Pertanika J. Sci. & Technol. 32 (6): 2679 - 2698 (2024)

PERTANIKA JOURNALS

SCIENCE & TECHNOLOGY

Journal homepage: http://www.pertanika.upm.edu.my/

A Framework for Prioritising the Performance Criteria of Natural Fibre Composite Materials: Incorporation of CRITIC-TOPSIS Method

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ABSTRACT

Selecting an appropriate Multi-Criteria Decision-Making (MCDM) method to provide a solution to assist design engineers in prioritising the right criteria in the early design process is essential. Part of the aim of this study is to establish an integration CRITIC-TOPIS for selecting the most efficient framework to choose performance criteria, namely density, tensile strength, Young's modulus, cellulose, and elongation at break for natural fibre material intended for cap toe shoes like abaca, bamboo, coir, jute, kenaf, sisal. Hence, a new framework was proposed and tested based on integrating Criteria Importance Through Inter Criteria Correlation (CRITIC)-Technique Order Preference by Similarity to Ideal Solution (TOPSIS). Therefore, this proposed framework consists of two phases: the first involves determining the weights of attributes using the CRITIC method, and the second consists of making material criteria decisions using the TOPSIS method. Meanwhile, to achieve this objective, numerical validation was obtained using data from selected past case studies, which were then replicated to validate the output of the proposed framework. According to the validation conducted using CRITIC-TOPSIS, the results show a significant level of similarity, with the rankings being consistent. Therefore, the proposed methodology may provide imprecise and ambiguous information for prioritising the performance criteria of

ARTICLE INFO

Article history:
Received: 18 December 2023
Accepted: 10 July 2024
Published: 25 October 2024

DOI: https://doi.org/10.47836/pjst.32.6.14

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ISSN: 0128-7680
e-ISSN: 2231-8526

natural fibre composite materials. Moreover, design engineers can utilise this framework in the composite industry to create the best possible evaluation model for composite material criteria selection for various applications.

Keywords: CRITIC method, framework, MCDM, natural fibre, TOPSIS method

INTRODUCTION

Decision Making (DM) is selecting an option by recognising a decision, collecting data, and evaluating several alternatives. One of the first in-depth studies on the concept of DM was published by the Psychological Bulletin, where the paper elaborates on the risk and psychology behind DM (Edwards, 1954). In order to make the best possible choice when dealing with numerous options, conflicts, or decision criteria, the Multi Criteria Decision Making (MCDM) methods are typically utilised (Jigeesh et al., 2018; Mastura et al., 2015; Mufazzal & Muzakkir, 2018). They are typically used to evaluate issues relating to the environment, society, technology, and material choice.

Past studies have reported on developing MCDM tools for various applications to determine the best alternative by considering more than one criterion in the selection process. An innovative study was undertaken to select a logistics service provider (Jharkharia & Shankar, 2007), where the selection procedure employed the Analytic Network Process (ANP). On the other hand, Han et al. (2020) examined road selection based on the Analytical Hierarchy Process (AHP) that involves a point of interest, model of roads, constituent density partitions and global connectivity of the selected network. Stević et al. (2019) studied sustainability in a supply chain where the need was to select a sustainable supplier using Simple Additive Weighting (SAW). Recently, Chan and Ch'ng (2023) analysed the risk factors of suicidal ideation among university students in Malaysia using the Technique Order Preference by Similarity to Ideal Solution (TOPSIS). Therefore, the MCDM method is well known for helping people solve complex real-life issues. It can compare choices based on different decision-making criteria and find the best acceptable criteria (Emovon & Oghenenyerovwho, 2020; Zavadskas et al., 2016). MCDM has gained popularity since it can assist decision-makers in evaluating all significant factors and making decisions based on priority (Kabir et al., 2014; Mufazzal & Muzakkir, 2018; Sattar & Ghazwan, 2023). When numerous aspects are concluded as a good design, an expert decision-maker may occasionally search for either technical or economic elements that can be compromised to prioritise decision-making. A DM can utilise MCDM to assign relative value to criteria to measure them.

Numerous studies have been done on selecting natural fibre for composite preparation. For example, an innovative study using the AHP method was undertaken to select biopolymer composites as a potential material for food packaging (Salwa et al., 2019).

However, the assumption of criteria independence (no correlation) is a limitation of AHP (Ishizaka & Labib, 2009). On the other hand, Maidin et al. (2022) examined a material selection of natural fibre using Grey Relational Analysis (GRA).

One of the tools used in MCDM approaches is the ability to determine ranking and define preferences. Hwang and Yoon (1981) introduced the TOPSIS method to assist decision-makers in making reliable and consistent judgments. Nevertheless, a significant weakness of the TOPSIS method is its lack of provisions for weight elicitation and consistency testing for judgment, as Shih et al. (2007) pointed out. Diakoulaki et al. (1995) developed the CRITIC method to establish an objective weight. Therefore, both methods can be utilised to prioritise performance requirements for natural fibre composite materials and integrating both methods may improve the decision-making outcome. Apart from these methods, Table 1 highlights the utilisation of both CRITIC and TOPSIS methods, which have been explored in information technology, financial and banking, sustainable energy, environmental and heavy industries. The CRITIC method is utilised to score and determine the importance of the relative weights for the decision criteria set. In contrast, the TOPSIS method determines the final ranking of all alternatives.

Although studies have been conducted on utilising both CRITIC and TOPSIS methods in material selection, there is still a lack of reported studies on natural fibre material selection using the integration of the CRITIC-TOPSIS method. Therefore, by fulfilling this research gap, designers and material engineers would greatly benefit from a clear

Table 1
Application sectors and domains covered by CRITIC and TOPSIS

Application sectors	**References**
Information technology	Berdie et al., 2017
- Computing software	Ertemel et al., 2023
- Smartphone addiction	
Environmental	Chen et al., 2022
- Monte Carlo simulation	
Supply chain management	Abdel-Basset & Mohamed, 2020
Sustainable Energy	Lakshmi et al., 2022
- Green energy	Babatunde & Ighravwe, 2019; Ighravwe &
- Renewable energy	Babatunde, 2018
- Value Added Intellectual Capital (VAIC)	Polcyn, 2022; Hassan et al., 2023
- Solar PV	
Financial and banking	Kazan & Ozdemir, 2014
- Financial	
Heavy industries	Mohamadghasemi et al., 2020
- Crane Industries	Wu et al., 2020
- Bridge construction	
Material	Slebi-Acevedo et al., 2019
- Polymer-modified binder (PMB)	

and methodical methodology selection procedure. Hence, this study is interested in using an innovative approach known as Criteria Importance Through Inter-criteria Correlation (CRITIC) and Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) to eliminate the need to compare characteristics and determine their weights. The following will ultimately reduce the decision maker's dependence on choosing the most suitable natural fibre material. Hence, incorporating these two MCDM methods is appropriate for evaluating the natural fibre composite materials. It will assist the business's design engineer and manufacturing team choose the most suitable materials for product design and development.

METHODOLOGY FOR FRAMEWORK DEVELOPMENT

The overall methodology of this study is presented in four phases for better clarity. Phase 1 involves criteria selection and prioritisation. Weightage determination using the CRITIC method and material ranking using the TOPSIS method were gathered in Phase 2. The conceptual framework review was gathered in Phase 3 through validation of the framework, and the study was concluded with a ranking of the material performance in Phase 4.

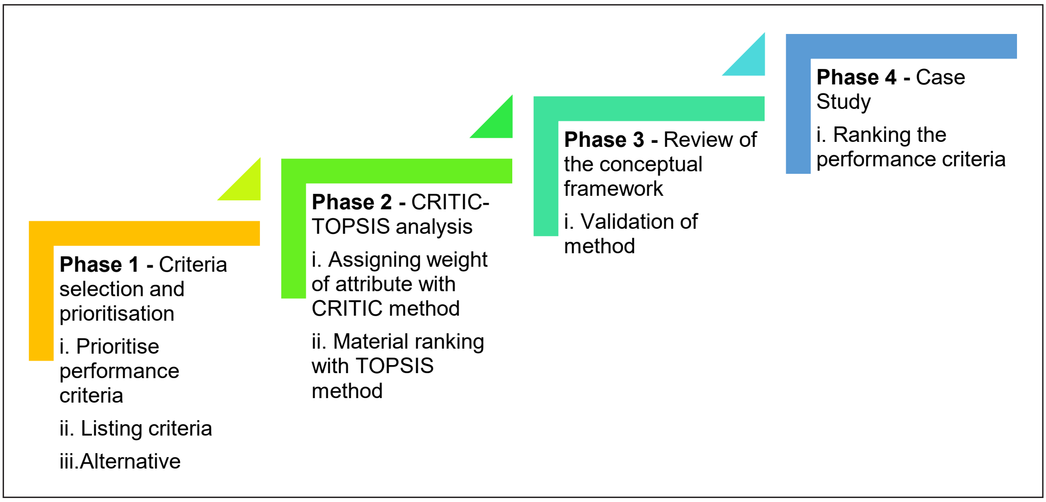

Figure 1. Methodology for framework development

Phase 1: Criteria Selection and Prioritization

The main objective of the DM process was established in the structural hierarchy at Level 1 (goal); that is, the performance criteria were ranked according to priority. In Level 2 (criteria), the performance specifications were listed as length (mm), diameter (m), tensile strength (MPa), Young's modulus (GPa), elongation at break (%), and cellulose (%). Lastly, in Level 3 (alternative), the performance standards list must be prioritised to meet the target in Level 1. A perspective structural hierarchy is shown in Figure 2 at Phase 1.

Phase 2: CRITIC-TOPSIS Analysis

The performance requirements of natural fibre composite materials are prioritised in this work using the CRITIC and TOPSIS methods. Figure 2 shows the proposed framework model structure for prioritising performance criteria. The framework is divided into 2 phases: (1) Phase 1 starts with collecting data and building a structural hierarchy, and (2) Phase 2 assigns weight by the CRITIC method, and the TOPSIS method is used to rank the criteria.

Weightage Determination Using CRITIC Method

The Criteria Importance Through Intercriteria Correlation (CRITIC) method is mostly employed to calculate attribute weights. The qualities in the current technique do not conflict

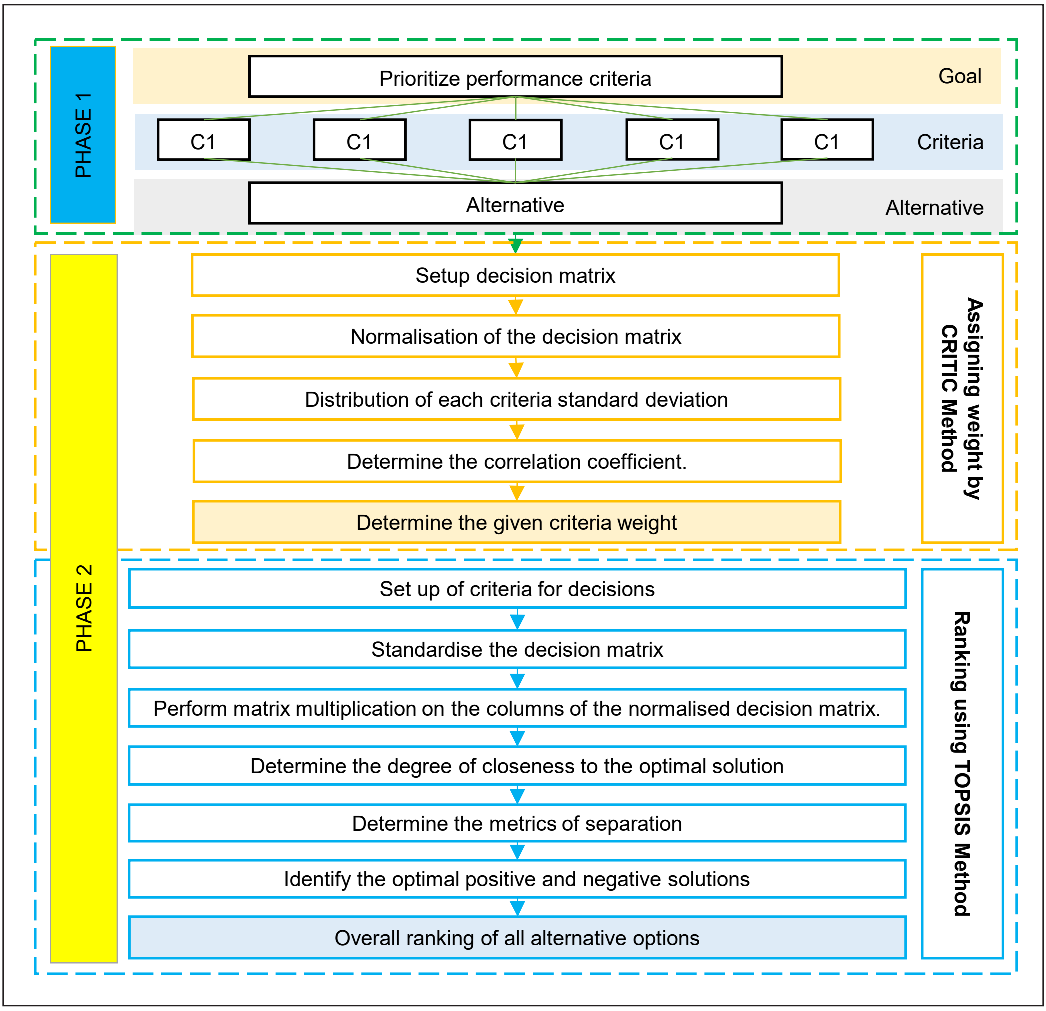

Figure 2. The proposed framework model structure

with one another, and the decision matrix is used to find the weights of the attributes. The CRITIC method is a correlation method that utilises correlation coefficients of all paired columns and the standard deviation of alternatives' ranking criteria values to determine criteria contrasts (Pamucar et al., 2022; Žižovic et al., 2020). Steps 1 to 5 detail the process's weightage (Alinezhad & Khalili, 2019; Anand et al., 2022; Diakoulaki et al., 1995).

Step 1: Starting from an initial decision matrix

The initial decision matrix is obtained using Equation 1 (Anand et al., 2022).

$$A = \begin{bmatrix} x_{11} & \cdots & x_{1j} & \cdots & x_{1n} \\ \vdots & \ddots & \vdots & \ddots & \vdots \\ x_{i1} & \cdots & x_{ij} & \cdots & x_{in} \\ \vdots & \ddots & \vdots & \ddots & \vdots \\ x_{m1} & \cdots & x_{mj} & \cdots & x_{mn} \end{bmatrix}_{m\ x\ n} \quad ; i = 1, \ldots, m, j = 1, \ldots, n \qquad [1]$$

Step 2: Normalisation of the decision matrix

The scores of the various criteria cannot be compared since they are expressed using various measuring scales or units. As part of the normalisation procedure, the scores are transformed into standard scales with a 0 to 1 range. The choice matrix's scores are initially determined using the suggested method by utilising Equation 2.

$$\overline{X_{ij}} = \frac{x_{ij} - x_j^{worst}}{x_j^{best} - x_j^{worst}} \qquad [2]$$

Where $\overline{X_{ij}}$ is the normalised score of alternative *i* with respect to criterion *j*, x_{ij} is the actual score of alternative *i* with respect to criterion x_j^{best} is the best score of criterion *j*, and x_j^{worst} is the worst score of criterion *j*.

Step 3: Distribution of each criteria standard deviation

In the third step, the standard deviation of each criterion, s_j, is calculated using Equation 3. Note that $\overline{X_j}$ in Equation 2 is the mean score of criterion *j* and that *m* is the total number of alternatives.

$$s_j = \sqrt{\left(\frac{\sum_{i=1}^{m} x_{ij} - \overline{x_j}}{m-1}\right)^2} \qquad [3]$$

Where $\overline{X}_j$ is the mean score of the criterion *j* and *m* is the total number of alternatives.

Step 4: Determine the correlation coefficient

The correlation coefficient among attributes is determined by Equation 4.

$$\rho_{jk} = \frac{\sum_{i=1}^{m}(x_{ij} - \bar{x}_j)(x_{ik} - \bar{x}_k)}{\sqrt{\sum_{i=1}^{m}(x_{ij} - \bar{x}_j)^2 \sum_{i=1}^{m}(x_{ik} - \bar{x}_k)^2}} \qquad [4]$$

Step 5: Determine the given criteria weight

The weights of attributes are determined by Equation 5

$$w_j = \frac{C_j}{\sum_{j=1}^{n} C_j} \;;\; j = 1, \ldots, n \qquad [5]$$

Material Ranking Using TOPSIS Method

The Technique Order Preference by Similarity to the Ideal Solution (TOPSIS) method is based on the idea that the chosen option should be most distant from the worst possible solution and the closest to the best possible solution (Hwang & Yoon, 1981). Steps 1 until 7 detailed the processes of the material ranking (Chodha et al., 2021; Pavić & Novoselac, 2013; Rahim et al., 2018).

Step 1: Set up of criteria for decisions (A)

The criteria for decisions are set up using Equation 6 (Chodha et al., 2021).

$$A = \left(x_{ij}\right)_{m\ x\ n} = \begin{bmatrix} x_{12} & x_{12} & \cdots & x_{1n} \\ x_{21} & x_{22} & \cdots & x_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ x_{m1} & x_{m2} & \cdots & x_{mn} \end{bmatrix} \qquad [6]$$

Step 2: Standardise the decision matrix

The standardised value r_{ij} is calculated using Equation 7.

$$r_{ij} = \frac{f_{ij}}{\sqrt{\sum_{j=1}^{j} f_{ij}^{\,2}}} \;, j = 1,2,\ldots,j;\; i = 1,2,\ldots,n \qquad [7]$$

Step 3: Perform matrix multiplication on the columns of the normalised decision

The weighted normalised value v_{ij} is calculated using Equation 8.

$$v_{ij} = w_j \text{ x } r_{ij} \;, j = 1, 2, \ldots, J \,; i = 1, 2, \ldots, n, \qquad [8]$$

Where w_j is the weight of the i^{th} criterion and $\sum_{i=1}^{n} w_j = 1$.

Step 4: Determine the degree of closeness to the optimal solution, the positive ideal (A) and the negative ideal (A-) solutions*

The positive ideal (A*) and negative ideal (A-) solutions are expressed using Equation 9 (Rahim et al., 2018).

$$A^* = \left\{ \left(\max_i v_{ij} \,\middle|\, j \in C_b \right), \left(\min_i v_{ij} \,\middle|\, j \in C_c \right) \right\} = \left\{ v^*_j \,\middle|\, j = 1, 2, \ldots, m \right\}$$

$$A^- = \left\{ \left(\min_i v_{ij} \,\middle|\, j \in C_b \right), \left(\max_i v_{ij} \,\middle|\, j \in C_c \right) \right\} = \left\{ v^-_j \,\middle|\, j = 1, 2, \ldots, m \right\} \qquad [9]$$

Step 5: Determine the metrics of separation

The measures of separation between each alternative and the positive and negative ideal solutions, respectively, are as in Equation 10:

$$S_i^* = \sqrt{\sum_{j=1}^{m}\left(v_{ij} - v_j^*\right)^2}\ , \quad j = 1, 2, \dots, m \qquad [10]$$

Similarly, the distance from the negative ideal solution is stated in Equation 11.

$$S_i^- = \sqrt{\sum_{j=1}^{m}\left(v_{ij} - v_j^-\right)^2}\ , \quad j = 1, 2, \dots, m \qquad [11]$$

Step 6: Identify the optimal positive and negative solutions

The proximity of the alternate Pi with respect to P* is defined as stated in Equation 12.

$$Pi_i^* = \frac{S_i^-}{S_i^* + S_i^-}\ , i = 1, 2, \dots, m \qquad [12]$$

Step 7: Overall ranking of all alternative options

Phase 3: Review of the Conceptual Framework: Data Validation of the Framework

Before being used in a case study, the suggested method conducted validation by applying it to previous research. Validation data was gathered from studies from past researchers (Saputra et al., 2018). Sample S1 (Muhammad Musa), S2 (Alvin Syahrin), S3 (Noviyanti), S4 (Sofia), S5 (Syyaiful Aswad). The researcher studies a comparison between AHP and SAW, which was selected and replicated. Saputra et al. (2018) studied a decision support system that helps solve the problem of selecting a department chief.

Table 2 displays the findings collected from the CRITIC-TOPSIS (current), AHP (Saputra et al., 2018) and SAW (Saputra et al., 2018) with extent analysis methods that provide equivalent rankings. For instance, according to the CRITIC-TOPSIS method, the ranking of the alternative based on the numerical validation were S1>S2>S3>S4>S5, AHP and SAW method produced the same ranking as CRITIC-TOPSIS. Therefore, the

Table 2
Result Ranking for validation

	MCDM Method					
	CRITIC-TOPSIS (current)		**AHP** (Saputra et al., 2018)		**SAW** (Saputra et al., 2018)	
Alternative	**Value**	**Rank**	**Value**	**Rank**	**Value**	**Rank**
S1	0.997	1	0.274	1	0.993	1
S2	0.629	2	0.241	2	0.883	2
S3	0.435	3	0.193	3	0.707	3
S4	0.237	4	0.158	4	0.578	4
S5	0.015	5	0.135	5	0.490	5

proposed framework utilising the CRITIC-TOPSIS method for ranking calculation is considered suitable, as it provides equivalent preference rankings to those obtained via AHP and SAW.

Phase 4: Case Study

In this phase, the ranking of the performance criteria for cap-toe shoes is taken as an investigation of a case. A case study is carried out to determine the suitability of the suggested framework. The following part will explain the upcoming tasks.

CASE STUDY ON THE PERFORMANCE CRITERIA FOR CAP TOE SHOES

Phase 1: Criteria Selection and Prioritization

Table 3 shows the performance criteria for cap-toe shoes. The six established alternatives are composed of six criteria.

Table 3
Selection of performance criteria adapted from (Biagiotti et al., 2004 Luhar et al., 2020 Peças et al., 2018)

	Diameter (μm)	Length (mm)	Tensile Strength (MPa)	Young's Modulus (GPa)	Elongation at Break (%)	Cellulose (%)
Abaca	20	4.9	621.5	41	2.9	59.5
Bamboo	58	2.75	566	53	4.65	34.5
Coir	18.2	1.65	175	6	20	45.6
Jute	15	3.4	547.5	46.25	2.3	65.25
Kenaf	24	6.2	612.5	41	4.8	53.5
Sisal	27	4.4	681	15.5	2.45	68.5

Phase 2: CRITIC-TOPSIS Analysis

CRITIC Method

The application of the CRITIC method in choosing the performance criterion for the design process is shown below.

Step 1: Starting from an initial decision matrix
The decision matrix shown in Table 3, all criteria are beneficial.

Step 2: Normalisation of the decision matrix
After calculating x_j^{best} and x_j^{worst}, the normalisation of the decision matrix can be determined from Equation 2. Where x_j^{best} is the maximum value of the dataset, and x_j^{worst} is the minimum value of the dataset. For the example $\bar{x}_{ij}$ = (20-15)/(58-15) = 0.1163. The entire results of the normalisation of the decision matrix are shown in Table 4.

Step 3: Determine the standard deviation of each criterion

The distribution of each criterion's standard deviation can be determined from Equation 3. For the example $\bar{x}$ = (0.1163+1+0.0814+0+0.2093+0.2791)/6 = 0.2810, and s_j = $\sqrt{((0.1163-0.2810)^2 + (1-0.2810)^2 + (0.0814-0.2810)^2 + (0-0.2810)^2 + (0.2093-0.2810)^2 + (0.2791-0.2810)^2)/(6-1)}$ = 0.3655. The entire results of the standard deviation of each criterion are shown in Table 5.

Step 4: Determine the correlation coefficient

Table 6 shows the pairwise criteria correlation coefficient values. Equation 4 was used to measure the correlation.

Step 5: Determine the given criteria weight W_j

After calculating $c_j = \sum_{j=1}^{n} c_j$, the Weight of the selected criteria can be determined from Equation 5. For the example $c_j = \sum_{j=1}^{n} c_j$ = ((1-1) + (1-(-1.1914)) + (1-0.2122) + (1-0.4168) + (1-(-0.1694) + (1-(-0.7022)) x 0.3655 = 1.9863, $\sum c_j$ = 1.9863 + 7.5357 + 1.4437 + 3.0608 + 2.0520 = 11.8920, and w_j = 1.9863/11.8920 = 0.1670. The weight of all the results of the selected criteria is shown in Table 7.

Figure 3 illustrates the relative importance of evaluation indicators. The findings show that the ranking order for criteria = Elongation at Break > Cellulose > Diameter > Young's

Table 4
Normalisation of the decision matrix

	Diameter (µm)	Length (mm)	Tensile Strength (MPa)	Young's Modulus (GPa)	Elongation at Break (%)	Cellulose (%)
Abaca	0.1163	0.7143	0.8824	0.7447	0.0339	0.7353
Bamboo	1.0000	0.2418	0.7727	1.0000	0.1328	0.0000
Coir	0.0814	0.0000	0.0000	0.0000	1.0000	0.3265
Jute	0.0000	0.3846	0.7362	0.8564	0.0000	0.9044
Kenaf	0.2093	1.0000	0.8646	0.7447	0.1412	0.5588
Sisal	0.2791	0.6044	1.0000	0.2021	0.0085	1.0000

Table 5
Distribution of each criteria standard deviation

	Diameter (µm)	Length (mm)	Tensile Strength (MPa)	Young's Modulus (GPa)	Elongation at Break (%)	Cellulose (%)
Abaca	0.1163	0.7143	0.8824	0.7447	0.0339	0.7353
Bamboo	1.0000	0.2418	0.7727	1.0000	0.1328	0.0000
Coir	0.0814	0.0000	0.0000	0.0000	1.0000	0.3265
Jute	0.0000	0.3846	0.7362	0.8564	0.0000	0.9044
Kenaf	0.2093	1.0000	0.8646	0.7447	0.1412	0.5588
Sisal	0.2791	0.6044	1.0000	0.2021	0.0085	1.0000
STDEV	**0.3655**	**0.3567**	**0.3596**	**0.3963**	**0.3873**	**0.3759**

Table 6
Pairwise criteria correlation coefficient values

	Diameter (µm)	Length (mm)	Tensile Strength (MPa)	Young's Modulus (GPa)	Elongation at Break (%)	Cellulose (%)
Diameter (µm)	1.0000	-0.1914	0.2122	0.4168	-0.1694	-0.7022
Length (mm)	-0.1914	1.0000	0.7488	0.3231	-0.6419	0.4565
Tensile Strength (MPa)	0.2122	0.7488	1.0000	0.5469	-0.9631	0.4401
Young's Modulus (GPa)	0.4168	0.3231	0.5469	1.0000	-0.6690	-0.1933
Elongation at Break (%)	-0.1694	-0.6419	-0.9631	-0.6690	1.0000	-0.4596
Cellulose(%)	-0.7022	0.4565	0.4401	-0.1933	-0.4596	1.0000

Table 7
Determine the weight of the selected criteria

	Major Criteria	C_j	W_j
Diameter (µm)	5.4341	*1.9863*	0.1670
Length (mm)	4.3049	7.5357	0.1291
Tensile Strength (MPa)	4.0151	1.4437	0.1214
Young's Modulus (GPa)	4.5756	1.8135	0.1525
Elongation at Break (%)	7.9031	3.0608	0.2574
Cellulose (%)	5.4586	2.0520	0.1725
TOTAL		**11.8920**	**1.0000**

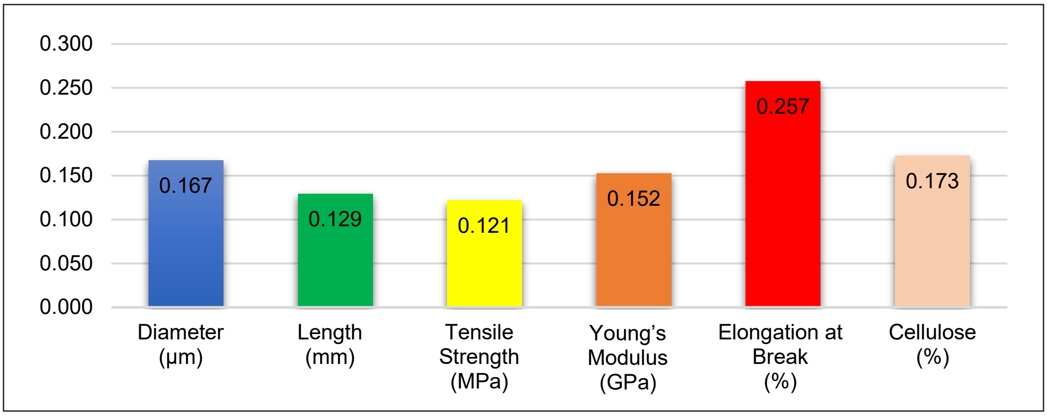

Figure 3. Weight for each performance criterion

Modulus > Length > Tensile Strength. The most preferred criterion is Elongation at Break, and the least preferred criterion is Tensile Strength. The Elongation at Break (%) and the Cellulose (%) correspond to the two highest weights in the results, indicating that these two performance criteria were given preferences. At the same time, Tensile Strength (MPa) has the lowest value corresponding to the least preferred criterion.

TOPSIS Method

The TOPSIS method has been used to solve evaluation and selection problems. Here is the implementation of the TOPSIS approach for selecting the criteria for design process performance.

Step 1: Set up of criteria for decisions (A)

Table 8 shows the decision matrix. Equation 6 is used to obtain the construction decision matrix.

Step 2: Standardise the decision matrix

After calculating $\sum f_{ij}{}^2$ all, the standardised decision matrix can be determined from Equation 7. For the example $\sum f_{ij}{}^2$= (20^2) + (58^2) + (18.5^2) + (15^2) + (24^2) + (27^2) = 5636.25, $r_{ij} = 20/\sqrt{5636.25}$ = 0.2664. The entire results of the standardised decision-making matrix are shown in Table 9.

Step 3: Perform matrix multiplication on the columns of the normalised decision by the associated weights to generate the weighted normalised decision matrix, which is the weighted normalised value

Equation 8 can determine the weighted normalisation value—for example, v_{ij} = 0.266 × 0.1670 = 0.445.The entire results of the weighted normalisation value are shown in Table 10.

Step 4: Determine the degree of closeness to the optimal, positive ideal (A) and negative ideal (A^-) solutions*

The degree of closeness to the optimal solution can be determined using Equation 9. For example, the positive ideal (A^*) is the maximum value of the dataset, maximum = 0.1290, and the negative ideal (A^-) is the minimum value of the dataset, minimum = 0.0334. The entire results of the degree of closeness to the optimal solution are shown in Table 11.

Step 5: Determine the separation measures: The separation measures of each alternative from the positive ideal solution and the negative ideal solution, respectively, are as follows:

All separation measures can be determined from Equations 10 and 11. For the example,

$$S_i^* = \sqrt{\begin{matrix}(0.445 - 0.1290)^2 + (0.0622 - 0.0786)^2 + (0.0551 - 0.0604)^2 + \\ (0.0675 - 0.0872)^2 + (0.0346 - 0.2389)^2 + (0.0752 - 0.0866)^2\end{matrix}} = 0.2229$$

$$S_i^- = \sqrt{\begin{matrix}(0.445 - 0.0334)^2 + (0.0622 - 0.0209)^2 + (0.0551 - 0.0155)^2 + \\ (0.0675 - 0.0099)^2 + (0.0346 - 0.0275)^2 + (0.0752 - 0.0436)^2\end{matrix}} = 0.0881$$

The entire results of the separation measure for each performance criterion are shown in Table 12.

Step 6: Identify the optimal positive and negative solutions. The relative closeness of the alternative Pi with respect to P is defined as follows:*

Relative closeness to the ideal solution can be determined using Equation 12. For the example, *Pi* = 0.0881/(0.2229+0.0881)=0.2832. The results of relative closeness to the ideal solution are shown in Table 13.

Equation 12 is used to calculate the relative closeness to the ideal solution.

Table 13 presents six natural fibre alternatives, ordered according to their priority Pi scores. Based on the findings, coir has the highest Pi score of 0.6006. Bamboo has the second-highest score of 0.4047, followed by kenaf, abaca, jute, and sisal, which gathered Pi values of 0.3351, 0.2832, 0.2688, and 0.2523, respectively. The result showed that coir has exceptional mechanical and thermal stability. It corresponds to research by Hasan et al. (2021).

Step 7: Establish a ranking of preference

The ranking of each alternative according to the performance score is displayed in Table 14.

As a result, the ranking results of the CRITIC-TOPSIS method are shown in Table 14. The results from synthesising data on the critical criteria were used to generate a list

Table 8

Original data matrix

	Diameter (µm)	Length (mm)	Tensile Strength (MPa)	Young's Modulus (GPa)	Elongation at Break (%)	Cellulose (%)
WEIGHT	**0.1670**	**0.1291**	**0.1214**	**0.1525**	**0.2574**	**0.1725**
Abaca	20	4.9	621.50	41	2.90	59.50
Bamboo	58	2.75	566	53	4.65	34.50
Coir	18.5	1.65	175	6	20	45.60
Jute	15	3.40	547.50	46.25	2.30	65.25
Kenaf	24	6.20	612.50	41	4.80	53.50
Sisal	27	4.40	681	15.5	2.45	68.50

Table 9

Normal decision-making matrix

	Diameter (µm)	Length (mm)	Tensile Strength (MPa)	Young's Modulus (GPa)	Elongation at Break (%)	Cellulose (%)
WEIGHT	**0.1670**	**0.1291**	**0.1214**	**0.1525**	**0.2574**	**0.1725**
Abaca	0.2664	0.4813	0.4538	0.4425	0.1346	0.4360
Bamboo	0.7726	0.2701	0.4132	0.5720	0.2158	0.2528
Coir	0.2464	0.1621	0.1278	0.0648	0.9281	0.3342
Jute	0.1998	0.3340	0.3997	0.4991	0.1067	0.4782
Kenaf	0.3197	0.6090	0.4472	0.4425	0.2227	0.3921
Sisal	0.3596	0.4322	0.4972	0.1673	0.1137	0.5020

Table 10
Decision matrix with weights and normalisation

	Diameter (µm)	Length (mm)	Tensile Strength (MPa)	Young's Modulus (GPa)	Elongation at Break (%)	Cellulose (%)
WEIGHT	**0.1670**	**0.1291**	**0.1214**	**0.1525**	**0.2574**	**0.1725**
Abaca	0.0445	0.0622	0.0551	0.0675	0.0346	0.0752
Bamboo	0.1290	0.0349	0.0502	0.0872	0.0555	0.0436
Coir	0.0412	0.0209	0.0155	0.0099	0.2389	0.0577
Jute	0.0334	0.0431	0.0485	0.0761	0.0275	0.0825
Kenaf	0.0534	0.0786	0.0543	0.0675	0.0573	0.0676
Sisal	0.0601	0.0558	0.0604	0.0255	0.0293	0.0866

Table 11
Compared to negative ideal solutions, positive ideal solutions

	Diameter (µm)	Length (mm)	Tensile Strength (MPa)	Young's Modulus (GPa)	Elongation at Break (%)	Cellulose (%)
A^*	0.1290	0.0786	0.0604	0.0872	0.2389	0.0866
A^-	0.0334	0.0209	0.0155	0.0099	0.0275	0.0436

Table 12
Separation Measure for each performance criterion

	Abaca	Bamboo	Coir	Jute	Kenaf	Sisal
S_i^*	0.2229	0.1936	0.1410	0.2353	0.1987	0.2303
S_i^-	0.0881	0.1316	0.2120	0.0865	0.1001	0.0777

Table 13
Relative closeness to the ideal solution for each performance criterion

	Abaca	Bamboo	Coir	Jute	Kenaf	Sisal
Pi	0.2832	0.4047	0.6006	0.2688	0.3351	0.2523

of six (6) natural fibres. These fibres were ordered based on their positive ideal solution (Pi) scores, which were calculated using the Microsoft Excel 2016 software and a specific method. According to Guerrero (2010), excel has become as common as calculators in data analysis and decision-making. Table 14 displays the results. Coir achieved the highest score of 0.6006,

Table 14
Overall ranking of all alternative options

Alternatives	Pi	Ranking
Abaca	0.2832	4
Bamboo	0.4047	2
Coir	0.6006	1
Jute	0.2688	5
Kenaf	0.3351	3
Sisal	0.2523	6

positioning it in the highest position in the rating. Bamboo received the grade that is ranked just behind the highest score determined by a score of 0.4047, followed by kenaf, abaca, jute, and sisal with values of 0.3351, 0.2832, 0.2688, and 0.2523, respectively.

This study demonstrates that coir has a potential material for cap-toe shoes, as indicated by its top rating among the alternatives, as shown in Table 14. Despite the decisive confirmation of the results, incorporating extra details from other criteria could have made the natural fibre selection procedure more comprehensive. When developing requirement criteria, it is essential to consider multiple variables to make informed selections. Hence, while choosing natural fibres, decision-makers should meticulously establish precise selection criteria based on specific requirements, as this will significantly impact the outcome of the selection process.

Coir fibre is a good alternative to traditional materials due to its cost-effectiveness, renewability, recyclability, biodegradability, and environmental friendliness compared to synthetic fibres. Several industries, including mat production, yarn making, rope manufacturing, floor articles, insulating panels, stackings, and textile goods, can utilise Coir due to its versatility. The automotive and construction sectors extensively utilise Coir to enhance the strength of polymer composites (Goyat et al., 2022). Onukwuli et al. (2022) demonstrate that coir fibre has the benefits of being lightweight, having a high strength-to-weight ratio, being inexpensive, and being widely available.

DISCUSSION

Analysing natural fibre's chemical composition and shape of natural fibre to comprehend their distinct features is crucial. Although the framework has been thoroughly tested, the authors argue that the natural fibre selection approach could have been more comprehensive if it had incorporated additional features from other criteria. When making a decision, multiple considerations must be examined in order to ensure the appropriate selection of natural fibres that fulfil a certain requirement; it is imperative for individuals responsible for the selection process to establish highly detailed criteria about that need.

The framework of integrating the CRITIC-TOPSIS method can be applied as a substitute to combine different performance indicators or criteria into a single score that can be used to compare and rank different options. Data validation was carried out to verify the suggested framework and ascertain whether the rankings provided by the suggested combined CRITIC-TOPSIS and the rankings produced by other MCDM approaches were comparable. The results indicate that the proposed framework can provide a ranking compatible with other DM methods.

The TOPSIS method has been well recognised by researchers for its ability to effectively determine the optimal decision by considering selection criteria and their connections when combined with competing criteria and alternative solutions. The main benefit of using the CRITIC-TOPSIS methodology over other MCDM methods is that it allows for the simultaneous consideration of negative and positive criteria in decision-making. Furthermore, it is simpler and more effective than other methods like AHP. TOPSIS algorithm chooses the alternative most similar to the positive ideal solution and most dissimilar to the negative ideal alternative. Therefore, this approach offers a more accurate representation of models than non-compensatory alternatives.

CONCLUSION

This study has successfully developed a framework for prioritising performance criteria in selecting natural fibre materials. Hence, it provides helpful knowledge for selecting constituent materials based on the integrated CRITIC-TOPSIS framework. The enhancement of knowledge and findings of this study can benefit material designers and engineers in selecting the most suitable fibre by prioritising performance criteria.

The validation of the proposed framework is illustrated based on the data and results from a reputable past study, where the present results are shown to have good conformance. For comparison, an effective ranking method has been developed to address this issue, where the decision-making (DM) method is suggested to involve the integration of the CRITIC and TOPSIS methods. Generally, the CRITIC method is used to acquire the weight of criteria. However, the TOPSIS method is employed to prioritise the criterion. As far as the authors know, there has been limited research on applying the CRITIC-TOPSIS method towards material selection for natural fibre composite materials. Hence, this study is novel as it has successfully incorporated the CRITIC and TOPSIS methods to prioritise performance criteria of natural fibre materials for cap toe shoes, using performance criteria. The results have been verified using a reliable publication. The CRITIC-TOPSIS method is an effective tool for objectively evaluating and ranking the performance criteria of natural fibre composite materials. This framework can help design engineers identify the most suitable natural fibre composite materials.

In summary, this study presents a structure for determining the order of importance of performance requirements for natural fibre composite materials. The current study shows the effectiveness of using the integrated CRITIC-TOPSIS method as a classification tool for selecting natural fibre composite materials. It is especially relevant when selecting a decision-making method, as it frequently involves evaluating numerous criteria and can be described as an MCDM problem.

As the present study only involves performance criteria of the material, the outcome may not represent the overall condition of all the natural fibre composite materials, which constitutes the present study's main limitation. Furthermore, the number of fibres studied is limited (only six), as the complete information for many other natural fibres is currently unavailable for comparison. Nevertheless, the result of the present study is promising, showing that Coir has the optimum performance criteria for natural fibre composite material. Further research is necessary to support the statistical judgment of selecting the optimum natural fibre. The interconnections of input data can also be investigated in depth to understand the selection process.

ACKNOWLEDGEMENTS

The authors express deep gratitude to the Ministry of Higher Education (MOHE) Malaysia for awarding the scholarship to the principal author to conduct this research. The acknowledgements also extend to the College of Engineering, Universiti Teknologi MARA, Shah Alam, and Universiti Teknikal Malaysia Melaka (UTeM) for providing facilities and assistance. The College of Engineering, Universiti Teknologi MARA, Shah Alam, also provides financial support for publication.

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