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Application of the MABAC Method for the Selection of Denim Fabrics with Sustainability Framework

Esra Akgül*1
*1 Erciyes Üniversitesi Mühendislik Fakültesi Endüstriyel Tasarım Mühendisliği, KAYSERİ

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Abstract: Denim fabrics are known as popular fashion products preferred by all age groups on a global scale. With the growing environmental awareness among consumers, denim fabric manufacturers have increasingly adopted environmentally sustainable production practices. This study aims to evaluate eight different denim fabric samples based on their tearing strength and tensile strength properties using the Multi-Attributive Border Approximation Area Comparison (MABAC) method. The denim fabrics analysed in this study are composed of 100% cotton, 100% organic cotton, 70% cotton with 30% pre-consumer recycled cotton, and 80% cotton with 20% post-consumer recycled cotton. Each denim fabric undergoes laser treatment at varying levels, after which they are subjected to either rinse or 30-minute stone washing processes. The MABAC method ranks the fabrics based on the selected performance criteria. According to the ranking results obtained by the MABAC method, the denim fabric sample produced from 100% organic cotton, processed with 32 dpi laser resolution, 150 pixel duration and then rinsed, was determined as the denim fabric with the best tearing and tensile strength performance.

Sürdürülebilirlik Çerçevesinde Denim Kumaş Seçimi için MABAC Yönteminin Uygulanması

Anahtar Kelimeler

Denim
MABAC yöntemi
Lazer yıkama
Sürdürülebilirlik

Öz: Denim kumaşlar, küresel ölçekte her yaş grubu tarafından tercih edilen popüler moda ürünleri olarak bilinmektedir. Tüketiciler arasında artan çevresel farkındalıkla birlikte, denim kumaş üreticileri de giderek daha çevre dostu üretim uygulamalarını benimsemektedir. Bu çalışmada, Çok Nitelikli Sınır Yaklaşım Alanı Karşılaştırılması (Multi-Attributive Border Approximation Area Comparison/MABAC) yöntemi kullanılarak sekiz farklı denim kumaş örneğinin yırtılma mukavemeti ve kopma mukavemeti özelliklerine göre değerlendirilmesi amaçlanmıştır. Çalışmada analiz edilen denim kumaşlar, %100 pamuk, %100 organik pamuk, %70 pamuk ile %30 üretim öncesi geri dönüştürülmüş pamuk ve %80 pamuk ile %20 kullanım sonrası geri dönüştürülmüş pamuk karışımlarından oluşmaktadır. Kumaşlar, her biri farklı seviyelerde lazer işlemine tabi tutulmuş ve ardından 30 dakikalık taş yıkama veya durulama işlemlerinden geçirilmiştir. Seçilen performans kriterlerine göre kumaşların sıralaması MABAC yöntemi ile yapılmıştır. MABAC yöntemi ile elde edilen sıralama sonuçlarına göre, %100 organik pamuktan üretilen, 32 dpi lazer yoğunluğu, 150 piksel süre ile işlenen ve ardından durulanan denim kumaş numunesi, yırtılma ve kopma mukavemeti performansı en iyi olan denim kumaş olarak tespit edilmiştir.

1. Introduction

Denim fabrics are a significant textile product with a prominent role in the fashion industry. They are typically produced from 100% cotton fabrics. The popularity of this product can be attributed to its ability to meet to a diverse range of age groups and to be styled in a multitude of ways through the use of different industrial washes. However, the production of denim is not environmentally friendly due to the considerable amount of water consumed and the waste generated during the manufacturing process. Alternative production methods have been developed to address these challenges, reduce environmental impact, and support the circular economy.
These methods can be addressed through the utilisation of more environmentally friendly raw materials in the production of denim fabric or through the implementation of more sustainable finishing processes throughout the production cycle.

In recent years, cotton fibres have been mechanically recycled and reintroduced into the production cycle. The utilisation of mechanically recycled fibres in denim fabric production, as pre-consumer and post-consumer recycled cotton fibres, serves to diminish the necessity for raw materials, conserve natural resources and reduce waste. Moreover, the life cycle analysis of denim production has revealed that the employment of recycled cotton results in a diminished environmental impact in comparison to conventional cotton [1]. In order to enhance the quality attributes of recycled fibres, they are blended with cotton at varying blend ratios and employed in denim production [2]. At the same time, laser technologies are used to enhance the visual appeal of denim fabric. This environmentally friendly washing technique is more sustainable than traditional physical and chemical processes. It offers several advantages, including reduced pollution, water and chemical consumption, ease of processing and design flexibility [3]. The selection of environmentally friendly denim fabric according to the quality requirements of the consumer can be considered as a complex problem that requires multiple criteria to be considered together.

Multi-Criteria Decision Making (MCDM) methods allow the decision maker to make the best choice among complex and close results in situations where there are more than one alternative. In recent years, multi-criteria decision-making methodologies have been employed with increasing frequency in the context of textile-related problems. These methods facilitate the resolution of complex problems in a manner that is both practical and beneficial to the decision-maker. A variety of MCDM methodologies have been successfully employed in the existing literature for the selection of textile products. Acar et al. [2] used the MCDM methods as the logarithm methodology of additive weights (LMAW) and the double normalization-based multiple aggregation (DNMA) methods for determining the optimal fabric structures of denim fabrics containing recycled cotton. Majumdar et al. [4] used the technique for order preference by similarity to ideal solutions (TOPSIS) and the analytic hierarchy process (AHP) for selection of the most appropriate navel rotor spinning machine. Yıldırım et al. [5] investigated the selection of dual-core yarn production parameters for denim fabric with Multi-Objective Optimization on the Basis of Ratio Analysis (MOORA) method. Wanassi et al. [6] investigated the relationship between the cost and quality of yarn from recycled fibre using the analytical hierarchy process (AHP).

The multi-criteria boundary approach area comparison (MABAC) method is a kind of MCDM methodology. Agarwal et al. employed a combination of the decision-making trial and evaluation laboratory (DEMATEL) and the MABAC methods for the assessment of jute fibre batches based on a range of properties, including strength, defects, root content, colour, fineness, and bulk density [7]. Torkayesh et al. [8] analysed the concepts of sustainable development and circular economy with the MABAC method. Dokovıc and Doljanica [9] used AHP and MABAC method for selection investment projects. Xu et al. [10] proposed a selection model with MABAC method for green supplier evaluation. The aim of this study is to make sustainable textile production and raw material selection with a multi-criteria decision-making approach. For this purpose, the multi-criteria boundary approach area comparison (MABAC) method was used to evaluate eight different denim fabrics in terms of tearing and tensile strength properties.

The initial section of this study presents a comprehensive literature review. The subsequent section elucidates the characteristics of the denim fabrics utilized, the outcomes of the some quality testing, and the specifics of the MABAC methodology. The third section of the study showcases the outcomes of the methodology's implementation. Ultimately, the findings are subjected to a critical analysis, and in the conclusion, the study offers final evaluations and recommendations for jean manufacturers.

2. Material and Method

2.1. Material

For the production of jeans, the most appropriate selection will be made from denim fabrics with different contents. The eight denim fabrics are composed of a variety of cotton blends, including 100% cotton, 100% organic cotton, 70% cotton+30% pre-consumer recycled cotton, and 80% cotton + 20% post-consumer recycled cotton for this study. In this study, two laser process parameters were used as pixel time and resolution. The pixel time/tpx is expressed in μs and controls the time required to position the laser beam in a given area. Another laser process parameter, resolution, which regulates the intensity of laser beam positioning within a given area, is expressed in dots per inch and is usually represented in dpi [13]. The all fabrics were subjected to laser treatment at varying pixel time (tpx/μs) and resolution (dpi), and after some were subjected to 30'stone washing or rinse processes. In general, denim fabrics are cleaned with water, softened and discoloured slightly by rinse washing, softer and more discoloured by using pumice stones by stone washing. Tearing and tensile strength tests were conducted on the denim fabrics in both the warp and weft directions. The properties of the denim fabrics are presented in Table 1.

Table 1. The alternative denim fabric properties

Samples	Fibre type	Washing type	Pixel time (μs)	Density of intense (dpi)
D1	100 % cotton	30' stone	100	32
D2	100 % cotton	rinse	125	34
D3	100 % organic cotton	30' stone	125	36
D4	100 % organic cotton	Rinse	150	32
D5	%80 cotton, %20 postconsumer recycle cotton	30' stone	150	34
D6	%80 cotton, %20 postconsumer recycle cotton	rinse	100	36
D7	%70 cotton, %30 pre-consumer recycle cotton	30' stone	150	34
D8	%70 cotton, %30 pre-consumer recycle cotton	rinse	100	32

2.2. The multi-attributive border approximation area comparison (MABAC) method

The Multi-attributive border approximation area comparison (MABAC) method is firstly introduced by Pamučar and Ćirović in 2015 for solving the real-world problems [11]. The computational simplicity and robustness of the method ensure that the increase in the number of criteria and alternatives in the problem does not result in a complex solution structure. The MABAC method considers the strengths and weaknesses of each alternative compared to the other alternatives for the solution and performs the process according to each criterion evaluated. It provides consistent results in the case of criteria with different measurement units of alternatives. The performance of each criterion function is divided into two separate areas, the upper approximation area consisting of ideal alternatives and the lower approximation area containing non-ideal alternatives. The MABAC method consists of the following process steps [12]:

Step 1. *To create decision matrix*

The decision matrix was created for the purpose of facilitating the evaluation of alternatives.

$$A = \begin{bmatrix} x_{11} & \cdots & x_{1i} \\ \vdots & \ddots & \vdots \\ x_{j1} & \cdots & x_{ji} \end{bmatrix}$$

the i represents number of alternatives to be decided and, j represents the number of evaluation criteria. Where $x_{\ ji}$ is the element of the decision matrix for i_{th} ith alternative in j_{th} attribute.

Step 2. *To normalize of the decision matrix*

In order to eliminate the potential for inconsistency in the data set, all results are normalised by reduction to the range [0, 1]. Once the positive and negative attributes of the decision matrix have been identified, the following Equations (1) and (2) are employed to normalise the data, respectively.

$$x_{ij}^{*} = \frac{x_{ij}-x_i^-}{x_i^+-x_i^-};\ \ i = 1, \dots m\ \ j = 1, \dots .n \qquad (1)$$

$$x_{ij}^{*} = \frac{x_{ij}-x_i^+}{x_i^+-x_i^-};\ \ i = 1, \dots m\ \ j = 1, \dots .n \qquad (2)$$

where $x_{\ ji}$ indicates the normalized value of the decision matrix of i_{th} alternative in j_{th} attribute. In addition, x_i^+ *and* x_i^- denotes as $x_i^+ = \max\,(x_1, x_2 \dots \dots x_m)$ and $x_i^- = \min(x_1, x_2 \dots \dots x_m)$.

Step 3. To calculate of the weighted normalized matrix

The normalised values of the decision matrix and the weights of the relevant attributes, represented by $[w_1, w_2, \dots . w_n]$, are calculated using the following equation 3:

$$\acute{x}_{ij} = w_j + x^*_{ij} w_j; \qquad i = 1, \dots \dots, m \quad j = 1, \dots \dots . n \tag{3}$$

Step 4. To determinate of the border approximation area matrix (G)

The boundary approximation area matrix is obtained by using Equation 4.

$$G = [g_1, g_2, \dots g_n]$$

$$g_j = \left(\prod_{i=1}^{m} \acute{x}_{ij}\right)^{1/m}; \quad j = 1, \dots . . n \tag{4}$$

Step 5. To calculate of the distance of the alternative from the border approximation area for the matrix elements

The distance of the alternatives to the boundary approximation area is determined based on the quantities of the boundary approximation area matrix and the weighted normalised values of each attribute, as illustrated in Eq. 5

$$q_{ij} = \acute{x}_{ij} - g_j; \qquad j = 1, \dots \dots n \tag{5}$$

$$q_{ij} = \begin{bmatrix} \acute{x}_{11} - g_1 & \cdots & \acute{x}_{1n} - g_n \\ \acute{x}_{12} - g_1 & \ddots & \acute{x}_{2n} - g_n \\ \acute{x}_{mn} - g_1 & \cdots & \acute{x}_{mn} - g_n \end{bmatrix}$$

The position of an alternative D_i is always within the upper approximation domain G^+, whereas the ideal alternative is situated within the D^+domain. The position of the anti-ideal alternative D^-, is consistently located within the lower approximation domain G^-. The position of the alternative within the approximation field is contingent upon the following condition;

$$D_i \in \begin{cases} G^+ \; if \; q_{ij} > 0 \\ G \; if \; q_{ij} = 0 \\ G^- \; if \; q_{ij} < 0 \end{cases}$$

For an alternative D_i to be identified as the best in the cluster, it must have the maximum number of criteria belonging to the upper approximation domain G^+.

Step 6. To calculate of the Total Distances from the Border Approximate Area

The total distance of the alternatives to the approximate boundary zone is calculated using the following Equation 6:

$$S_i = \sum_{j=1}^{n} q_{ij}; \qquad i = 1, \dots . . m \tag{6}$$

Step 7. Ranking of Alternatives

The total distances of the alternatives from the borderline approximation area, determined in the previous stage, are ranked in descending order to finalize the prioritization of alternatives. The alternative with the highest S_i value is identified as the most favourable option.

3. Results

The study used the MABAC method to make the right choices in denim fabric production process and raw material preference for environmental sustainability. The results of the performance tests of denim fabrics, as presented in Table 2, were used to create the decision matrix, which represents the initial step of the MABAC method.

Table 2. The tearing and tensile strength results of denim fabric samples

Samples	Tearing strength		Tensile strength	
	Warp direction	Weft direction	Warp direction	Weft direction
D1	3830	3513.33	56.333	48.666
D2	4883.33	4283.33	65.333	54.333
D3	3450	4256.66	47.666	49.666
D4	4586.66	5346.66	60.666	59.666
D5	3183.33	4360	44.666	49.666
D6	5043.33	5353.33	66.00	58.666
D7	2866.66	2456.66	35.33	25.66
D8	3930	2640	41.33	31.33
max	*5043.33*	*5353.33*	*65.333*	*59.666*
min	*2866.66*	*2456.66*	*35.33*	*25.66*

Subsequently, in order to optimise the data, normalisation was performed using Eq. 1 in the second step. The maximum performance criteria was determined by the experts working in the denim sector, and since high tear and tearing strength during use is also desired, the normalisation process was conducted according to the maximum equation. The normalised data are presented in Table 3.

Tablo 3. The normalized matrix of denim fabric performance

	Tearing strength		Tensile strength	
Samples	Warp direction	Weft direction	Warp direction	Weft direction
	Max	Max	Max	Max
D1	0.442575	0.364788	0.86217	0.815561
D2	0.926493	0.63061	1	0.910581
D3	0.267997	0.621403	0.729439	0.832328
D4	0.790198	0.997697	0.928527	1
D5	0.145484	0.657079	0.683496	0.832328
D6	1	1	0.00047	0.983233
D7	0	0	0	0
D8	0.488517	0.063293	9.19E-05	9.51E-05

The weights assigned to the performance criteria of denim fabrics were derived from the collective expert opinion of individuals with a minimum of five years' experience working in the denim sector. The assigned weights for each criterion are presented in Table 4. Subsequently, the weighted normalised data were calculated using Eq. 3, and the results are displayed in Table 5.

Table 4. The weights of denim performance characteristics

	Tearing strength		Tensile strength	
	Warp direction (max)	Weft direction (max)	Warp direction (max)	Weft direction (max)
w	0.27	0.23	0.27	0.23

Table 5. The weighted normalized matrix

Samples	Tearing strength		Tensile strength	
	Warp direction (max)	Weft direction (max)	Warp direction (max)	Weft direction (max)
D1	0.389495	0.313901	0.502786	0.417579
D2	0.520153	0.37504	0.54	0.439434
D3	0.342359	0.372923	0.466949	0.421435
D4	0.483353	0.45947	0.520702	0.46

D5	0.309281	0.381128	0.454544	0.421435
D6	0.54	0.46	0.270127	0.456144
D7	0.27	0.23	0.27	0.23
D8	0.4019	0.244557	0.270025	0.230022

In the MABAC method, the boundary proximity area is calculated using Eq. 4. In other words, each element of the weighted normalised decision matrix is multiplied, and the resulting gi values are calculated by taking the 1/8th power. These values are presented in Table 6. Subsequently, by subtracting each of the criteria of the weighted normalised decision matrix from the boundary proximity area, the matrix of distances to the boundary proximity area is obtained. This matrix is given in Table 7.

Table 6. The border approximation area matrix

	Tearing strength		**Tensile strength**	
	Warp direction (max)	**Weft direction (max)**	**Warp direction (max)**	**Weft direction (max)**
g_i	0.396233	0.344616	0.39486	0.37137

Table 7. The distance matrix for the MABAC method

	Tearing strength		**Tensile strength**			
Samples	**Warp direction (max)**	**Weft direction (max)**	**Warp direction (max)**	**Weft direction (max)**	s_i	**Rank**
D1	-0.00674	-0.03071	0.107926	0.046209	0.116682	**4**
D2	0.12392	0.030424	0.14514	0.068064	0.367548	**2**
D3	-0.05387	0.028307	0.072088	0.050066	0.096587	**5**
D4	0.08712	0.114854	0.125842	0.08863	0.416447	**1**
D5	-0.08695	0.036512	0.059684	0.050066	0.059309	**6**
D6	0.143767	0.115384	-0.12473	0.084774	0.219191	**3**
D7	-0.12623	-0.11462	-0.12486	-0.14137	-0.50708	**8**
D8	0.005666	-0.10006	-0.12484	-0.14135	-0.36058	**7**

In order to ascertain the distance matrix values for each boundary proximity area, the row values of each alternative must be summed. The quality performance test results for denim fabrics are then considered and ranked in relation to the resulting si value. The results of the study are shown in Table 8.

Table 8. Ranking of the considered denim fabrics

Samples	**Fibre type**	**Washing type**	**Pixel time (µs)**	**Density of intense (dpi)**	s_i	**RANK**
D1	100 % cotton	30' stone	100	32	0.416447	4
D2	100 % cotton	rinse	125	34	0.367548	2
D3	100 % organic cotton	30' stone	125	36	0.219191	6
D4	**100 % organic cotton**	**Rinse**	**150**	**32**	**0.116682**	**1**
D5	%80 cotton, %20 postconsumer recycle cotton	30' stone	150	34	0.096587	3
D6	%80 cotton, %20 postconsumer recycle cotton	rinse	100	36	0.059309	5
D7	%70 cotton, %30 pre-consumer recycle cotton	30' stone	150	34	-0.36058	8
D8	%70 cotton, %30 pre-consumer recycle cotton	rinse	100	32	-0.50708	7

4. Discussion and Conclusion

In this paper presents the application of the MABAC method in the evaluation of laser-treated denim fabrics produced with different contents in the context of jean production. In the study, the tearing and tensile strength properties of denim fabrics in both the weft and warp directions were considered. In order to ensure greater objectivity in the decision-making process, the weights of four denim fabric performance characteristics were determined through the application of expert opinion. The MABAC method was employed to assign a ranking to the eight denim fabrics in accordance with their quality performance values. The results show that the D4 sample can be selected among the other denim fabric options with the most favourable tear and tensile strength properties. The D4 fabric is composed of 100% organic cotton and has undergone laser processing at a resolution density of 32 dpi, a pixel time of 150 μ, and subsequent rinse washing. The fabric designated D7, among the alternatives, is positioned at the last of the ranking. The fabric designated D7 is composed of 70% cotton and 30% pre-consumer recycled cotton fibre, and was subjected to laser processing at a resolution density of 34 dpi for 150μ pixel time, followed by 30-minute stone washing. The findings indicated that stone washing resulted in a more pronounced reduction in strength compared to rinse washing. Additionally, it was observed that pre-consumer fibre waste resulted in a reduction in denim strength. The application of high laser intensity to denim fabrics was observed to be effective in terms of strength values. When considered together with the previous observations of denim experts, it can be concluded that this ranking can be effectively used for a more rigorous scientific evaluation of denim fabrics to be selected. In future studies, the MABAC method can be applied in textile studies by combining it with various experimental designs or clustering algorithms in the presence of multiple options and evaluation criteria.

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Reference

[1] Yüksel, Y. E., & Korkmaz, Y. 2023. Eco-friendly denim fabric design and life cycle analysis. Kahram. Sütçü İmam Üni. Müh. Bil. Derg, 26, 117-125.

[2] Acar, E., Tama Birkocak, D., Özdağoğlu, A., Ünal, Z., Özdemir, G., & Josè Abreu, M. 2024. Prioritizing Sustainable Denim Fabric through Integrated Decision-Making Framework. *Materials*, *17*(13), 3291.

[3] Ortiz-Morales, M., Poterasu, M., Acosta-Ortiz, S. E., Compean, I., & Hernandez-Alvarado, M. R. 2003. A comparison between characteristics of various laser-based denim fading processes. Optics and Lasers in Engineering, 39(1), 15-24.

[4] Majumdar, A., Kaplan, S., & Göktepe, Ö. 2010. Navel selection for rotor spinning denim fabrics using a multi-criteria decision-making process. The Journal of The Textile Institute, 101(4), 304-309

[5] Yildirim, N., Akgül, E., & Türksoy, H. G. 2022. Selection of dual-core yarn production parameters for denim fabric by using MULTIMOORA method. The Journal of The Textile Institute, 113(6), 1039-1047

[6] Wanassi, B., Azzouz, B., & Hassen, M. B. 2018. Sustainable denim yarn: quality-cost analysis and analytic hierarchy process (AHP) optimization. AATCC Journal of Research, 5(4), 17-24.

[7] Agarwal, S., Chakraborty, S., & Chakraborty, S. 2020. A DEMATEL-MABAC-based approach for grading and evaluation of jute fibers. Research Journal of Textile and Apparel, 24(4), 341-355.

[8] Torkayesh, A. E., Tirkolaee, E. B., Bahrini, A., Pamucar, D., & Khakbaz, A. 2023. A systematic literature review of MABAC method and applications: An outlook for sustainability and circularity. Informatica, 34(2), 415-448.

[9] Doković, L., & Doljanica, D. 2023. Application of AHP and MABAC methods in the framework of multi-criteria decision-making in the selection of investment projects. Journal of process management and new technologies, 11(3-4), 105-114.

[10] Xu, X. G., Shi, H., Zhang, L. J., & Liu, H. C. 2019. Green supplier evaluation and selection with an extended MABAC method under the heterogeneous information environment. Sustainability, 11(23), 6616.

[11] Pamučar, D., & Ćirović, G. 2015. The selection of transport and handling resources in logistics centers using Multi-Attributive Border Approximation area Comparison (MABAC). Expert systems with applications, 42(6), 3016-3028.

[12] Alinezhad, A., Khalili, I., 2019. International Series in Operations Research & Management Science. Springer International Publishing, 277s.

[13] Kan, C. W. 2014. Colour fading effect of indigo-dyed cotton denim fabric by CO 2 laser. Fibers and Polymers, 15, 426-429.