	1
<b>Total</b>			<b>258</b>

The parameters of the marker used in this study include: the quantity of garments per marker, the quantity of sizes per marker, the marker length, and the marker efficiency. The marker was generated using MakerMaking V6R2 software. The markers were arranged by synchronously all pattern pieces of the garment, appropriate for the fabric.

The fabric consumption per garment for each marker was determined using Equation (1):

$$DM = \text{Marker length} / \text{Quantity of garments per marker (m/garment)} \tag{1}$$

An investigation of the effects of the quantity of garments and sizes on a marker on fabric consumption was carried out using observed variables. These observed variables include the quantity of garments and sizes per marker, the marker efficiency, and the fabric consumption, all of which were determined based on the marker results. The coding of the observed variables is presented in Table 2.

Table 2. Coding of observed variables

No	Observed variables	Code
1	Quantity of garments per marker	SP
2	Quantity of sizes per marker	SC
3	Marker efficiency	HS
4	Fabric consumption per garment	DM

Because the observed variables vary over different ranges and their absolute values differ substantially, plotting them on the same scale results in some variables exhibiting large fluctuations while others exhibiting low variability. This leads to an imbalance among the observed variables in the chart. Therefore, it is necessary to normalize the scale so that the observed variables fluctuate within comparable ranges and the correlations among the variables are improved [15].

The study employed mean normalization to standardize the measurement scales of each observed variable. The normalized value of an observed variable was determined as follows:

$$x^{i} = \frac{x^i - \bar{x}}{x_{max} - x_{min}} \tag{2}$$

here,  $\bar{x}$  is denotes the mean value of the observed variable

$x^i$  is represents the value of the observed variable to be normalized

$x_{max}$  is the maximum value of the observed variable

$x_{min}$  is the minimum value of the observed variable

### 2.2. Determining the impact of the quantity of garments and sizes on fabric consumption

To determine the effects of the quantity of garments per marker and the quantity of sizes included in a marker on fabric consumption, a multivariate linear regression model in matrix form is as follows:

$$DM = X\beta + \epsilon \tag{3}$$

Here, DM is a vector comprising the determined fabric consumption of the marker. X is the matrix of values representing the garment quantities in a marker and the size quantities in a marker,  $\beta$  is the vector of regression coefficients,  $\epsilon$  is the vector of residual [15].

The R software was used to determine the relationship between the quantity of garments on a marker and the quantity of sizes on a marker with respect to fabric consumption. The cbind function was applied to examine the correlations among pairs of input variables, and the summary command was used to report the results, ensuring a high level of reliability and accuracy. To examine the influence of each input variable on the variation of fabric consumption, the LMG method was employed to decompose the model’s coefficient of determination ( $R^2$ ) for each input variable. The functions calc.relimp and boot.relimp in R were used to allocate the model’s  $R^2$  to per input variables [15].

## 3. RESULTS

### 3.1. Marker results and fabric consumption

Table 3. Marker making results

Marker types	SP	SC	Quantity of markers	DM	HS
Marker type 1	1	1	5	1.1054	80.392
Marker type 2	2	1	5	1.0206	87.142
Marker type 3	2	2	10	1.0229	86.95

Marker type 4	3	1	5	1.0117	87.09
Marker type 5	3	2	20	1.0199	87.263
Marker type 6	3	3	10	1.0172	87.433
Marker type 7	4	1	5	1.0119	87.896
Marker type 8	4	2	10	1.0141	87.698
Marker type 9	4	3	30	1.0136	87.737
Marker type 10	4	4	5	1.0148	87.638
Marker type 11	5	1	5	1.0118	87.894
Marker type 12	5	2	67	1.0064	87.802
Marker type 13	5	3	60	1.0128	87.78
Marker type 14	5	4	20	1.0139	87.705
Marker type 15	5	5	1	1.0128	87.81
<b>Total</b>			<b>258</b>		

Standardization of the scale show in Table 4.

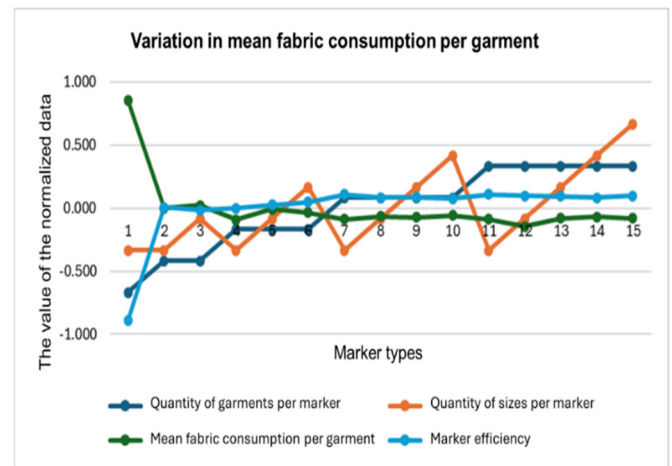


Figure 2. Variation in the mean fabric consumption

Figure 2 illustrates the variation of fabric consumption with changes in garment quantity, the quantity of sizes in a marker, and marker efficiency. Fabric consumption tends to decrease as marker efficiency increases and as the garment quantity per marker increases.

When marker making is performed with a size and a garment per marker, the average fabric consumption is significantly higher than in combine-size with multiple garments arranged in the marker. In such cases, the marker efficiency is low, leading to substantial fabric waste.

### 3.2. The relationship between input variables and fabric consumption

The input observed variables include the garment quantity (SP), the sizes quantity per marker (SC), and the marker efficiency (HS). These variables are correlated as follows:

Table 4. Results of the marker after normalization by average

Marker types	SP is standardized	SC is standardized	Quantity of markers	DM is standardized	HS is standardized
Marker type 1	-0.667	-0.333	5	0.8560	-0.8915
Marker type 2	-0.417	-0.333	5	-0.0005	0.0080
Marker type 3	-0.417	-0.083	10	0.0227	-0.0176
Marker type 4	-0.167	-0.333	5	-0.0904	0.0011
Marker type 5	-0.167	-0.083	20	-0.0076	0.0241
Marker type 6	-0.167	0.167	10	-0.0349	0.0468
Marker type 7	0.083	-0.333	5	-0.0884	0.1085
Marker type 8	0.083	-0.083	10	-0.0662	0.0821
Marker type 9	0.083	0.167	30	-0.0712	0.0873
Marker type 10	0.083	0.417	5	-0.0591	0.0741
Marker type 11	0.333	-0.333	5	-0.0894	0.1082
Marker type 12	0.333	-0.083	67	-0.1440	0.0959
Marker type 13	0.333	0.167	60	-0.0793	0.0930
Marker type 14	0.333	0.417	20	-0.0682	0.0830
Marker type 15	0.333	0.667	1	-0.0793	0.0970
<b>Total</b>			<b>258</b>		

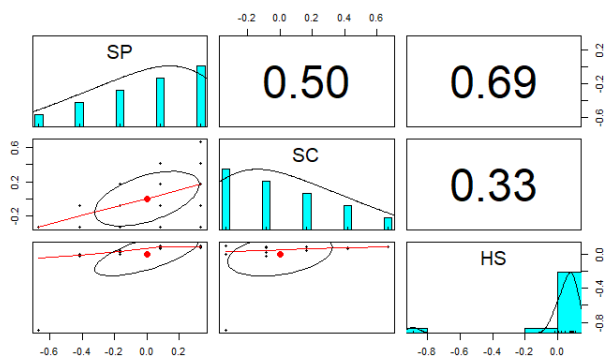


Figure 3. Correlations among the observed variable pairs

When examining the correlations among pairs of input variables with the participation of all three variables, the results shown in the correlation plot indicate that none of the correlation coefficients  $r$  reaches or exceeds 0.95, implying that the input variables are independent of one another. Therefore, it is reasonable to consider and investigate the individual relationships between the output variable and each input variable separately.

The data were processed using R software to examine the linear relationships between the input variables, including the garment quantity (SP), the sizes quantity per marker (SC), and marker efficiency (HS), and the output variable - fabric consumption (DM). The results

indicate that there exists a multivariate relationship between fabric consumption and the input variables, considering the interaction effects among these variables, as follows:

$$DM = 2.121 - 0.541*SP + 0.468*SC - 0.012*HS + 0.001*SP*SC + 0.006*SP*HS - 0.005*SC*HS \quad (4)$$

Model (4) has a coefficient of determination of  $R^2 = 0.9942$ ;  $p\text{-value} = 1.656e-08 < 0.05$ , indicating statistical significance. Therefore, the variations in the input variables SP, SC, and HS explain 99.42% of the variability in fabric consumption (FC) within the scope of this study.

Table 5. Results of the determination of the coefficient of determination ( $R^2$ ) for each variable in model (4)

No	Input variable	Coding	Partitioning of the $R^2$
1	Quantity of garments per marker	SP	0,215
2	Quantity of sizes per marker	SC	0,03
3	Marker efficiency	HS	0,73
4	Interaction effect between SP and SC	SP*SC	0,011
5	Interaction effect between SP and HS	SP*HS	0,007
6	Interaction effect between SC and HS	SC*HS	0,001

The fabric consumption (DM) model depends on three input variables: the garments quantity (SP), the

sizes quantity per marker (SC), and marker efficiency (HS). The model indicates the extent to which all three variables affect the variation in fabric consumption (DM) through the coefficient of determination  $R^2$ . To further clarify the influence of each input variable on fabric consumption, the study employed the `calc.relimp` and `boot.relimp` functions in R to decompose the model's  $R^2$  and attribute it to each input variable. The results are presented in Table 5.

Thus, the variation in the input variable quantity of garments (SP) explains 21.5%, the quantity of sizes per marker (SC) explains 3%, and marker efficiency (HS) explains 73% of the variation in fabric consumption (DM) for shirt within the scope of this study. Other interactions among the input variables explain a negligible proportion ( $\leq 1\%$ ) of the variation in fabric consumption (DM).

These results indicate that marker efficiency (HS) has the greatest influence (73%) on the variation in fabric consumption. Garment quantity (SP) also exerts a significant effect (21.5%) on the variation in fabric consumption within the scope of the study.

Therefore, the multivariate relationship between fabric consumption (DM) and SP, SC, and HS, ignoring the interaction effects among the variables, is as follows:

$$DM = 2,12 - SP + SC - 0,012*HS \quad (5)$$

$$R^2 = 0,986; p\text{-value: } 1.29e-11$$

Model (5) represents the relationship between the input variables: the garments quantity (SP), the sizes quantity per marker (SC), and the marker efficiency (HS) and the fabric consumption (DM). The regression coefficients in the model indicate that fabric consumption (DM) decreases as the garments quantity (SP) increases, while the sizes quantity (SC) and the marker efficiency (HS) are held constant. Specifically, when the garments quantity (SP) increases by one unit, with SC and HS unchanged, the fabric consumption (DM) for the garment decreases by one unit within the scope of the study.

In model (5), after determining the coefficient of determination ( $R^2$ ) for each input variable, the results indicate that SP, SC, and HS explain the variation in fabric consumption (DM) by 21.5%, 3%, and 74.2%, respectively. This model enables the estimation of fabric consumption given the garments quantity per marker (SP), the sizes quantity per marker (SC), and the marker efficiency (HS) within the scope of the study.

The regression model results show that the variation in fabric consumption is strongly explained by the quantity of garments, the quantity of sizes per pattern layout, and the layout efficiency, with high coefficients of determination for both the full model ( $R^2 = 0.9942$ ) and the parsimonious model ( $R^2 = 0.986$ ). Analysis of the  $R^2$  coefficients reveals that layout efficiency has the greatest influence, contributing approximately 73 - 74.2% to the variation, the quantity of garments influences 21.5%, the quantity of sizes per pattern layout influences approximately 3%, and other factors are negligible. Furthermore, the negative coefficients of the quantity of garments and layout efficiency indicate that fabric consumption decreases when more garments are arranged on a pattern layout and when layout efficiency increases. The positive coefficient of the quantity of sizes per pattern indicates only a small direct impact under the study conditions. From a practical perspective, these findings suggest that efforts to reduce shirt fabric consumption in industrial garment manufacturing should focus primarily on improving pattern efficiency and increasing the quantity of garments produced per pattern within the study area.

#### 4. CONCLUSIONS

Fabric consumption per garment depends on marker efficiency, quantity garment, and the sizes quantity in a marker. The multivariate relationship between fabric consumption, marker efficiency, quantity garment, and the sizes quantity in a marker is determined as follows:

$$DM = 2,12 - SP + SC - 0,012*HS ;$$

$$R^2 = 0,986; p\text{-value: } 1.29e-11$$

When the quantity of garments on a marker (SP) increases by one unit, while the quantity of sizes (SC) and the marker efficiency (HS) remain unchanged, the fabric consumption (DM) for the garment decreases by one unit within the scope of the study.

The variation in garment quantity (SP) explains 21.5%, the quantity of sizes per marker (SC) explains 3%, and marker efficiency (HS) explains 74.2% of the variation in fabric consumption (DM) for shirt within the scope of the study. Other interactions among the input variables account for a negligible proportion ( $\leq 1\%$ ) of the variation in fabric consumption (DM).

The proposed multivariate model enables the estimation of fabric consumption when the garment quantity (SP), the sizes quantity on a marker (SC), and the marker efficiency (HS) are known within the scope of the

study. Accordingly, appropriate values of garment quantity and the sizes quantity on a marker can be determined to reduce fabric consumption, thereby contributing to increased profit in industrial garment manufacturing.

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