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Research Paper

Understanding the drivers of marker efficiency for improved fabric utilization in apparel production: an analytical approach

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ABSTRACT

Purpose: This study aims to investigate and identify the critical factors that exert a statistically significant influence on marker efficiency, with the ultimate goal of optimizing fabric utilization and minimizing material wastage in readymade garment (RMG) production.
Methods: A quantitative research approach was utilized, analyzing primary data from 56 woven markers collected across three factories. The analysis employed Pearson Correlation Coefficients for relationship assessment, one-tailed hypothesis testing to confirm directional impact, and Multiple Linear Regression (MLR) followed by an ANOVA Test to assess the collective predictive power of the independent variables.
Results: The MLR model predicting Marker Efficiency was statistically significant Prob (F-statistic = 0.000), explaining 32.72% (R2) of the variance. The Hypothesis Testing confirmed a statistically significant positive impact from Marker Length (r =0.4901), the strongest correlation). Marker Pieces (r = 0.3536). Functional Area (r = 0.3515). In contrast, Marker Width was found to have no statistically significant linear relationship (p = 0.1861). An almost perfect positive correlation was observed between Marker Efficiency and Fabric Utilization (r=0.9985).

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1. INTRODUCTION

The textile industry is one of the most dynamic and fast-expanding sectors, contributing greatly to business growth and economic development. In the face of rising global competition, it presents vast scope for researchers and industry professionals to introduce innovative solutions and technologies that can effectively tackle existing challenges [1]. The readymade garments (RMG) sector is the largest industrial industry in Bangladesh, playing a vital role in the national economy through its significant contribution to GDP, foreign currency earnings, and employment opportunities. Throughout the last five years, RMG consistently accounted for more than 81% of the country's total exports, underscoring its dominant role in the national economy which is described in Table 1. The RMG industry in Bangladesh provides employment to millions of local workers, making it the country's largest single source of jobs. Both foreign exchange earnings and employment opportunities in the RMG sector are growing steadily each year [2].

Table 1. Bangladesh RMG Export Growth in the Last Five Years

Year	Export of RMG in Million USD	Total Export of Bangladesh in Million USD	% Of RMG's to Total Export
2020-21	31456.73	38758.31	81.16
2021-22	42613.15	52082.66	81.82
2022-23	38142.1	46430.71	82.15
2023-24	36151.31	44469.74	81.29
2024-25	39346.97	48283.93	81.49

In most cases, woven garment factories rely heavily on imported fabrics, which leads to a significant outflow of foreign currency to the countries that supply these materials. It is noted that 10–15% unavoidable wastage occurs during cutting and marker making. While larger pattern pieces generally improve marker efficiency and reduce fabric usage, in the case of extremely large sizes (such as 3XL), marker efficiency tends to decline even though fabric consumption rises [3]. Textile waste can generally be divided into two main types: pre-consumer waste and post-consumer waste. Pre-consumer waste refers to the material discarded during the production process, such as fabric edges, cuttings, and leftover scraps generated on factory floors while manufacturing garments. Post-consumer waste, on the other hand, comes from products that have already been used, including discarded clothing, towels, bed linens, carpets, rugs, upholstery, and other household textile items [4]. This study is focused on pre-consumer waste in the RMG industry aims to find out a way to reduce the wastage. Marker efficiency plays a crucial role in determining the amount of fabric wasted during garment production. A marker refers to the layout plan of pattern pieces on the fabric, designed to make the best possible use of the material. Higher marker efficiency means the patterns are arranged more compactly, allowing for maximum fabric utilization and reducing leftover scraps. Conversely, poor marker efficiency results in more gaps between pattern pieces, leading to greater fabric waste and increased production costs. Therefore, optimizing marker efficiency is essential for achieving cost-effective and sustainable apparel manufacturing. If we want to optimize the marker efficiency, we must focus on factors that affect marker efficiency. This study is focused on those factors.

Problem Statement

Approximately 60–70% of global fabric production is consumed in apparel manufacturing, while the rest is utilized in areas such as home furnishings and industrial textiles [5]. Marker making is very important because raw material cost is from 50–60 % of the total cost in apparel industry. It means that if we can save 2 % of the fabric, we can increase 1% profit margin [6].

According to EEA (European environment Agency) worldwide cloth end up wasting is anticipated of between sprout through 25% among 2023 - 24 which is described in Figure 1 but also mid - century. Solely 20% of both the end up wasting would be gathered, and indeed the percentage of what had to be

used in textile and apparel seems to be recirculated in to the new stuff is amazingly drop which is shown in Figure 1 (less than 1% of usable reusable material) [7].

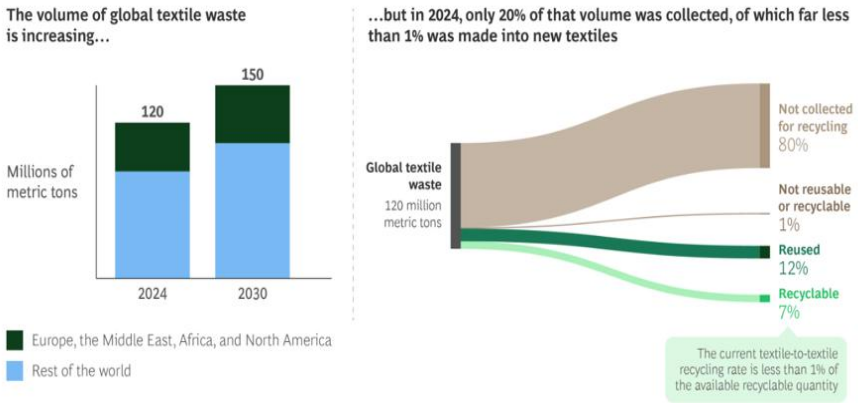

Figure 1. Global Textile Waste and Recycling

Signiface of the Research

The study is significant in understanding the which impact marker efficiency & cost in garment manufacturing. Research Aim is t o identify the factors that impact of marker efficiency & increase fabric utilization by reducing fabric wastage.

2. RELATED WORK

2.1. Marker Efficiency Across Garments Sizes

Marker efficiency and fabric use vary by garment size. From XS to XL efficiency improves slightly, but fabric consumption still increases because the patterns get bigger. For XXL efficiency drops again and fabric use rises sharply, showing that this size needs much more material. The mixed-size marker performs the best overall, reaching an efficiency of 89.05%, making it one of the most effective layout options [8]. We have also found the same higher efficiency on mixed sizes & the lowest efficiency on a single size.

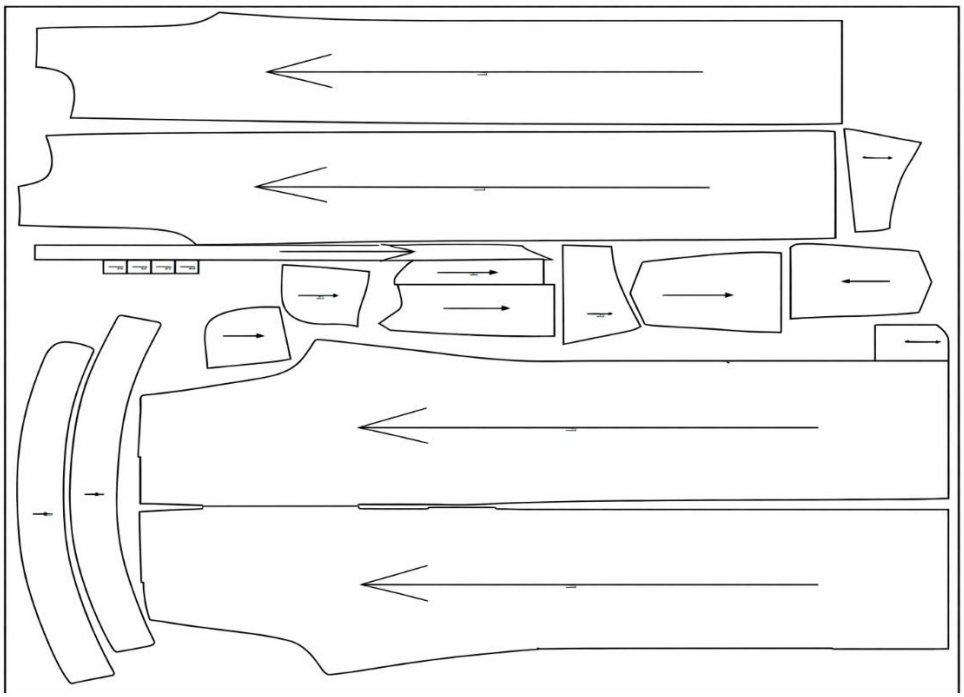

Figure 2. Marker Making for 1 Size Garment

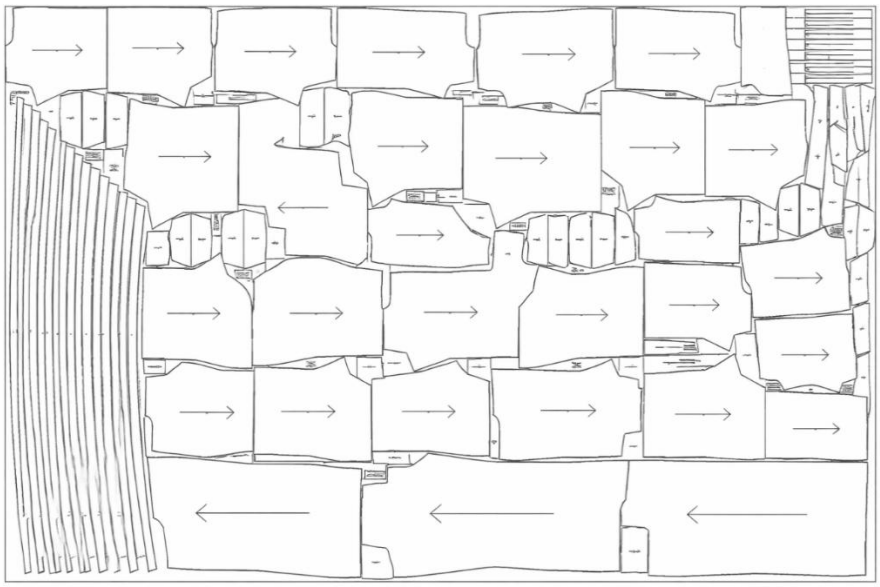

Figure 3. Marker Making for a Combination of 10 Sizes Garment

We also found the significant improvement in marker efficiency from 77.8% which is showed in Figure 2 for a single garment size to 90.7% for a 10-size combination demonstrates a crucial principle in apparel manufacturing fabric utilization which is shiwed in Figure 3. This substantial gain of over 16 percentage points is achieved through advanced pattern nesting, where the varying shapes and contours of multiple sizes interlock more tightly, dramatically minimizing the wasted fabric area in the cutting marker. This optimized layout is vital for large-scale production, directly translating to considerable material cost savings and enhanced sustainability by reducing textile scrap.

2.2. Marker Efficiency Across Fabric Width, Style and Size Combination

Marker efficiency varied significantly depending on fabric width, size-combination and style-combination. Combining multiple sizes in one marker (multi-size marker) led to higher marker efficiencies than single-size markers in many cases. There was also a significant interaction effect between these two variables. Fabric width matters: some widths gave better efficiencies, indicating that choosing optimum usable width is a relevant decision [9].

2.3. Marker Efficiency Across Fabric Shrinkage

A study on Mans shirt found that fabric shrinkage and the ratio of garment sizes included in a marker have a clear impact on how efficiently fabric can be used. As shrinkage percentages increased, marker efficiency improved, meaning the pattern pieces were arranged more effectively on the fabric. The effect on fabric consumption, however, was not linear: when shrinkage was set at 2% in both length and width, the amount of fabric required per shirt increased, but at 3% shrinkage the consumption dropped again. The results also showed that different size combinations produced noticeable variations in both efficiency and consumption, indicating that selecting the right size ratio is important for minimizing fabric waste in shirt production [10]. H. Bilgiç and P. D. Baykal showed that A weak positive correlation between fabric width and marker efficiency (Pearson coefficient 0.367). A weak positive correlation for the total number of patterns vs. efficiency (Pearson coefficient 0.356), and a moderate positive correlation for the number of small patterns vs. efficiency (Pearson coefficient 0.548) [11].

3. METHODOLOGY

3.1. Conceptual Framework

The proposed relationships between several factors (independent variables) and the outcome of Marker Efficiency which is illustrated & described with Figure 4.

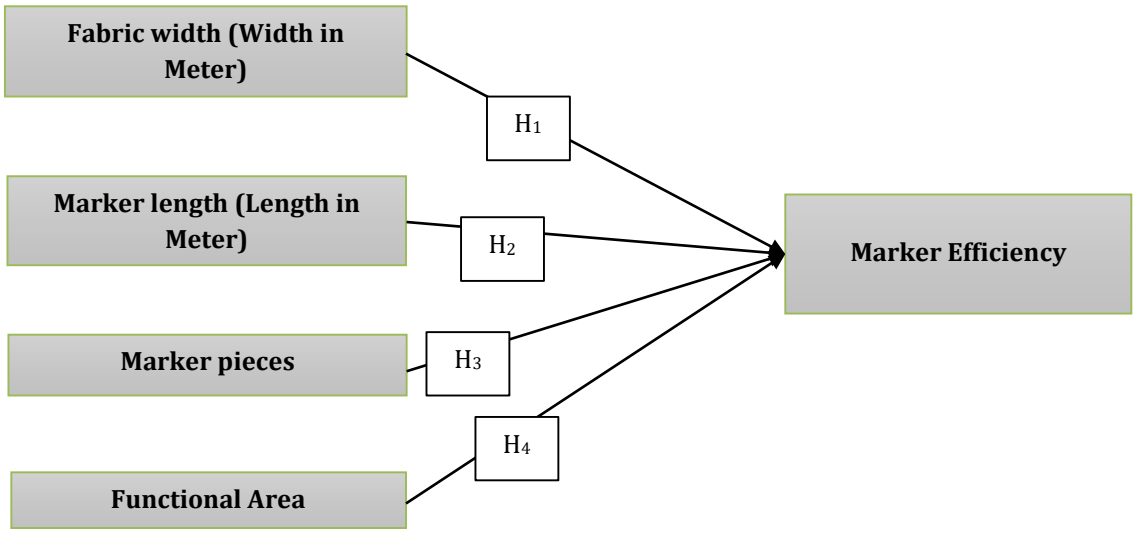

Figure 4. Proposed a Conceptual Framework for the Study

3.2. Hypotheses Development

H1: Alternative Hypothesis: There is a positive impact of Fabric width on Marker efficiency & Fabric Utilization.
H0: Null Hypothesis: There is no impact of fabric width on Marker Efficiency & fabric utilization.
H2: Alternative Hypothesis: There is a positive impact of Marker Length on Marker efficiency & Fabric Utilization.
H0: Null Hypothesis: There is no impact of Marker Length on Marker efficiency & Fabric Utilization.
H3: Alternative Hypothesis: There is a positive impact of Marker pieces on Marker efficiency & Fabric Utilization.
H0: Null Hypothesis: There is no impact of Marker pieces on Marker efficiency & Fabric Utilization.
H4: Alternative Hypothesis: There is a positive impact of functional area on Marker efficiency & Fabric Utilization.
H0: Null Hypothesis: There is no impact of functional area on Marker efficiency & Fabric Utilization.

3.3. Data Collection

Primary data collection has been selected as the data type that the present research study is using in investigating and collecting data from three different factories in Bangladesh related with woven bottom item only. The author collected a combination of 56 markers from different buyers. The makers range from 1 to 30 pieces which is employed in Table 2.

Table 2. Date Collection

	Buyer	Style	Marker Pieces	Functional Area (M^2)	Plies	Length in Meter	Width in Meter	Total Functional Area (M2)	Total Lay Area (M2)	Marker Efficiency	Fabric Utilization %		
1	ARDENE	DP-520-MIDRIPED HEM	12	17.54	101		11.32	1.71	1771.91	1959.48	90.67 %	90.43 %	109.40
2	ARDENE	DP-512-LIGHT	15	25.26	100		15.93	1.71	2526.44	2730.48	92.73 %	92.53 %	119.01

3	EURODESH	02318148 GT-28''-P2-BLUE	10	16.08	72		13.39	1.36	1157.83	1309.68	88.50%	88.41%	111.74
4	EURODESH	02318148 GT-28''-P2-BLUE	10	15.92	60		13.09	1.38	955.27	1087.54	87.91%	87.84%	95.54
5	COSTCO	WHARF-CHARCOAL	22	25.52	202		19.13	1.48	5154.97	5716.23	90.33%	90.18%	379.35
6	COSTCO	WHARF-BLACK STRIP	17	19.70	180		15.60	1.46	3546.90	4099.93	86.61%	86.51%	378.66
7	EURODESH	02318148GT-28''-P-2	10	16.08	68		13.50	1.35	1093.21	1235.82	88.51%	88.46%	105.94
8	EURODESH	02318148GT-30''-BLUE	5	8.03	99		6.45	1.41	794.92	900.39	88.38%	88.29%	74.82
9	EURODESH	02318148GT-30''-BLUE	5	8.09	104		6.71	1.37	841.13	956.53	88.20%	87.94%	84.13
10	EURODESH	02318148GT-30''-BLUE	5	8.02	71		6.71	1.37	569.09	653.02	87.41%	87.15%	61.19
11	SIPLEC	EFCTTBP TDENSLIM STONE	16	11.02	98		7.59	1.63	1080.29	1209.89	89.45%	89.29%	79.72
12	ARDENE	DP 512-F4	10	16.81	48		10.69	1.71	806.81	880.02	91.84%	91.68%	42.70
13	ARDENE	DP-512-F4	10	16.75	52		10.74	1.70	871.20	950.79	91.72%	91.63%	46.77
14	EURODESH	02318148GT-30''	6	9.31	113		7.61	1.38	1052.49	1189.98	88.60%	88.45%	99.32
15	EURODESH	02318148GT-30''	10	16.77	95		13.68	1.37	1593.46	1782.26	89.49%	89.41%	137.65

16	ARDENE	DP-512-F4	7	11.50	73		7.32	1.71	839.25	915.56	92.02%	91.67%	44.51
17	ARDENE	DP-512-F4	12	19.99	92		12.64	1.71	1838.80	1993.21	92.35%	92.25%	90.06
18	COLINS	1019142-32''	12	21.43	116		15.51	1.52	2485.59	2729.91	91.30%	91.05%	160.99
19	EURODESH	02318148GT-30''-BLUE	8	13.05	75		11.01	1.35	978.95	1111.72	88.47%	88.06%	98.62
20	ARDENE	DP-512-F4-MID	12	19.87	57		12.57	1.73	1132.38	1237.82	91.68%	91.48%	61.05
21	COLINS	1019142-32''-MID TROY	13	23.12	127		16.70	1.52	2936.07	3218.88	91.25%	91.21%	186.35
22	COLINS	1019141-32''-MID TROY	14	23.22	125		17.02	1.52	2902.04	3228.42	90.03%	89.89%	215.06
23	EURODESH	02318148GT-30''	12	19.73	89		16.61	1.35	1755.99	1990.27	88.41%	88.23%	174.03
24	COLINS	1048831-32''-DARK PARIS	11	16.43	102		12.51	1.45	1676.21	1847.35	90.83%	90.74%	118.21
25	COLINS	1019135-32''-LIGHT TROY	12	21.07	125		15.29	1.52	2633.24	2900.76	90.90%	90.78%	176.27
26	COLINS	1047569-32''-MID TROY	12	18.87	117		13.72	1.52	2207.43	2435.48	90.70%	90.64%	150.27
27	COLINS	1019135-30''-LIGHT TROY	5	8.44	96		6.16	1.52	810.70	897.40	90.57%	90.34%	57.13
28	COSTCO	WHARF-CHARCOAL	12	13.74	203		10.35	1.48	2789.28	3108.76	89.84%	89.72%	215.93
29	COLINS	1047569-32''-MID TROY	8	12.64	100		9.23	1.52	1264.45	1401.23	90.37%	90.24%	90.13

30	COLINS	1019135-34''-LIGHT TROY	10	18.88	106		13.68	1.52	2001.03	2200.38	91.03%	90.94%	131.35
31	COLINS	1019140-32''-NAVY TROY	7	11.43	115		8.36	1.52	1314.40	1458.48	90.13%	90.12%	94.93
32	COSTCO	WHARF-KHAKI	11	12.81	206		9.96	1.47	2639.70	3021.68	87.43%	87.36%	259.29
33	COLINS	1019135-32''-LIGHT TROY	7	11.83	88		8.66	1.52	1041.18	1156.76	90.35%	90.01%	76.16
34	COLINS	1048741-28''-MID PARIS	5	5.91	95		4.67	1.44	561.91	637.62	88.54%	88.13%	52.72
35	COLINS	1048831-30''-DARK PARIS	5	7.57	87		6.05	1.40	658.62	734.73	90.02%	89.64%	54.48
36	COLINS	1048831-34''-DARK PARIS	9	14.85	78		11.33	1.44	1157.94	1273.69	91.18%	90.91%	80.30
37	COLINS	1019135-32''-LIGHT TROY	12	21.13	130		15.46	1.52	2747.00	3049.36	90.20%	90.08%	199.23
38	COLINS	1019141-34''-MID TROY	9	16.01	100		11.73	1.52	1601.21	1780.93	90.01%	89.91%	118.42
39	H&M	BEPPE LOOSE - JUDE WASH	30	26.77	100		18.08	1.62	2676.54	2928.38	91.40%	91.40%	155.53
40	H&M	Indiana Wide HW - CAROL	15	28.00	100		19.33	1.57	2800.47	3043.99	92.00%	92.00%	154.64
41	H&M	LOOSE BARREL	17	14.52	100		10.19	1.54	1452.50	1565.19	92.80%	92.80%	73.33
42	H&M	BEPPE LOOSE - COAST WASH	30	26.12	106		17.68	1.63	2769.02	3046.23	90.90%	90.90%	170.53

43	H&M	Indiana Wide HW - Rinse HM	15	26.40	84		18.21	1.59	2217.26	2428.54	91.30%	91.30%	133.09
44	H&M	STRAIGHT LOOSE	10	17.55	100		11.89	1.63	1754.60	1932.38	90.80%	90.80%	109.36
45	H&M	MADISON HW SKINNY JEANS	18	24.23	120		19.23	1.44	2907.28	3311.26	87.80%	87.80%	281.49
46	H&M	FLARE 5PKT SOFT - DK	23	20.36	120		16.74	1.36	2442.93	2729.53	89.50%	89.50%	210.91
47	H&M	SKINNY KNIT - LT	30	23.92	136		19.76	1.35	3253.33	3635.01	89.50%	89.50%	282.19
48	H&M	SKINNY KNIT - MID	30	23.79	128		19.43	1.36	3045.21	3379.81	90.10%	90.10%	246.23
49	H&M	SKINNY KNIT - DK	30	24.15	136		19.46	1.37	3284.56	3629.35	90.50%	90.50%	251.38
50	H&M	FLARE 5PKT SOFT - MID	23	20.07	120		16.64	1.35	2408.10	2687.61	89.60%	89.60%	207.63
51	H&M	FRANK RELAXED - JOCKE	16	14.33	128		10.62	1.51	1834.10	2053.86	89.30%	89.30%	145.41
52	H&M	FRANK RELAXED - RINSE	18	14.28	107		10.62	1.51	1528.04	1716.90	89.00%	89.00%	124.96
53	H&M	FRANK RELAXED - DANIL	20	18.07	120		12.57	1.61	2168.23	2433.48	89.10%	89.10%	164.45
54	H&M	AMICA LLIGHT	1	1.91	12		1.32	1.71	22.945112	27.12	84.60%	84.60%	2.44
55	H&M	AMICA LLIGHT	1	1.80	12		1.31	1.71	21.648785	26.96	80.30%	80.30%	3.10
56	H&M	AMICA LLIGHT	1	1.91	12		1.32	1.71	22.960663	27.24	84.30%	84.30%	2.49

4. RESULTS AND DISCUSSION

Descriptive Statistics often referred to as exploratory statistics in specific contexts provide an ideal framework for organizing and distilling numerical data into meaningful summaries [12]. We use decriptive statistics for collected data to simplify, organize, and summarize the data set is shown in Table 3.

Table 3. Descriptive Analysis of Recorded Data

	Marker Efficiency %	Total Functional Area (m2)	Length in Meter	Width in Meter	Fabric Utilization %	Total Wastage (m)
count	56	56	56	56	56	56
mean	0.897	1792.84	12.197	1.513	0.895	134.831
std	0.022	1020.91	4.841	0.124	0.022	83.307
min	0.803	21.649	1.31	1.346	0.803	2.436
25%	0.885	1025.62	9.09	1.394	0.884	78.832
50%	0.901	1715.41	12.541	1.518	0.9	118.313
75%	0.909	2634.86	16.097	1.614	0.909	174.589
max	0.928	5154.97	19.761	1.727	0.928	379.347

4.1. Correlation Analysis

The Pearson Correlation Coefficient is a statistical metric used to quantify the magnitude and orientation of the straight-line relationship that exists between two distinct variables. The resulting value ranges from -1 to +1, where the extremes indicate a perfect linear association (positive or negative), and a value of -1 signifies the absence of any linear link. From the analysis based on the real data set, the grab transportation system has a strong positive correlation interms of the two variables of interest studied [13]. The Pearson correlation method involves constructing a linear regression line that best represents the relationship between two variables. The resulting coefficient (r), serves as a metric for how closely the individual observations cluster around this central trend line [14]. In the current study, we have found below Pearson Correlation Coefficient (r) value by using SPSS which we described in Table 4.

Table 4. Correlation Analysis of 56 Data Set

Variable	Pearson Correlation Coefficient (r)
Length in meter	0.4901
Marker Pieces	0.3536
Total Functional Area (m2)	0.3515
Width in meter	0.1216

Length in meter (0.4901) exhibits the strongest positive correlation. This suggests that as the marker length increases, the marker efficiency tends to increase. This is a moderate relationship, meaning length is a significant factor, but not the only determinant.

Marker Pieces (0.3536) and Total functional area (0.3515) both show a moderate positive correlation. This indicates a slight tendency for higher efficiency as the number of marker pieces and the total functional area increase.

Width in meter (0.1216) shows a very weak positive correlation. This suggests that marker width, within the scope of this data, has a negligible linear impact on the marker efficiency.

The correlation analysis between marker efficiency and Fabric Utilization reveals an extremely strong, positive linear relationship which is shown in Table 5.

Table 5. Correlation between Marker Efficiency and Fabric Utilization

Statistic	Value
Pearson Correlation Coefficient (r)	0.9985

The Pearson correlation coefficient of 0.9985 is extremely close to +1. This means almost a perfect positive linear correlation between marker efficiency and fabric utilization. The positive value means that as the marker efficiency increases, the fabric utilization % also increases by an almost identical proportion, and vice versa.

4.2. Hypothesis Test

In Carver's view, the primary function of a statistical hypothesis test is to generate a p-value a specific calculation used to decide whether a set of results is statistically significant or merely a product of random variation [15]. Based on the data from the sheet and using a one-tailed Pearson correlation test with a significance level of alpha (α) = 0.05, here is the hypothesis test conclusion for each factor's impact on Marker Efficiency % is shown in Table 6.

Table 6. Hypothesis Test

Hypothesis ID	Independent Variable	Pearson's r	P-Value (One-Tailed)	H0 Conclusion (α=0.05)	Interpretation
H1	Fabric Width (Width in meter)	0.1216	0.1861	Fail to Reject H0	The positive correlation is not statistically significant. We cannot conclude that increasing fabric width has a positive impact.
H2	Marker Length (Length in meter)	0.4901	0.0001	Reject H0	There is a significant positive impact of Marker Length on Marker Efficiency.
H3	Marker Pieces	0.3536	0.0038	Reject H0	There is a significant positive impact of the number of Marker Pieces on Marker Efficiency.
H4	Functional Area	0.3515	0.004	Reject H0	There is a significant positive impact of Functional Area on Marker Efficiency.

H1 (Fabric Width): The null hypothesis (Ho: There is no impact) is not rejected. The observed positive relationship is too weak to be considered statistically significant.
H2 (Marker Length/Length in Meter): The null hypothesis is rejected. There is strong evidence to support the alternative hypothesis that Marker Length has a positive impact on Marker Efficiency.
H3 (Marker Pieces): The null hypothesis is rejected. There is strong evidence to support the alternative hypothesis that Marker Pieces has a positive impact on Marker Efficiency.
H4 (Functional Area): The null hypothesis is rejected. There is strong evidence to support the alternative hypothesis that Functional Area has a positive impact on Marker Efficiency.

4.3. Model Fit Measures

The model uses Length in meter, Width in meter, Total Functional Area, and Marker Pieces to predict Marker Efficiency which is shown in

Table 7.

Table 7. Model Fit Measures

Measure	Value	Interpretation
R-squared	0.3272	32.72% of the variability in marker efficiency % is explained by the four independent variables.
Adjusted R-squared	0.2745	After adjusting for the number of predictors in the model (4), the explained variance is 27.45%.

4.4. ANOVA Test

Commonly used in factorial research, ANOVA is essentially a version of the General Linear Model. In these types of studies, conditions are grouped by specific factors, and each factor is further divided into multiple levels or categories [16]. The ANOVA Test (using the F-statistic) assesses the overall significance of the regression model. Null Hypothesis (H0): All regression coefficients are zero (i.e., the model has no predictive power). Alternative Hypothesis (HA): At least one regression coefficient is not zero (i.e., the model has predictive power) which is shown in Table 8.

Table 8. ANOVA Test

Statistic	Value
F-statistic	6.2018
Prob (F-statistic)	0.0004
Degrees of Freedom (Regression)	4
Degrees of Freedom (Residual)	51

Since the Prob (F-statistic) (0.0004) which is shown in Table 8 is much less than the standard significance level of alpha = 0.05, we reject the Null Hypothesis (H0). The regression model is statistically significant, meaning the four independent variables collectively provide a reliable prediction of Marker Efficiency.

The findings of this study establish the vital role of marker efficiency in optimizing fabric utilization [17]. A positive correlation exists, indicating that enhanced fabric utilization directly leads to a substantial reduction in material wastage [18]. Consequently, this research focused on identifying and analyzing the specific factors that exert a significant impact on marker efficiency. The current analysis indicates a statistically significant positive relationship between marker length (Length in meter) and marker efficiency. This finding is supported by a Pearson Correlation Coefficient (r) of 0.4901, which confirms the tendency for marker efficiency to increase as the marker length increases. Both the number of Marker Pieces of (0.3536) and the Total Functional Area of (0.3515) exhibited a moderate positive correlation with marker efficiency. This statistically consistent finding suggests a tendency for marker efficiency to rise proportionally with an increase in either the count of marker pieces or the overall functional area [19]. No significant linear relationship was observed between marker width and marker efficiency as the most commonly used width of fabric was used in the collected marker.

5. CONCLUSION

The findings of this research emphasize that marker efficiency plays a crucial role in maximizing fabric usage and minimizing waste within garment production. The analysis shows that marker length has a strong and statistically significant positive effect on marker efficiency, while the number of marker pieces and the total functional area also contribute moderately to improving efficiency levels [20]. These results suggest that thoughtful adjustments to marker layout and dimensions can lead to better material utilization. On the other hand, marker width shows no meaningful linear relationship with efficiency, which may be due to the uniform fabric widths used in the samples. In summary, the study highlights the

importance of deliberate marker planning as a practical approach to boosting operational efficiency and reducing fabric waste in the apparel industry.

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Based on the results of this study, it is recommended that apparel manufacturers place greater emphasis on optimizing marker length, marker piece count, and functional area when planning marker layouts, as these factors directly contribute to improved marker efficiency and reduced fabric waste. Production teams should consider adopting advanced marker-making software and layout techniques that enable more effective arrangement of pattern pieces, particularly for markers with higher complexity or larger piece counts. Since marker width does not significantly influence efficiency due to standardized fabric widths, efforts should instead focus on refining layout strategies rather than altering fabric width selections. Regular monitoring of marker performance, combined with training for cutting room personnel on best practices for marker planning, can help sustain higher efficiency levels. By integrating these improvements into routine operations, garment manufacturers can enhance material utilization, reduce overall production costs, and strengthen their competitiveness in the industry. Finally, width wise booking with esurient, fabric diameter adjustment, both vertical & horizontal both side cuttable fabric can increase marker efficiency significantly

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Author Contributions Statement

Name of Author	C	M	So	Va	Fo	I	R	D	O	E	Vi	Su	P	Fu
Md. Taslim	✓	✓	✓	✓		✓		✓	✓	✓	✓			
Mohammad Tanvirul Hasnat	✓	✓				✓	✓	✓			✓	✓	✓	

C : **C**onceptualization
M : **M**ethodology
So : **So**ftware
Va : **Va**lidation
Fo : **Fo**rmal analysis
I : **I**nvestigation
R : **R**esources
D : **D**ata Curation
O : Writing - **O**riginal Draft
E : Writing - Review & **E**diting
Vi : **Vi**sualization
Su : **Su**pervision
P : **P**roject administration
Fu : **Fu**nding acquisition

Conflict of Interest Statement

The authors declare that they have no financial conflicts of interest related to this research. However, corresponding author and co-author are the employee of the organization from where the sample data has been congregated.

Informed Consent

The protection of privacy is a legal right that must not be breached without individual informed consent. In cases where the identification of personal information is necessary for scientific reasons, authors should obtain full documentation of informed consent, including written permission from the patient prior to inclusion in the study. Incorporate the following (or a similar) statement: We have obtained informed consent from all individuals included in this study.

Ethical Approval

There was no involvement of using people or animals, & the research followed all national rules and institutional policies, and it was approved by affiliated organizations of the authors.

Data Availability

Data supporting the conclusions of this article are available from the authors upon reasonable request. The materials used in the experiments, including reagents and software tools, can be found in the supplementary files attached to this publication. For any request for data please contact Md. Taslim (Corresponding author) by email: taslim7@ymail.com or Mohammad Tanvirul Hasnat (Corresponding author) by email: tanvirulhasnat397@gmail.com

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