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Failure Mode and effects analysis of selected weaving defects in viscose/linen fabrics using the fuzzy TOPSIS method

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Abstract: Production-related weaving defects are a significant issue in the textile industry, directly impacting the material quality of products. These defects typically arise from mechanical, material, or operator-related problems during production processes, negatively affecting the durability, aesthetics, and functionality of the product. This study aims to identify the causes of weaving defects encountered in viscose/linen woven fabrics and determine the importance of these defects from the customer's perspective. Therefore, Failure Mode and Effects Analysis (FMEA) was conducted using the Fuzzy TOPSIS optimization technique to analyze selected weaving defects frequently encountered in viscose/linen woven fabric within a textile company. The analyzed woven fabric has a warp yarn count of Ne 16/1 Viscose/Linen and a weft yarn count of Ne 16/1 Viscose/Linen/Elastane. For the produced material, selected weaving defects were classified using linguistic variables by decision-making experts during the final fabric quality control process. This approach allowed the experts to prioritize weaving defects of greater importance to the customer by employing the Fuzzy TOPSIS optimization method. The study concluded that "Draft Defect" ranked first as the most critical defect, requiring immediate resolution.

Keywords: Viscose/Linen materials; Weaving Production Defects; Fuzzy TOPSIS; FMEA; Optimization.

1. Introduction

The rapid advancements in textile technology have accelerated the transformation of the industry from a labor-intensive structure to a capital-intensive one. Modern textile machines, with high production capacities and skilled personnel, are replacing traditional equipment. The widespread adoption of automation has increased both production efficiency and product quality. Quality control systems, along with efficient and hygienic distribution methods, not only enhance product quality but also facilitate the sale of more affordable raw materials and improve customer distribution processes. The quality of raw materials directly impacts the characteristics of the final product.

Faults encountered in woven fabrics, which are widely used in the textile sector, have been systematically classified. Based on this classification, faults are generally divided into four categories: yarn faults, faults in the weft direction, faults in the warp direction, and finishing faults [1]. Production faults occurring during material manufacturing are directly related to the properties and strength of the weft and warp yarns, as well as the efficiency of the weaving machine (e.g., number of stops and yarn breakage rates) [2] Ensuring customer satisfaction requires identifying, eliminating, or minimizing faults during the production process. Failure Mode and Effects Analysis (FMEA) is recognized as an effective method in quality improvement processes [3]. Preventing faults before they occur is crucial for the efficient use of resources. As one of the fundamental tools of total quality management, FMEA is an effective method for identifying and prioritizing potential faults. It aims to eliminate errors and enhance quality levels by developing and implementing preventive measures for each type of fault [4].

In order to detect the errors encountered, analyze their risks and prioritize them, the Fuzzy TOPSIS method and Failure Mode and Effects Analysis (FMEA) can be used together as a new method in various fields. While the Fuzzy TOPSIS method allows errors to be evaluated through linguistic variables, preventive measures can be taken to reduce errors with severity, probability and detectability criteria [3,4]. TOPSIS (Technique for

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Order Preference by Similarity to Ideal Solution) method is a method used in multi-criteria decision-making processes developed by Hwang and Yoon (1981). This method aims to determine the alternative closest to the positive ideal solution and farthest from the negative ideal solution by considering the criteria weights. Due to the inadequacy of numerical expressions in measuring human judgments, the TOPSIS method has been extended with fuzzy numbers [5]. The fuzzy TOPSIS method is one of the multi-criteria decision-making techniques. This approach, first developed by Chen and Hwang (1992), utilized trapezoidal fuzzy numbers [6]. In later studies, methods using different types of fuzzy numbers such as triangular fuzzy numbers have also been developed. These developments have facilitated the modeling of uncertainty and subjective evaluations of the method [7]. When the areas of use of the fuzzy TOPSIS method are examined, it is seen that it is used in a wide range of sectors and application areas. It has been stated that it is widely used in main subjects such as supplier selection [8], performance evaluation processes [9], risk analysis and management [10] and personnel selection [11]. The fuzzy TOPSIS method allows the alternatives to be ranked in a way that they are closest to the positive ideal solution and farthest from the negative ideal solution. The positive ideal solution can be defined as the situation where the benefit criteria are optimized to the maximum level and the harm criteria are minimized. In contrast, the negative ideal solution refers to the situation where the harm criteria are maximized and the benefit criteria are minimized [8]. It basically solves the problem based on the TOPSIS method. Unlike this method, subjective evaluations about the criteria are evaluated using linguistic variables and the most appropriate alternative is determined. The fuzzy TOPSIS method provides more realistic solutions to problems by using verbal expressions instead of numerical values, allowing human judgments to be reflected more accurately in the model. In the method, decision criteria and their weights are evaluated with verbal expressions such as "low," "very low," "high." The fuzzy TOPSIS method first begins with defining the alternatives to be evaluated, the decision criteria by which these alternatives will be measured, and the decision-making group. Decision makers evaluate the alternatives and criteria with the determined verbal expressions. Especially in cases where there is uncertainty and differences or variability arise in the evaluations of decision makers, the fuzzy TOPSIS method allows group decisions to be made more consistently and accurately. In addition, the fact that the decision criteria used in the evaluation of alternatives have different weights is one of the basic features of the method [12].

Tooranloo and Ayatollah (2016), Failure Mode and Effects Analysis (FMEA) is a powerful method in the field of risk management and is widely used to increase process reliability in the production and service sectors. In order to better manage uncertainties, the intuitive fuzzy approach-based FMEA model was used to evaluate error types for internet banking service quality [13]. Yılmaz and Şenol (2017) added the cost factor to the traditional risk analysis and determined the factor weights with Fuzzy AHP and prioritized the hazards and precautions with Fuzzy TOPSIS. In the application made in the metal industry, it was determined that the cost factor was more effective in the magnitude of the hazard, the most important risk sources were determined as the work environment, machine and employee-related hazards, and the priority precautions were determined as drill, training and machine renewal [14].

İşçi et al. (2024) applied Fuzzy AHP and Fuzzy TOPSIS methods in a company that produces parking equipment in order to evaluate risks in a more mathematical and objective way. In the sample including physical, chemical, ergonomic and psychological risks, the analysis results using probability and severity variables were compared and the hazards were ranked according to their importance [10]. Nadaban et al. (2016) conducted a compilation study describing the development of fuzzy TOPSIS methods [15]. Ünlükal and Yücel (2021) evaluated the risks in the production process of a company in the aviation sector with the FMEA and fuzzy TOPSIS approach; risk factors were weighted and prioritized by experts [16].

Günaydın (2022) used fuzzy multi-criteria decision-making techniques in a company operating in the fasteners sector to eliminate the disadvantages of the classical FMEA method. Potential errors were determined by the brainstorming method and divided into two groups as product and process-based, then weighted with the DEMATEL method and analyzed with fuzzy VIKOR, TOPSIS, MOORA and Gray Relational Analysis (GIA) methods. A model combining these methods was proposed to increase the consistency of the results obtained from different methods and to minimize errors [17].

In this study, it is aimed to determine the reasons for weaving defects encountered in viscose/linen blended woven fabrics as material and the importance level of these defects for the customer. Therefore, Failure Mode and Effects Analysis (FMEA) was performed using the fuzzy TOPSIS optimization technique for selected weaving defects frequently encountered in viscose/linen blended woven fabrics in a textile company.

2. Materials and Methods

2.1. Materials

The material used in this study is a woven fabric with a plain weave structure, featuring warp yarn of Ne 16/1 Viscose/Linen and weft yarn of Ne 16/1 Viscose/Linen/Elastane. After being woven on a weaving machine, the finished fabric undergoes quality control by an operator on fabric inspection tables. During this process, various defects, such as color and pattern irregularities, are identified on the fabric. Defects detected on the fabric flowing over the inspection panel are recorded, and those that can be rectified are reprocessed for correction. Defects that cannot be remedied are categorized into different quality grades based on their severity. In this study, common weaving defects originating from the weaving department were selected for analysis. These include frequent-sparse density variations, weft skip, warp streak, lattice defect, and draft defect. ▶Table 1 presents the selected defects along with their definitions.

Table 1. Selected weaving defects, their definitions

Selected weaving defects	
Frequent-sparse density variations	Frequent refers to the placement of one or more weft yarns at intervals closer than the standard density. Sparse, on the other hand, refers to the placement of one or more weft yarns at intervals wider than the standard density.
Weft skip	It refers to the absence of one or more weft yarns in the weaving during the weaving process.
Warp streak	It is the difference in color tones that occurs because of the change in warp threads.
Lattice defect	It is a situation where the warp threads are not included in the weave and remain free, passing over the weft threads.
Draft defect	It is a fault that results from one or more of the warp threads being passed through the heddles incorrectly, causing the weave pattern to be disrupted throughout the fabric.

2.2. Methods

In this study, selected production-related defects of the produced material were detected, and these defects were analyzed using the Fuzzy TOPSIS method according to severity, probability and detectability criteria. The criteria were compared by three experts, their importance weights were determined and then the proximity coefficients for the alternatives were calculated using the Fuzzy TOPSIS method and a ranking was made. In the solution of the multi-criteria decision-making problem, the Fuzzy TOPSIS method developed by Chen (2000) was used and the triangular linguistic expressions in the evaluation of the alternatives and criteria are presented in ▶Table 2 [3, 4, 18].

The process steps of the fuzzy TOPSIS method and the equations used are shown in ▶Table 3 (3, 19, 20).

3. Results and Discussions

The Fuzzy TOPSIS method has been applied step by step according to ▶Table 3, and the results are presented sequentially in the following tables (Tables 4-10). Initially, verbal expressions for the criteria and alternatives were converted into numerical values, and a fuzzy decision matrix was constructed. The normalized fuzzy decision matrix was then calculated, followed by the weighted normalized fuzzy decision matrix. Positive and negative ideal solutions were determined, and the closeness coefficients were obtained. Finally, the alternatives were ranked from highest to lowest based on their CC_i values, assigning rankings from 1 to 5.

Step 1: Assignment of judgment values to verbal expressions for the criteria and calculation of their importance weights.

In ▶Table 4, the importance of weights for severity, probability and detectability criteria were calculated using formula 1. The importance weight for the severity criteria was found to be (0.03; 0.17; 0.37), the importance weight for the probability criteria was found to be (0.3; 0.5; 0.7) and the importance weight for the detectability criteria was found to be (0.57; 0.77; 0.93).

Step 2: Assignment of judgment values to verbal expressions for the alternatives and calculation of their importance weights.

In ▶Table 5, the importance weights were calculated using Formula 2 by assigning judgment values to the verbal expressions of the alternatives (frequent-sparse density variations, weft skip, warp streak, lattice defect, draft defect). Accordingly, as an example, it can be observed that the importance weight of the judgment value for Decision Maker 1 (DM1) under the severity criterion for the frequent-sparse density variation alternative is (1; 3; 5).

Step 3: Creating the fuzzy decision matrix

In ▶Table 6, the fuzzy decision matrix for the alternatives and criteria was created by applying Formula 3. As an example, in ▶Table 6, the fuzzy decision matrix value for the weft skip alternative under the severity criterion was calculated as (0.33; 1.67; 3.67).

Step 4: Creation of normalized fuzzy decision matrix

The normalized fuzzy decision matrix for the alternatives and criteria was created using Formula 4 and is presented in ▶Table 7. As an example, when examining ▶Table 7, it can be observed that the normalized fuzzy decision matrix value calculated for the lattice defect alternative under the probability criterion is (0.13; 0.47; 0.87).

Step 5: Weighted normalized fuzzy decision matrix

The weighted normalized fuzzy decision matrix for the alternatives and criteria was created using Formula 5 and is presented in ▶Table 8. As an example, when examining ▶Table 8, it can be observed that the weighted normalized fuzzy decision matrix value calculated for the draft defect alternative under the severity criterion is (0.0143; 0.1190; 0.3667).

Step 6: Calculation of fuzzy positive ideal solutions (A^+) and negative ideal solutions (A^-)

In ▶Table 9, the fuzzy positive ideal solutions (A^+) and negative ideal solutions (A^-) were calculated using For-

Table 2. Verbal expressions and their triangular fuzzy number equivalents in the evaluation of alternatives and criteria [18]

For alternatives		For criteria	
Verbal Expression	Triangular Fuzzy Number	Verbal Expression	Triangular Fuzzy Number
Very Bad (VB)	(0; 0; 1)	Very Weak (VW)	(0; 0; 0,1)
Bad (B)	(0; 1; 3)	Weak (W)	(0; 0.1; 0.3)
Medium Bad (MB)	(1; 3; 5)	Medium Weak (MW)	(0.1; 0.3; 0.5)
Medium (M)	(3; 5; 7)	Medium (M)	(0.3; 0.5; 0.7)
Medium Good (MG)	(5; 7; 9)	Medium Strong (MS)	(0.5; 0.7; 0.9)
Good (G)	(7; 9; 10)	Strong (S)	(0.7; 0,9; 1.0)
Very Good (VG)	(9; 10; 10)	Very Strong (VS)	(0.9; 1.0; 1.0)

Table 3. Process steps and equations of the fuzzy TOPSIS method

Steps	Formulas	Formula no
Step 1: Verbal expressions for the criteria are evaluated using triangular fuzzy numbers by decision-makers (DM1, DM2, DM3), and the importance weights of the criteria are calculated. $\widetilde{w_{ij}}$: the weight of relation to jth criterion K: number of decision-makers	$\widetilde{W}_{ij}=\frac{1}{K}\left[\widetilde{w}_{ij}^{1}+\widetilde{w}_{ij}^{2}+\ \dots\dots\dots+\widetilde{w}_{ij}^{K}\right]$	(1)
Step 2: The alternatives are evaluated by the decision-makers using verbal expressions, which are represented by triangular fuzzy numbers. The importance weights of the alternatives are then calculated. $\widetilde{X_{ij}}$: the weight of relation to ith alternative	$\tilde{X}_{ij}=\frac{1}{K}\left[\tilde{x}_{ij}^{1}+\tilde{x}_{ij}^{2}+\ \dots\dots\dots+\tilde{x}_{ij}^{K}\right]$	(2)
Step 3: For the Fuzzy TOPSIS method, the decision problem is formulated in the format of a fuzzy decision matrix. $\widetilde{D}$: Fuzzy decision matrix $\widetilde{x_{ij}}$: The criterion value of the alternative according to the decision criterion. $\widetilde{w_{ij}}$: Fuzzy weight matrix	$\widetilde{D}=\begin{bmatrix}\tilde{x}_{11} & \tilde{x}_{12} & \dots & \tilde{x}_{1n}\\ \tilde{x}_{21} & \tilde{x}_{22} & \dots & \tilde{x}_{2n}\\ . & . & \dots & .\\ . & . & \dots & .\\ \tilde{x}_{m1} & \tilde{x}_{m2} & \dots & \tilde{x}_{mn}\end{bmatrix}\ \widetilde{W}=\left[\widetilde{w}_1,\widetilde{w}_2,\dots\dots,\widetilde{w}_n\right]$	(3)
Step 4: The normalized fuzzy decision matrix is calculated considering the benefit criterion. $\widetilde{r_{ij}}$: Normalized fuzzy decision matrix c_j: In the case where the decision criterion is a benefit criterion, it is obtained by dividing each element in the column by the element with the largest third component within that column.	$\tilde{r}_{ij}=\left(\frac{a_{ij}}{c_j^*},\frac{b_{ij}}{c_j^*},\frac{c_{ij}}{c_j^*}\right),\ j\in B$ $c_j^+=\max c_{ij},\ \forall_j\in B$	(4)
Step 5: The weighted normalized fuzzy decision matrix is calculated. $\widetilde{v_{ij}}$: Weighted normalized fuzzy decision matrix	$\tilde{v}_{ij}=\tilde{r}_{ij}.\tilde{w}_j$	(5)
Step 6: The fuzzy positive ideal solutions (A^+) and negative ideal solutions (A^-) are determined by identifying the maximum and minimum values for each criterion. A^+: Fuzzy positive ideal solutions A^-: Fuzzy negative ideal solutions	$A^+=\{v_1^+,v_2^+,\dots\dots\dots..v_n^+\}$ $A^-=\{v_1^-,v_2^-,\dots\dots\dots v_n^-\},$ $\tilde{v}_j^*=max_i\{v_{ij3}\}$ ve $\tilde{v}_j^-=min_i\{v_{ij1}\}$	(6)
Step 7: In this step, the closeness of the alternatives to the ideal solutions (d_i* and d_i^-) is calculated using the Vertex method. d_i* and d_i^-: The closeness of the alternatives to the ideal solutions	$d_v(\tilde{a},\tilde{b})=\sqrt{\frac{1}{3}[(a_1-b_1)^2+(a_2-b_2)^2+(a_3-b_3)^2]}$ $d_i^+=\sum_{j=1}^{n}d\left(\tilde{v}_{ij},\tilde{v}_j^+\right)$ $d_i^-=\sum_{j=1}^{n}d\left(\tilde{v}_{ij},\tilde{v}_j^-\right)$	(7) (8) (9)
Step 8: The CCi values are calculated using the closeness coefficients of the alternatives to the ideal solution. The alternatives are then ranked from highest to lowest, and the most suitable alternative is determined. CCi: Closeness coefficient for alternatives	$CC_i=\frac{d_i^-}{d_i^*+d_i^-}$	(10)

Table 4. Evaluation of criteria using linguistic variables by decision-makers and calculation of importance weights

Criteria	DM1	DM2	DM3	Weights
Severity	(0; 0.1; 0.3)	(0.1; 0.3; 0.5)	(0; 0.1; 0.3)	(0.03; 0.17;0.37)
Probability	0.3; 0.5; 0.7	(0.5; 0.7; 0.9)	(0.1; 0.3; 0.5)	(0.3; 0.5; 0.7)
Detectability	(0.7; 0.9; 1.0)	(0.5; 0.7; 0.9)	(0.5; 0.7; 0.9)	(0.57; 0.77; 0.93)

Table 5. Evaluation of alternatives using linguistic variables by decision-makers and calculation of importance weights.

Alternatives	Frequent-sparse density variations			Weft skip			Warp streak			Lattice defect			Draft defect		
Criteria	DM1	DM2	DM3	DM1	DM2	DM3	DM1	DM2	DM3	DM1	DM2	DM3	DM1	DM2	DM3
Severity	1 3 5	3 5 7	0 0 1	3 5 7	0 1 3	0 1 3	1 3 5	0 1 3	0 0 1	3 5 7	0 1 3	3 5 7	5 7 9	3 5 7	1 3 5
Probability	3 5 7	1 3 5	0 1 3	3 5 7	1 3 5	0 0 1	0 1 3	1 3 5	0 1 3	0 1 3	1 3 5	1 3 5	0 0 1	0 1 3	1 3 5
Detectability	3 5 7	5 7 9	0 1 3	3 5 7	3 5 7	5 7 9	1 3 5	0 1 3	1 3 5	3 5 7	1 3 5	0 1 3	7 9 10	5 7 9	3 5 7

Table 6. The fuzzy decision matrix

Alternatives	Criteria								
	Severity			Probability			Detectability		
Frequent-sparse density variations	1.33	2.67	4.33	1.33	3.00	5.00	2.67	4.00	6.33
Weft skip	0.33	1.67	3.67	1.33	2.67	4.33	3.67	5.67	7.67
Warp streak	0.33	1.33	3.00	0.33	1.67	3.67	0.67	2.33	4.33
Lattice defect	2.00	3.67	5.67	0.67	2.33	4.33	1.33	3.00	5.00
Draft defect	3.00	5.00	7.00	0.33	1.33	3.00	5.00	7.00	8.67

Table 7. Normalized fuzzy decision matrix

Alternatives	Criteria								
	Severity			Probability			Detectability		
Frequent-sparse density variations	0.19	0.38	0.62	0.27	0.60	1.00	0.31	0.46	0.73
Weft skip	0.05	0.24	0.52	0.27	0.53	0.87	0.42	0.65	0.88
Warp streak	0.05	0.19	0.43	0.07	0.33	0.73	0.08	0.27	0.50
Lattice defect	0.29	0.52	0.81	0.13	0.47	0.87	0.15	0.35	0.58
Draft defect	0.43	0.71	1.00	0.07	0.27	0.60	0.58	0.81	1.00

Table 8. Weighted normalized fuzzy decision matrix

Alternatives	Criteria								
	Severity			Probability			Detectability		
Frequent-sparse density variations	0.0063	0.0635	0.2270	0.0800	0.3000	0.7000	0.1744	0.3538	0.6821
Weft skip	0.0016	0.0397	0.1921	0.0800	0.2667	0.6067	0.2397	0.5013	0.8256
Warp streak	0.0016	0.0317	0.1571	0.0200	0.1667	0.5133	0.0436	0.2064	0.4667
Lattice defect	0.0095	0.0873	0.2968	0.0400	0.2333	0.6067	0.0872	0.2654	0.5385
Draft defect	0.0143	0.1190	0.3667	0.0200	0.1333	0.4200	0.3269	0.6192	0.9333

Table 9. Calculation of fuzzy positive and negative ideal solutions (A^+, A^-)

Alternatives	Criteria								
	Severity			Probability			Detectability		
Frequent-sparse density variations	0.0063	0.0635	0.2270	0.0800	0.3000	0.7000	0.1744	0.3538	0.6821
Weft skip	0.0016	0.0397	0.1921	0.0800	0.2667	0.6067	0.2397	0.5013	0.8256
Warp streak	0.0016	0.0317	0.1571	0.0200	0.1667	0.5133	0.0436	0.2064	0.4667
Lattice defect	0.0095	0.0873	0.2968	0.0400	0.2333	0.6067	0.0872	0.2654	0.5385
Draft defect	0.0143	0.1190	0.3667	0.0200	0.1333	0.4200	0.3269	0.6192	0.9333
A+		0.3667			0.7000			0.9333	
A-		0.0016			0.0200			0.0436	

Table 10. Calculation of closeness coefficients (d_i and d_i^-) and ranking of alternatives (CC_i)

Alternatives	Severity		Probability		Detectability		Σ di		CCi	Ranking
	di*	di-	di*	di-	di*	di-	Σ di*	Σ di-		
Frequent-sparse density variations	0.283581102	0.134979757	0.425989	0.425989	0.5701	0.4167	1.28	0.98	0.43	3
Weft skip	0.300381885	0.112149344	0.440034	0.369063	0.4759	0.5353	1.22	1.02	0.46	2
Warp streak	0.310566687	0.091482384	0.510454	0.297147	0.7160	0.2617	1.54	0.65	0.30	5
Lattice defect	0.264873348	0.177553241	0.469783	0.360596	0.6628	0.3141	1.40	0.85	0.38	4
Draft defect	0.248654733	0.221540906	0.536007	0.240031	0.3943	0.6333	1.18	1.09	0.48	1

mula 6. The highest and lowest values among the calculated results for the severity, probability, and detectability criteria are highlighted. Accordingly, the highest and lowest values are as follows: for the severity criterion, (0.3667 and 0.0016); for the probability criterion, (0.7000 and 0.0200); and for the detectability criterion, (0.9333 and 0.0436).

Step 7 and Step 8: Calculation of closeness coefficients (d_i and d_i^-) and ranking of alternatives (CC_i)

▶**Table 10** was created by calculating the closeness coefficients (CC_i) and ranking values of the alternatives and criteria using Formulas 7–10. When the alternatives are ranked based on the obtained CCi values, it is observed that the draft defect alternative has the highest CC_i value.

In the last step, according to ▶**Table 10** of the severity, probability and detectability criteria with the fuzzy TOPSIS approach, it is seen that the drafting error ranked 1st has the highest CC_i value. Accordingly, it is seen that it is the most important production error that needs to be solved first by ranking 1st. By analyzing the error type and effects with the fuzzy TOPSIS method, it is possible to evaluate each error independently, and the priority order in solving the error types is determined by including the opinions of the decision makers in the process.

4. Conclusions

In this study, production-related selected defects were identified during the quality control process conducted on a woven fabric with a plain weave structure, featuring warp yarn of Ne 16/1 Viscose/Linen and weft yarn of Ne 16/1 Viscose/Linen/Elastane. The importance weights of the defects were determined based on the criteria of severity, probability, and detectability through evaluations by three experts. The defects were analyzed using the Fuzzy TOPSIS method within the framework of Failure Mode and Effects Analysis (FMEA). According to Step 8 outlined in ▶**Table 3** of the Method section, the CC_i values were calculated and ranked from highest to lowest. It was determined that "draft defect" with the highest closeness coefficient (CC_i) and were identified as the most critical production defect. Consequently, it was concluded that this defect should be prioritized for corrective actions. The other most important faults that need to be addressed are, in order of priority, "weft skip", "frequent-sparse density variations", "lattice defect", and "warp streak". Additionally, this study presents an innovative approach for the textile industry by prioritizing defects that cannot be corrected after weaving in viscose/linen blended fabrics, calculating their importance weights, and determining the top-ranking alternative using the fuzzy TOPSIS method.

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Research ethics

Not applicable.

Author contributions

The author solely conducted all stages of this research.

Competing interests

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