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PRIORITIZATION OF CIRCULAR ECONOMY PRACTICES IN THE TEXTILE INDUSTRY: A MCDM APPROACH

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Abstract

The textile and apparel sectors have substantial global significance because of their large socioeconomic contribution. Nevertheless, it is among the most environmentally detrimental sectors. Research on the adoption of a circular economy has seen a substantial increase to mitigate its environmental effects. However, there is a significant gap in evaluating the advancement in the current research. Despite this, the adoption of circular practices successfully facilitates the implementation of the circular economy. Hence, the primary objective of this research is to identify the implementation of circular economy practices to convert a linear model into a circular economy framework. To achieve this objective, twelve circular economy practices are identified with the help of existing literature and experts. After that, these practices are evaluated with the help of the TOPSIS method and prioritizeds according to their importance. The results indicate that 'Designing products intended for circularity' is the most significant circular practice. Subsequently, 'Processes designed to eliminate waste', '5 R's of Circular Economy', 'Staff Training allied to the circular economy practice', and 'Execution of reverse logistics' came out with significant circular practices. Managers and professionals may successfully embrace circular processes by prioritizing them and optimizing their organizational resources.

Keywords – circular economy, sustainability, SDGs, textile industry

INTRODUCTION

In the current global competitive landscape, every firm aspires to enhance the sustainability of its supply chain through economic, environmental, and social perspectives (Nosratabadi et al., 2019). The Circular Economy (CE) relies upon the principles of the regeneration cycle, which enables the effective reuse of discarded products, components, and materials. This approach aims to enhance profitability while simultaneously mitigating environmental impact (Chiappetta Jabbour et al. 2020). However, the accomplishment of the Circular Economy relies on the efficient implementation of circular practices. The circular economy has emerged as a significant concern within the industrial sector, garnering more attention from both firms and scholars in recent times (Dev, N. K. et al. 2020). Despite being aware of the advantages associated with circular economy activities, organizations encounter several obstacles when it comes to implementing these practices (Kristoffersen et al. 2020). These shifts are leading to the adoption of sustainable practices. While these techniques have an impact on performance and help minimize the environmental impact, a comprehensive approach is still necessary to effectively address these challenges in a systematic manner (Centobelli et al., 2020). In this situation, the CE has emerged as a superior choice, bringing sustainability into the system and enhancing the organization (Cayzer, Griffiths, and Beghetto 2017; Sassanelli et al. 2019; Centobelli et al., 2020). The CE is seen by organizations and practitioners as a viable remedy for environmental issues, including but not limited to resource exhaustion (Sharma, Joshi, and Kumar 2020; Haleem et al. 2020; Bendikiene, Ciuplys, and Kavaliauskiene 2019).

The adoption of the circular economy is contingent upon the identification and implementation of several circular practices, which are necessary to expedite the transition from the conventional linear economy to the circular economy (Khan, Haleem, and Khan 2020). The instantaneous adoption of all indicated practices is not feasible, necessitating the prioritization of circular practices and the implementation of high-priority circular practices. Hence, this research aims to comprehend the circular practices. This study specifically emphasizes the two research objectives. The first research objective is to identify the major significant circular economy practices in the context of the Textile industry and the second research objective is to prioritize these identified circular economy practices.

In order to achieve the above-mentioned research objectives, we have used an appropriate multi-criteria decision-making technique to rank the important practices of the circular economy. This study aims to make substantial additions to the current literature. This paper presents an extensive list of important pertaining to the adoption of Circular Economy (CE) within the textile industry.

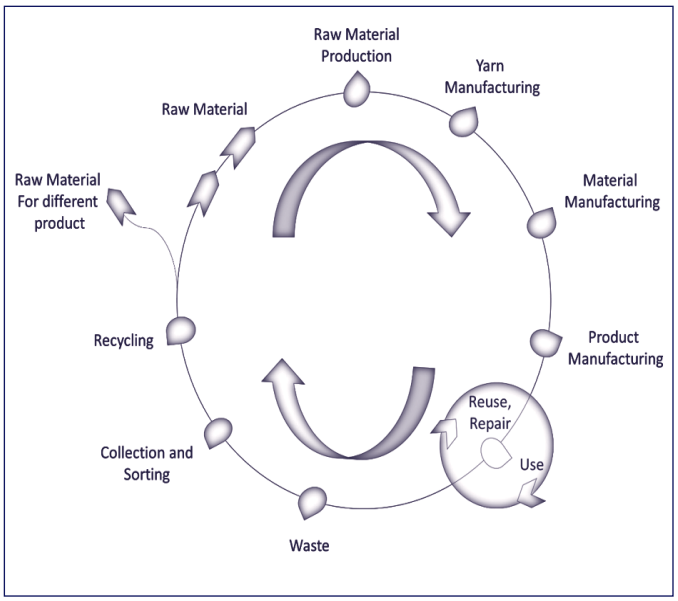
The suggested TOPSIS model is making a valuable contribution to the application of the Multiple Criteria Decision Making (MCDM) approach in the field of Circular Economy (CE). This study recommends to use of the TOPSIS-based model for analyzing the implementation of circular practices in order to effectively embrace CE. The chosen methodological framework is characterized by its simplicity, ease of implementation, and logical coherence in analyzing circular processes.

Furthermore, this research presents a comprehensive framework that may successfully assist policy planners and

decision-makers in the development of crucial policies aimed at implementing circular practices inside organizations.

The subsequent sections of the article are structured as follows: Section 2 presents the Background of the research. Section 3 provides a methodology used; Section 4 focuses on the analysis of the data and presents the results; Section 5 provides a discussion of the results while Section 6 explores the conclusion of the study. Section 7 provides the limitations and future research scope of this work.

Figure 1: Circular economy principle



BACKGROUND

From 2019 to 2026, the Indian textile and apparel sector is projected to increase at a 10% compound annual growth rate (CAGR) to reach US$ 190 billion. India now has a 4.6% market share in the worldwide textiles and clothing sector. Furthermore, India has the distinction of being the third biggest global exporter of Textiles & Apparel. India is positioned among the top five worldwide exporters across several textile categories, and it is projected that its exports will attain a value of US$ 65 billion by the fiscal year 2026 (Annual report 2023: Ministry Of Textiles, GOI). The textile and apparel sector has been identified as one of the most environmentally detrimental and socially disastrous industries globally and the process of textile manufacture requires significant quantities of energy and water (Boström and Micheletti, 2016).

This pertains to the need to construct a model that takes into account environmental, social, and economic issues (Genovese et al. 2017). The textile supply chain encompasses several challenges pertaining to design, resource procurement, yarn advancement, garment manufacture, packaging and distribution, utilization and maintenance, as well as waste management (Clancy et al., 2015). To achieve the goal of sustainability and elimination of waste within the Textile industries, the circular economy (CE) is considered a very significant approach, and several organizations are actively pursuing a shift towards the circular economy.

CIRCULAR ECONOMY

The conventional system of industrial manufacture and consumption operates on the linear economy model, which follows the sequence of take-make-consume-dispose (Goyal et al., 2018). Nevertheless, the linear economy model is not suitable for sustainability due to its substantial waste generation. The circular economy paradigm aims to maintain a continuous flow of resources and energy inside a closed system, hence minimizing the need for further raw material inputs in manufacturing processes (Genovese, A. et al. 2016). The concepts of the circular economy demonstrate a visionary aspiration to expand the limits of sustainable supply chain management methods.in the context of the Textile industry the adoption of circular practices enhances product design, and product end-of-life management in order to optimize value generation during the whole lifespan, and it is necessary to recover the value of items after they have been used, either by the original producer or by a third party.

METHODOLOGY

CE research is growing continuously. Particularly in the last few years, this directed both practitioners and researchers to recognize how to quantity and measure its influences in an existent context. This paper intends a multi-criteria decision approach to evaluate and rank the practices that can be adopted in the textile industry for implementing circularity. Based on the research objectives, this study is conducted in two stages. A survey of the scientific literature is used to identify the circular practices in the initial phase. After that, a group of experts discussed these observed circular practices to finalize the list. The list of circular practices was finalized by this group with consideration in the context of the textile industry. We ranked the identified circular practices according to their significance in the second phase. Prioritizing circular practices is done using the *Technique for Order of Preference by Similarity to the Ideal Solution* (TOPSIS), an efficient MCDM approach that was recently created.

Decisions must be taken in many real-world situations based on a range of criteria, many of which may conflict with others. MCDM offers methods and techniques that aid decision-makers in evaluating choices and identifying the optimal course of action in light of these many factors. MCDM approaches, such as the Promethee Method, Electre Method, Weighted Sum Method (WSM), Analytic Hierarchy Process (AHP), and Technique for Order Preference by Similarity to Ideal Solution (TOPSIS), COPRAS and Multi-Objective Optimization. Generally, when having greater than nine independent factors and a hierarchical structure AHP and BWM are not suitable. Moreover, the expert's response in the case of BWM is reasonably complex makes difficult for the experts to provide their answers. The result obtained by TOPSIS is consistent with the results found by other MCDM techniques and does not get affected by criteria weights (Wen et al. 2019). TOPSIS shows robust performance through a wide range of decision circumstances, making it useful and applicable in different domains. Therefore, in this article, we have used the TOPSIS method to provide more stability and reliability to the results.

Figure 1 gives illustrations of the proposed research approach as employed in this article.

TECHNIQUE FOR ORDER PREFERENCE BY SIMILARITY TO IDEAL SOLUTION (TOPSIS)

TOPSIS was established under the concept that the selected alternative is the nearby from the ideal solution and the furthest from the negative-ideal solution. It selects the alternative according to relative closeness to the ideal solution which is considered simultaneously a distance between the ideal solution and the negative-ideal solution. The steps of TOPSIS are provided in detail as:

Firstly, the linguistic assessment matrix is established using linguistic relations for the assessment criteria (Rodríguez et al. 2012). The Linguistic Assessment Matrix (LAM) is a technique used in multi-criteria decision-making (MCDM) to handle linguistic preferences and expressions of decision-makers. It provides a structured framework for decision-makers to express their subjective verdicts in linguistic terms, which are then quantified and integrated into the decision-making development. Further, this matrix is transformed into an initial decision-making matrix, as per Table 1. Initially, the Decision-Making Matrix was constructed as follows:

$$X_{ij} = \begin{bmatrix} X_{11} & X_{12} & \cdots & X_{1n} \\ X_{21} & X_{22} & \cdots & X_{2n} \\ \vdots & \vdots & \ddots & X_{3n} \\ X_{m1} & X_{m2} & \cdots & X_{mn} \end{bmatrix}, \quad i = 1, \ldots m \quad \& \quad j = 1, \ldots n \tag{1}$$

The matrix $[x]_{(m\times n)}$ indicates the initial decision-making matrix, including the m-number of alternative and n-evaluation criteria. The matrix Xii element represents the performance of the

i^{th} alternative for the j^{th} criterion. In this study, practices act as an alternative and the experts act as a criterion.

Table 1: Linguistic assessment scale

S. No.	Linguistic assessment	Corresponding Scale
1	Very low importance (VL)	1
2	Low importance (L)	2
3	Moderate importance (M)	3
4	High importance (H)	4
5	Very high importance (V)	5

Step 1: Normalization of the initial decision matrix

After getting the initial decision matrix from the Linguistics assessment matrix, the next step is to perform normalization of the initial decision matrix. This step transforms different attribute dimensions into non-dimensional attributes, which allows links across criteria. Normalize the decision matrix as follows:

$$r_{ij} = \frac{X_{ij}}{\sqrt{\sum_{i=1}^{m}(X_{ij})^2}}, \quad i = 1, \ldots m \quad \& \quad j = 1, \ldots n \tag{2}$$

The values of r_{ij} represent the ratings of alternatives through a specific criterion in eqn. (2). All the possible number of alternatives is denoted by m, whereas n represents the number of criteria on which the performance of alternatives is measured. The normalized performance ratings r_{ij} can be given as a matrix R as shown in eqn. (3)

$$R = \begin{bmatrix} r_{11} & r_{12} & \cdots & r_{1n} \\ r_{21} & r_{22} & \cdots & r_{2n} \\ \vdots & \vdots & \ddots & r_{3n} \\ r_{m1} & r_{m2} & \cdots & r_{mn} \end{bmatrix}, \quad i = 1, \ldots m \quad \& \quad j = 1, \ldots n \tag{3}$$

Step 2: Integrate weight with normalized ratings

The weighted and normalized performance rating φ_{ij} is calculated from Eq. (3) as shown in eqn. (4). These weighted ratings are combined to form the weighted-normalized decision matrix φ in Eq. (5)

$$\varphi = (w_j \times r_{ij}); i = 1 \ldots m \ \& j = 1 \ldots . n \tag{4}$$

$$\varphi_{ij} = \begin{bmatrix} \varphi_{11} & \varphi_{12} & \cdots & \varphi_{1n} \\ \varphi_{21} & \varphi_{22} & \cdots & \varphi_{2n} \\ \vdots & \vdots & \ddots & \varphi_{3n} \\ \varphi_{m1} & \varphi_{m2} & \cdots & \varphi_{mn} \end{bmatrix}, \quad i = 1, \ldots m \quad \& \quad j = 1, \ldots n \tag{5}$$

Step 3: Determine the positive ideal and negative ideal solutions

A* and A' are denoted as the positive and negative ideal solution sets respectively which can be identified from Eq. (5) as

$$A^* = (\varphi_1^*, \varphi_2^*, \ldots . , \varphi_n^*) \tag{6}$$
$$A' = (\varphi_1', \varphi_2', \ldots . , \varphi_n') \tag{7}$$

Where,

$$\varphi_n^* = \begin{cases} \max \varphi_{ij}, if\ j\ is\ benefit\ attribute \\ \min \varphi_{ij}, if\ j\ is\ cost\ attribute \end{cases}$$

$$\varphi_n' = \begin{cases} \min \varphi_{ij}, if\ j\ is\ benefit\ attribute \\ \max \varphi_{ij}, if\ j\ is\ cost\ attribute \end{cases}$$

Step 4: Determine the separation values

The separation measure quantifies the distance of each alternative score from both the positive ideal solution and negative ideal solutions. Eq.8 and Eq. 9 show the steps for obtaining negative and positive separation values respectively.

$$\delta_i^* = \sum_{j=1}^{n}(\varphi_{ij} - \varphi_n^*)^2 \tag{8}$$
$$\delta_i' = \sum_{j=1}^{n}(\varphi_{ij} - \varphi_n')^2 \tag{9}$$

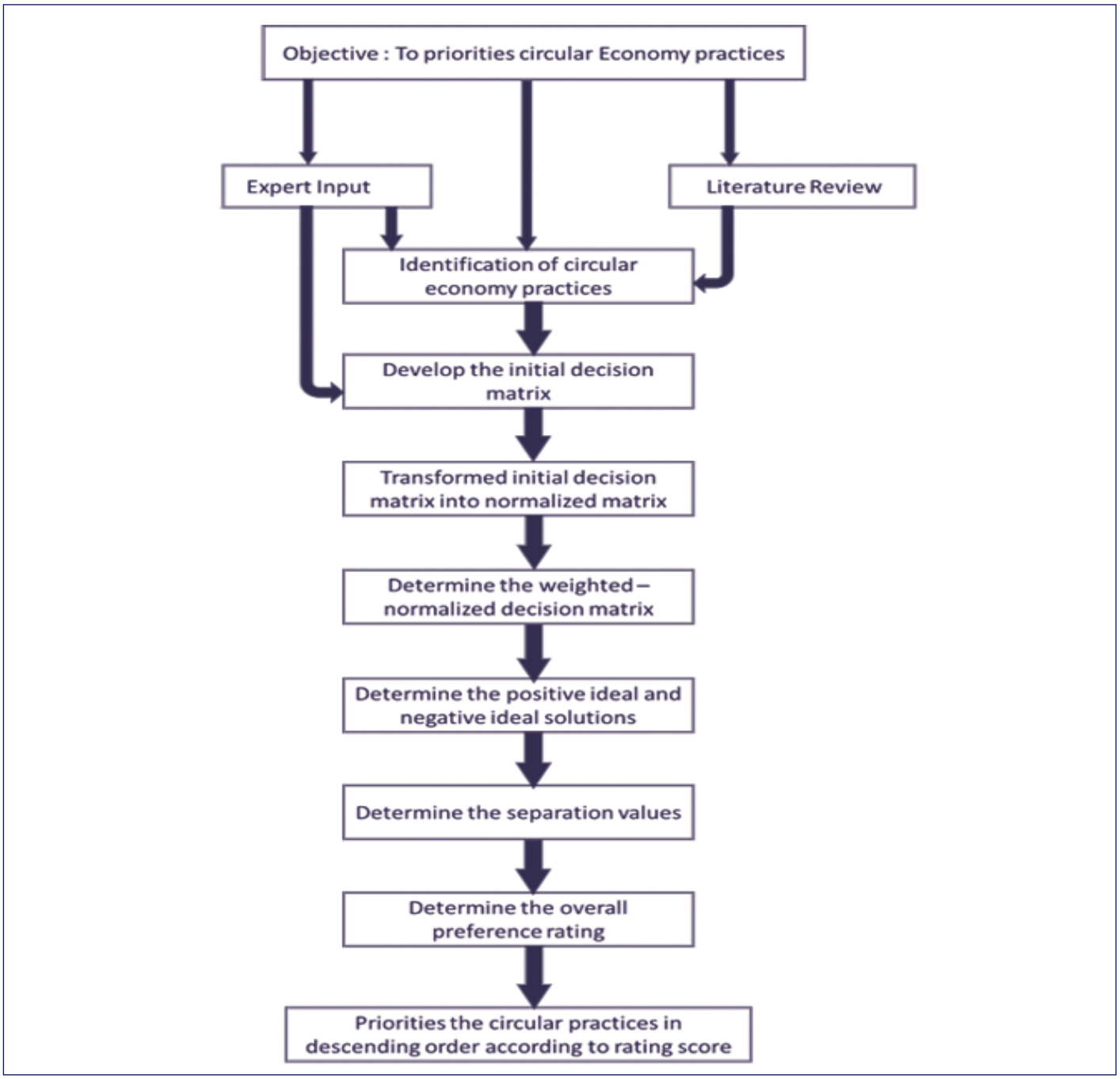
Step 5: Determine the overall preference rating

The overall performance rating η for each alternative is obtained as shown in Eq. (10)

$$\eta = \frac{\delta_i'}{\delta_i^* + \delta_i'} \tag{10}$$

The final ranking of each alternative is provided based on a higher value of η.

Figure 2: A proposed Research framework for this study



RESULTS

Identifying relevant literature on the circular economy, circular supply chain and sustainable supply chain helps identify the circular practices. The Web of Science (WoS) and SCOPUS databases were used to assess current practices in CE. The terms "circular economy AND practices," "circular supply chain AND practices," and "circular economy AND emerging economy or developing economy" were used to conduct this research. Duplicate articles were eliminated from the results, and only English-language articles were taken into consideration. In addition, we have reviewed the abstracts and titles of every publication to ensure that our objective is relevant to them. We selected the article for further examination if it supports our study objective. In this way, 32 articles are completed and then further examined to find any circular practices. After reviewing the selected papers, we have determined the nineteen circular practices.

Following that, five people are added to the expert panel: three from the academics and two professionals with backgrounds in sustainable supply chain management and CE. The experts are chosen from an Indian organization with a minimum staff size of seventy-five. The selection of the excerpt is chosen based on their profession and background in the relevant sector. The chosen experts hold management positions and have over 10 years of professional experience. Of the twelve experts who were contacted initially for this study,

only six indicated that they would be ready to participate. Later five experts were available for this study. Finally, we had proceeded with five experts to conduct this study. Which is considered satisfactory for applying the multi-criteria decision-making (MCDM) method (Rezaei, Ortt, and Scholten 2012). In the literature review of the multi-criteria decision-making (MCDM) technique, we have found that many studies have utilized a less number of experts (e.g. Khan, Haleem, and Khan 2020b; Moktadir et al. 2019; Sufiyan et al. 2019; Dou, Zhu, and Sarkis 2014; Luthra and Mangla 2018; Gupta and Barua 2018), as in contrast to data-oriented approaches, in expert- oriented methodologies we can depend on a less sample of experts (Rezaei, Ortt, and Scholten 2012; Moktadir et al. 2019). The responses provided by these five experts are reliable and used for further analysis.

The first compiled list of circular practices was provided to the panel of experts, who were then requested to offer their respective comments. Subsequently, the collected responses were shared with the experts' group, who were then engaged in a deliberative process to finalize the list of circular practices. In this way, a total of twelve circular practices pertaining to textile industries have been concluded, and these practices are Designing products intended for circularity (CE1), Processes designed to eliminate waste (CE2), Environmental benchmarks for vendor selection (CE3), Staff Training allied to the circular economy practice (CE4), Renewable resources and efficient utilization of energy (CE5), Execution of reverse logistics (CE6), Performance assessment considers the ecological factors (CE7), Develop the culture for circularity adoption (CE8), Awareness of consumer (CE9), Awareness among the supply chain stakeholders (CE10), Government Policies and Legislation (CE11), 5 R's of Circular Economy (CE12).

The final list of circular practices is prepared after that, the prioritization of the alternatives (CE practices) is done using the TOPSIS method. To apply the TOPSIS method, a linguistic matrix is given to each expert, and they reply with respective responses as per the importance of the circular practice. In this way, a linguistic matrix is obtained and shown in **Table 2**.

Table 2: The linguistic term matrix

Alternatives	Expert 1	Expert 2	Expert 3	Expert 4	Expert 5
CE1	VH	H	VH	VH	VH
CE2	VH	VH	VH	VH	H
CE3	H	M	M	H	M
CE4	L	M	M	M	L
CE5	H	H	H	M	M
CE6	H	VH	H	H	VH
CE7	M	M	L	M	M
CE8	M	H	L	M	H
CE9	H	M	M	H	H
CE10	H	H	H	H	M
CE11	H	M	M	H	M
CE12	VH	H	VH	VH	H

The obtained linguistic matrix is now converted into the Initial decision-making matrix by substituting the linguistic terms with the crisp values as per Table 1. After substituting the linguistic term matrix, the initial decision matrix is shown in Table 3. Subsequently, the initial decision-making matrix is normalized using Eq. 2. In this study, we have considered each expert's (criteria) equal importance; thus, equal weight (0.2) is provided to each expert's (criteria) input. Using this, normalization has been done on the initial decision-making matrix by applying Eq. 2. The obtained normalized matrix is shown in Eq. 3.

Further, in Step 2 the weights are integrated with the normalized matrix, this weighted normalized matrix is determined by Eq. 3 and Eq. 4. The final weighted – normalized matrix is shown in Eq. 5.

Further, in Step 3 we determine the positive ideal and negative ideal solutions by using the Equations 6, 7, and 8. While obtaining a positive ideal solution (PIS) and a negative ideal solution (NIS) select the best and worst values according to attributes whether it is a cost attribute or benefit attribute. In our study, we took our all criteria as benefit attributes.

Further, in Step 4, we calculate the separation measures for each alternative. Eq.8 and Eq. 9 show the steps for obtaining negative and positive separation values respectively.

At last in Step 5, we calculate the relative closeness to the ideal solution by using Eq. 10. The overall performance rating by selecting the option closest to 1. Table 4 represents the final ranking of alternatives.

Table 3: Initial decision-making matrix

Alternatives	Expert 1	Expert 2	Expert 3	Expert 4	Expert 5
CE1	5	4	5	5	5
CE2	5	5	5	5	4
CE3	4	3	3	4	3
CE4	2	3	3	3	2
CE5	4	4	4	3	3
CE6	4	5	4	4	5
CE7	3	3	2	3	3
CE8	3	4	2	3	4
CE9	4	3	3	4	4
CE10	4	4	4	4	3
CE11	4	3	3	4	3
CE12	5	4	5	5	4

Table 4: Ranking of each alternative (Circular practices)

Alternatives	NIS	PIS	Closeness TOPSIS Index	Rank
CE1	0.0854	0.0151	0.8496	1
CE2	0.0822	0.0157	0.8399	2
CE12	0.0779	0.0218	0.7816	3
CE6	0.0715	0.0256	0.7364	4
CE10	0.0497	0.0432	0.5350	5
CE5	0.0476	0.0499	0.4877	6
CE9	0.0475	0.0503	0.4857	7
CE3	0.0390	0.0572	0.4056	8
CE11	0.0390	0.0572	0.4056	9
CE8	0.0376	0.0655	0.3648	10
CE7	0.0213	0.0756	0.2196	11
CE4	0.0155	0.0824	0.1582	12

DISCUSSION

The ranking of circular practices is identified through the multi-criteria decision-making technique (MCDM). Among these identified circular practices, the most significant and top prioritized circular practice is 'Designing products intended for circularity'. The circular design is an approach to making products that are more sustainable, efficient, robust, and resilient. The designing for the circularity stretches the life cycle and throughout the product life cycle (from initiation to decline stage) waste is significantly eliminated. The next significant and second-priority circular practice is 'Processes designed to eliminate waste'. In the context of the textile industry to implement this practice, products are designed in such a way that in each process waste is minimized. Waste elimination is the key concept of the circular economy. This is essential for the effective process for circular business activity. The third and next significant practice is the '5 R's of circular economy'. These 5 R's are reduce, reuse, remanufacture, recycle, and refurbish. These R practices are useful and dominant in the Circular economy (CE) literature, and they offer better performances to supply chain processes. The industries must adopt these R practices to attain a circular economy.

The next and fourth significant practice in a row is the 'Execution of reverse logistics'. This is the soul function of the circular economy practice without which this concept is not fulfilled with its soul purpose. The execution of reverse logistics is to promote R practices of reuse, reduce, remanufacture, recycle, and refurbish. This is needed to adopt this circular practice in the textile industry for the successful implementation of circular economy and sustainability. The next significant circular practice is the 'Awareness among the supply chain stakeholders'. A supply chain is a complex network of various activities and stakeholders from the supplier to the end-user consumer. So understanding and awareness at each level in an organization play a vital role in the successful implementation of a circular economy in the industry. Workshop and training programs at the organizational level help in awareness of these practices. The next and sixth circular practice in the row is the 'Renewable resources and efficient utilization of energy'. This practice reduces the energy consumption and energy requirement. This practice can be addressed by using solar energy in the industries. Awareness about the efficient utilization of energy is required in the staff and workers of industry. Prioritazation of Rest of the circular practices are shown in above table 5.

CONCLUSION

This research article analyses the major significant circular practices in the context of the textile industry. This research initially identifies the twelve circular practices through the literature review and expert opinion. After recognizing these crucial circular practices, a multi-criteria decision-making (MCDM) method named TOPSIS is used to prioritize the circular practices based on their significance. The most important circular practices identified in this research article are 'Designing products intended for circularity', 'Processes designed to eliminate waste', '5 R's of circular economy', 'Execution of reverse logistics', e 'Awareness among the supply chain stakeholders', 'Awareness of consumer'. These practices are crucial for a company to efficiently transition towards the Circular Economy (CE). Moreover, the results indicate that knowledge is deficient among consumers and supply chain partners about the Circular Economy (CE) in developing nations, which requires attention. From an operational standpoint, it is crucial to prioritize the design of products for circularity, the use of renewable resources and energy, the execution of reverse logistics, and the adoption of R's practices. To foster sustainability, mitigate environmental consequences, and enhance economic efficacy, it is crucial to adopt circular practices within the textile sector. Companies may effectively address resource depletion and pollution throughout the product the lifespan by using multiple strategies, including recycling, upcycling, and waste reduction. Additionally, circularity presents opportunities for innovation, collaboration, and market differentiation, driving positive change within the industry. However, to realize the full potential of circularity, concerted efforts from all stakeholders in the organization.

LIMITATIONS AND FUTURE SCOPE

This study has many limitations that provide opportunities for further research in the field of the circular economy. One primary constraint is that the identification of circular practices relies on a review of existing literature, and this restriction is widening. Furthermore, experts may possess geographical and cultural prejudices, which may further influence their views. By incorporating fuzzy or gray theory into the chosen approach, the problem of biases may be effectively addressed. This research is built around the limited input provided by experts, which may be further expanded by performing a survey on the chosen practices. The assessment of identified circular practices may also be conducted through the use of other MCDM techniques.

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