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ASSESSING CIRCULAR TEXTILE INDUSTRY DEVELOPMENT

Ingrida Silobrit[1], Daiva Jureviciene[2]

[1]Vilnius Gediminas Technical University - VILNIUS TECH, Vilnius, Lithuania,, ingrida.silobrit@stud.vilniustech.lt

[2]Vilnius Gediminas Technical University - VILNIUS TECH, Vilnius, Lithuania, daiva.jureviciene@vilniustech.lt, ORCID ID: orcid.org/0000-0002-0039-6290

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Abstract

Research purpose. Identify the main textile exporters in the global world that would have the greatest impact on the development of geared textiles.

Design / Methodology / Approach. TOPSIS analysis has been applied as the most widely used efficiency measurement technique. The six criteria in the current research have been selected to describe the leading players in textiles globally and are available in a public database. In addition to the TOPSIS analysis, a clustering method has been employed to identify distinct groups among the countries under examination. Through this clustering analysis, countries with similar characteristics and practices.

Findings. The analysis of the textile and clothing industry has revealed the top ten economies that make the most significant contributions to global textile production. Through a comprehensive assessment based on predetermined criteria, these economies have been closely scrutinised, resulting in the European Union securing the leading position, followed by Malaysia in second place and China in the third. The leading position of the European Union can be attributed to its robust economic infrastructure, strong policy frameworks promoting sustainability, and a growing commitment to circular economy principles within the textile sector. Malaysia's second-place position may be influenced by its strategic investments in the textile industry, favourable business environment, and initiatives to foster sustainable practices. China's third-place ranking can be attributed to its substantial textile manufacturing capacity, extensive supply chains, and efforts to integrate circular economy principles into its textile production. The research findings indicate that several factors influence the rankings, including the level of economic development, technological advancements, population size, availability of cheap labour, and the influence of fashion trends, among others.

Originality / Value / Practical implications. The circular textile industry is a relatively new field, with the European Commission announcing the EU Strategy for Sustainable and Circular Textiles in 2022. This strategic initiative aims to propel the development and adoption of circular textile practices throughout the European Union, setting a benchmark for other regions to follow. It is important to underline that the study was carried out on a global scale in order to assess the world's main textile exporters. In order to assess the progress of circular textiles, we employ the TOPSIS (Technique for Order of Preference by Similarity to Ideal Solution) method. This approach allows us to rank and assess countries based on their implementation of strategies and initiatives for developing a circular textile industry. Furthermore, we utilise a clustering method to identify distinct groups or patterns within the data, enabling a deeper understanding of the similarities and differences among countries in their circular textile. This clustering analysis helps identify clusters of countries that exhibit similar characteristics or practices, facilitating the identification of best practices, knowledge sharing, and collaboration among countries within each cluster. The findings of this study hold significant value and practical implications for policymakers, industry stakeholders, and researchers.

Keywords: Circular textile industry; TOPSIS method; Clustering method.

JEL codes: C830; D160; D120; O440

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Introduction

The global market has seen a rapid exchange of raw materials and products over the past decades, with exports and imports fuelling the development of the international economy. International links and economic growth are increasing consumer demand. Businesses are producing more and more products, and consumption is increasing, leading to the irrational use of land resources. One of the largest irrational consumption industries is textile production. Textile production is the second most polluting industry in the world, behind the oil industry, which emits around 1.2 billion tonnes of greenhouse gases (more than international flights and maritime shipping combined) (Chen et al., 2021). In addition, the textile sector employs more than 1.5 million people, with more than 160 000 companies and a turnover of EUR 162 billion in 2019 (European Commission, 2022*).* In the context of the textile industry, the circular economy paradigm emphasises the need to shift from the traditional 'take-make-dispose' model to a more sustainable and regenerative framework. This entails implementing strategies such as recycling, upcycling, and reusing textiles, as well as promoting eco-design, product durability, and extended producer responsibility (Clark et al., 2016). By transitioning to a circular textile economy, numerous environmental benefits can be achieved. For instance, it can significantly reduce the extraction of virgin resources, decrease energy consumption, limit water usage, and mitigate pollution associated with textile production. Moreover, the circular textile industry offers opportunities for job creation, innovation, and the development of new business models. To accelerate the development of the circular textile industry, governments, businesses, and consumers must collaborate and align their efforts. Policy interventions, such as regulations that incentivise circular practices, can drive the adoption of sustainable production and consumption patterns. Additionally, fostering consumer awareness and education on the environmental and social benefits of circular textiles can stimulate demand and drive market transformation.

Literature review

Theoretical aspects of the circular textile economy

Today, one of the solutions to the global resource crisis and global warming is to change the entire supply chain from linear to circular. All industries are involved in this global change. One industry is fashion, with a global fashion industry worth USD 3,000 billion, representing more than 2% of the world's gross domestic product (GDP) (Shirvanimoghaddam et al., 2020). In just a few years, the circular economy has become a central tenet of industrial and environmental policy in China, Africa, the European Union (EU) and the United States, as well as to a growing list of corporations and local governments (see, for example, Ellen MacArthur Foundation, 2017) (Corvellec et al., 2022). As a result, the circular textile industry is increasingly mentioned in international agreements and policy strategies. One of the United Nations' goals for the textile sector is Goal 12 of the Sustainability Implementation Plans, which refers to sustainable production and consumption. Its concept is to change the supply chain to cover the entire cycle from product production to disposal (Muthu & Gardetti, 2020). We will discuss the circular textile industry later, but it is essential to identify the circular economy in general.

There are many definitions of the circular economy in the literature, and theoreticians and practitioners have different interpretations of the concept, and here are some of the relevant definitions (Table 1).

Table 1. The circular economy in Literature (Source: compiled by the author based on the sources cited)

Author and year	Circular economy
Suchek et al. (2021)	CE has a regenerative system that reduces resource input and waste, emissions and energy consumption by slowing, closing and straightening material and energy chains.
Grigoryan & Borodavkina (2017)	A new business model that requires a transformation of processes, from production to relationships with end users and customers. This model is an effective way to improve companies' competitiveness and contribute to social responsibility development.
Kirchherr et al. (2018)	A business model for an economic system that changes the concept of end-of-life for products. Reducing material reuse or recycling in the production, distribution and consumption processes to achieve sustainable development, which has the impact of creating environmental and economic prosperity and social equity for the benefit of present and future generations.

Summarising the circular economy is a new business model that involves an economic or renewable system, an adaptable synthesis approach in which resources and waste inputs, emissions and energy losses are closed into a closed cycle of energy and materials. In the current literature on the circular economy, this model seeks efficient resource management by covering all objects and processes in the chain throughout the entire life cycle and is characterised by closed loops that encourage maintenance, reuse and recycling. The circular economy is an alternative to the traditional economy (production, use and recovery). We keep resources in the chain for as long as possible, try to maintain their value during their lifetime and use them to produce new products. This model is illustrated in Figure 1, which shows the cycle's closing.



Fig. 1. The circular economy model (Source: H^2AD, 2017)

The circular economy is based on this model. The circular textile industry promotes three main activities: resource reduction, litter, reuse and recycling, typical of the traditional waste management approach (Ozili, 2021). Reduction involves reducing waste at all stages of production (including minimal use of raw materials) and at different stages of consumption and use. Reusing in this space requires rethinking production to obtain easily recyclable or usable products for other applications. Ultimately, increased reuse will reduce the increased demand for production (Chen et al., 2021), but it is important to stress that other activities will be covered.

The main actors in this system are the users of the biological cycle and the users of the technical cycle. Other stakeholders related to this definition are the service provider, the product manufacturer, and the part manufacturer. The three main principles of this model are as follows: firstly, preservation and enhancement of natural capital. Secondly, longer product and material cycles in both cycles and, thirdly, waste design. The principles of the circular textile industry are described in more detail in Table 2, which presents the characteristics provided by the different authors and adapted specifically to the fashion industry.

Table 2. Characteristics of the principles of a circular textile economy (Source: compiled by the author on the basis of the sources provided)

Principles of the circular textile industry	Basic characteristics
Textile sorting	The process by which textiles are collected from consumers into dedicated containers from which they are redistributed to centres for further use, incineration, or reuse in the manufacture of new products (Nikolic & Kostic-Stankovic, 2022).
Biodegradation of textiles	Use living organisms or enzymes to help clothes decompose faster. This approach can bypass sorting, reducing overall costs and waste (Chen et al., 2021).
Textile refusal	When a product is abandoned, unnecessary, or its function becomes redundant, choosing a product that performs the same function. Abandonment also refers to abandoning materials to optimise production (Morselellto, 2020).

Rethinking Textile	Rethinking objectives and strategies related to using textiles, recycled materials, and virgin and reusable materials (Clark et al., 2016).
Textile recycling	Recycling - when a by-product material is converted into a product of different quality, functionality or value (Worrell & Reuter, 2014).
Reusing textile	Reuse of textiles through resale and rental, use of garments for transfer from the original user to another user (Chen et al., 2021).
Reducing textile use	Reducing the use of textiles and their further use in other products. Use fewer natural resources, energy, raw materials and waste (Kirchherr et al., 2017).
Textile renovation	The reuse of textiles that perform the same function. Refurbishment of textiles means that other materials can be used to refurbish them (Kirchherr et al., 2017).

The characteristics of the principles of the circular textile economy, as described by different authors, vary. However, the idea is to minimise the use of resources by rethinking each consumer's choices and motives when choosing used textiles or renewing existing textiles. Less than 1% of clothing is recycled globally, partly due to a lack of appropriate technology (European Commission, 2022). In this case, the responsibility of the technical users - the manufacturing companies or businesses in general - is very high. Since they must review their existing technologies, established strategies and sales policies, technical users should set strategies based on sustainability, green economy principles, socially responsible business and the public good. Integrating these principles is a long and complex process. The following section will look at the economic and behavioural theory and how it can influence the development of the circular economy. It is also noted that much of the literature on the circular textile industry has focused on the production side, exploring circular business models, strategies for creating circular value propositions and the benefits of such models. However, less attention has been paid to how consumption and consumers affect or are affected by the circular economy. Therefore, the following section analyses behavioural economics and its impact on the circular textile industry in the context of consumption.

To summarise the literature review on the circular textile industry, the concept of the circular textile industry currently needs to be widely accepted. This concept is derived from the circular economy. It is still a definition that has yet to be found in the literature. It is frequently used in legislation, at global meetings and, of course, in new agreements and strategies, both in the European Union and in United Nations agreements. However, the value of the textile sector is evident, with an estimated increase of USD 192 billion in the global economy by 2030 in the fashion industry (Chen et al., 2021). Therefore, this will certainly further the analysis and evaluation of the actors, processes and opportunities for increasing the efficiency of the circular textile industry.

Research Methodology

When analysing the circular textile industry globally, we must look at international, transnational agreements. One of the critical United Nations Sustainable Development Goals is the proposal for waste legislation, which aims to increase global competitiveness, promote sustainable business and create new jobs in the transition to the circular economy. In order to analyse the development of the circular economy, it is necessary to clarify and identify the indicators needed for the analysis.

Due to the topic's novelty, the indicators for a circular textile industry still need to be identified for proper assessment and calculation. Therefore, based on the indicators provided by the European Union for the circular economy - Eurostat database and scientific insights, the following data were selected: used clothing exporters (billion US dollars), used clothing importers (billion US dollars), footwear and headgear exporters (billion US dollars), footwear and headgear importers (billion US dollars), textile exporters (billion US dollars), textile importers (billion US dollars).

A multi-criteria decision-making approach, the Technique for Order Preference by Similarity to the Ideal Solution, is used to assess the performance of the circular textile economy. In the following, we will refer to this method as TOPSIS. This method defines the rationality of options when the distance between the ideal positive and the ideal negative is sought, the minimum distance between the optimal

alternative from the ideal solution and the maximum distance from the worst solution (Simanaviciene, 2016).

The sequence of the TOPSIS solution method is described below; the elements of the decision matrix are normalised according to formula (1) (Simanaviciene, 2016).

$$n_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x_{ij}^2}} \tag{1}$$

where:

x_{ij} - is the value of the j-th indicator of the i-th alternative.

In the next step, the weights of the criteria are calculated on the basis of the Criteria Importance Through Intercriteria Correlation (Criteria Importance Through Intercriteria Correlation). In the following, we will refer to this method as CRITIC. We construct the decision matrix X (formula 2) (Adali & Isik,2017). It shows the performance of the different alternatives with respect to the different alternatives.

$$X = \left[x_{ij}\right]_{m\times n} = \begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1n} \\ x_{21} & x_{22} & \cdots & x_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ x_{m1} & x_{m2} & & x_{mn} \end{bmatrix} \; i \in \{1,2,\dots,m\}, j \in \{1,2,\dots,n\} \tag{2}$$

where:

x_{ij} - the efficiency value of the i-th alternative for the j-th criterion.

The decision matrix is then normalised according to formula (3):

$$r_{ij} = \frac{x_{ij} - x_j^{min}}{x_j^{max} - x_j^{min}}, i \in \{1,2,\dots,m\}, j \in \{1,2,\dots,n\} \tag{3}$$

where:

x_j^{max} - j-th largest value;

x_j^{mi} - the j-th smallest value.

Calculate the standard deviation. σj for each element of rij.

Also, we find the correlation coefficient with each normalised element and construct a symmetric matrix with Rij (4):

$$\sum_{j=1}^{n} (1 - R_{ij}) \tag{4}$$

where:

R_{ij} - the correlation coefficient between the two criteria.

The information content of the criteria is calculated in (5):

$$C_j = \sigma_j \sum_{j=1}^{n} (1 - R_{ij}) \tag{5}$$

where:

σ_j - the standard deviation of criterion j-th.

The weighting of the criteria considers both the standard deviation of the criterion and its correlation with the other criteria, as well as the correlation between the criteria. Taking this into account, the weight (wj) of the jth criterion is given by (6):

$$w_j = \frac{c_j}{\sum_{j=1}^{n} c_j} \tag{6}$$

Using the weights of the indicators nj j ω =, 1, and the normalised elements of the decision matrix, a weighted normalised matrix (7) is created:

$$v_{ij} = w_j n_{ij} \text{ for } i = 1, \dots, m; j = 1, \dots, n \tag{7}$$

The elements of the weighted normalised matrix are used to construct the 'ideal best' alternative according to formula (8) (Simanaviciene, 2016)

$$V^+ = (v_1^+, v_2^+, \dots, v_n^+) = \left(\left(\max_i v_{ij} | j \in I \right), \left(\min_I v_{ij} | j \in J \right) \right) \tag{8}$$

J - a set of indices with higher values for the indicators with better performance;
J′ - a set of indices for indicators with lower values that are better.
In addition, a "negative-ideal" alternative is generated according to formula (9):

$$V^- = (v_1^-, v_2^-, \dots, v_n^-) = \left(\left(\min_i v_{ij} | j \in I \right), \left(\max_I v_{ij} | j \in J \right) \right) \tag{9}$$

The distance between the comparative i-th alternative and the "ideal best" + A alternative is determined by calculating the distance in n-dimensional Euclidean space according to formula (10) (Simanaviciene, 2016):

$$S_i^+ = \sqrt{\sum_{j=1}^{n} \left(v_{ij} - v_i^+ \right)^2} \quad , \quad i = 1,2, \dots, m. \tag{10}$$

and between the i-th alternative and the "negatively ideal" alternative A, according to formula (11):

$$S_i^- = \sqrt{\sum_{j=1}^{n} \left(v_{ij} - v_i^- \right)^2} \quad , \quad i = 1,2, \dots, m \tag{11}$$

The final step of the TOPSIS method is to determine the relative distance of each i-th alternative to the "ideally worst" alternative according to the following formula (12):

$$P_i = \frac{S_i^-}{S_i^- + S_i^+} \tag{12}$$

where:

S_i^- - the distance between the comparative i-th variant and the negative-ideal variant;

S_i^+ - the distance between the i-th comparator and the ideal best option.

A priority ranking of the alternatives is established based on the Pi index values. The rational alternative is the one whose Pi value is closer to one the closer the comparative i-th option is to a+, i. e. the Pi value is the highest (Simanaviciene, 2016).

When we look at the indicators of the circular textile economy, we see that it is a large dataset, so one solution is to classify the data. Cluster analysis refers to a variety of numerical data analysis techniques

for identifying and interpreting groups or clusters of homogeneous and distinct objects. A cluster is a group of similar objects. The main objective of cluster analysis is to group objects in such a way that differences within clusters are minimised, and differences between clusters maximised. Based on the steps and formulas are presented below (Bileviciene & Jonusauskas, 2011). Stages of cluster analysis:

1. Select the clustering objects.

2. Choose the attributes to be clustered.

3. Choose a quantitative measure to assess the similarity of the objects.

4. One of the methods to classify objects into clusters.

5. Interpret the results.

In the study, all clustering steps were completed. Next, a proximity measure is selected.

For the cluster analysis, one metric distance measure was chosen. The essence of the measures is that the higher the value, the more dissimilar the objects are. There is a variety of these measures; during the tests and calculations, the Euclidean distance square was chosen. The Euclidean distance squared must be applied with the choice of the centroid, median or Ward clustering method. The Euclidean square of the distance between objects X and Y is calculated using formula (13):

$$d(X,Y) = \|X - Y\|^2 = \sum_{i-1}^{M} (x_i - y_i)^2 \tag{13}$$

where:
m – number of attributes

The study uses Ward's method, taking a pair of clusters and calculating the sum of the squares of the deviations of the feature vectors from the centre of the joint cluster. The same is done with the other pair of clusters, and so on. The clusters that are merged are those with the lowest sum of deviations.

The Ward similarity measure is calculated as (14) (Bileviciene & Jonusauskas, 2011):

$$\mathrm{d(U,V)} = \frac{1}{\frac{1}{n_U} + \frac{1}{n_V}} \|\bar{U} + \bar{V}\|^2 \tag{14}$$

where:
$\bar{U}, \bar{V}$ – averages of the feature vectors of the objects forming the clusters;
n_u – number of objects in cluster U;
n_v - number of objects in Cluster V

In this work, also for comparison purposes, the data variables were standardised so that all variables have the same influence on the distance calculation. Using SPSS, the data were standardised and calculated again using Ward's method with Euclidean distance squares.

Research results

Data for 2020 were used in this work, as not all countries and indicators have been published in the The Observatory of Economic Complexity (OEC) database for 2021. The nine countries of the world and the European Union, which are the largest exporters of textiles, were selected. The selected countries and the EU are mutually exclusive, as the EU countries share the same circular textile economy policy, and it is, therefore, more valuable to choose the EU rather than individual countries for further research

and conclusions. The top exporters analysed are the European Union, China, Malaysia, India, Hong Kong (China), the United Kingdom, Indonesia, Vietnam, Turkey, and Bangladesh.

For the analysis of the circular textile economy, eight indicators, in other words, criteria, were selected. The list of benchmarks was selected taking into account public data available on The Observatory of Economic Complexity (OEC), relevant requirements and standards. The criteria analysed were: 1. Exporters of second-hand clothing (USD billion), 2. Importers of second-hand clothing (USD billion), 3. Exporters of footwear and headwear (USD billion), 4. Importers of footwear and headwear (USD billion), 5. Exporters of textiles (USD billion), 6. Importers of textiles (USD billion), 7. Population, total, 8. GDP per capita (current, USD). A detailed description of the indicators is given in Annex 1. All indicators are maximising.

The analysis of the markets of the selected countries starts with the European Union, a giant in the textile industry. The main sorting centres are located in Western and Eastern Europe. Only about 10-12% of second-hand clothing (only the highest quality) is sold in local second-hand shops. Also, importantly, the amount of textiles purchased per person in the EU has increased dramatically since 1996, as the market itself has reduced prices very sharply, resulting in shorter wearing times. (Nguyen & Mogaji, 2023). Unrecyled textiles are either incinerated or sent to a landfill.

In India and Pakistan, second-hand garment residues are imported and sorted by sorting companies. Worn clothing is extracted from "mixed rags" and sold locally or sent to Africa. The recycled yarns are used to make new sweaters. Cotton wipers made from second-hand clothes are exported to the USA.

The TOPSIS survey method requires criterion weights to ensure the reliability of the results. The criterion weights were calculated using the CRITIC method, and the results are shown in Table 3:

Table 3. Results of the weighting of the criteria (Source: authors' contribution)

Σ *σ	0,97818	0,92960	2,10293	0,93136	1,48138	0,96041	2,53131	2,30533
WJ	0,08004	0,07607	0,17208	0,07621	0,12122	0,07859	0,20714	0,18864

Knowing the weights and identifying the significance of the criteria (maximising and minimising), we calculate the ideal positive solution (V+) and the ideal negative solution (V-). The resulting ideal positive and negative solutions are shown in Table 4:

Table 4. The result of the ranking of the ring textile economies using the TOPSIS method (Source: authors' contribution)

Si+	Si-	Pi	RANK	Countries
0,16643	0,17027	0,50569	1	European Union
0,24493	0,16216	0,39834	2	Malaysia
0,21303	0,10678	0,33388	3	China
0,28597	0,01981	0,06478	4	Viet Nam
0,26322	0,01206	0,04382	5	India
0,29270	0,01240	0,04064	6	Bangladesh
0,27445	0,00890	0,03141	7	United Kingdom
0,29111	0,00942	0,03134	8	Turkey
0,28732	0,00520	0,01778	9	Indonesia
0,28187	0,00089	0,00316	10	Hong Kong, China

The table shows that the European Union is in first place and Hong Kong, China is in tenth place. Based on this table, we can conclude that the alternative is the European Union, in terms of the selected indicators, which has most appropriately developed a circular textile economy strategy. In terms of suitability, Malaysia is in second place, China in third place and Vietnam and other countries in fourth place. A priority ranking of the alternatives has been drawn up (Table 4) and ranked from lowest relative distance to highest.

A cluster analysis was carried out using SPSS to group the ten alternative countries. The aim of this study is to group countries according to their common features/criteria set. It is important to note that there were no data gaps, hence the percentage of 0 in Table 5. Clustering was attempted in several ways, but the best option was found to be the hierarchical Ward's method with the Euclidean distance squared measure.

Table 5. Clustering study results (Source: authors' contribution)

Case Processing Summary[a,b]

Cases					
Valid		Missing		Total	
N	Per cent	N	Per cent	N	Per cent
10	100.0	0	.0	10	100.0

a. Cosine of Vectors of Values used

b. Complete Linkage

For hierarchical clustering, the best result was obtained using Ward's merging method with Euclidean distance measure. The results are shown in the dendrogram, Figure 2:

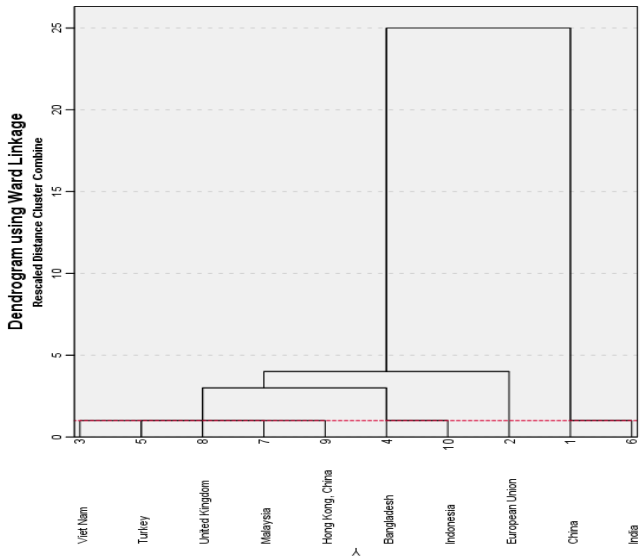


Fig. 2 Hierarchical clustering by Ward's join method with Euclidean square measure dendrogram
(Source: compiled by the author using SPSS software)

Ward's method separated two clusters consisting of eight and two countries each. However, in order to describe and interpret the result more precisely, it was chosen to group into 4 clusters, so a cut is made below, which separates the countries into the clusters to which they belong:

Cluster 1: Vietnam, Turkey, the United Kingdom, Malaysia, and Hong Kong, China.

Cluster 2: Bangladesh, Indonesia.

Cluster 3: the European Union.

Cluster 4: India, China.

Considering the layout of the clusters, it can be explained that, according to the circular textiles set of criteria, the distance between two clusters is defined as the maximum distance between the members, i.e., the distance between the two entities that are furthest from each other.

A comparison of the indicators selected by the studies shows that countries could have been clustered in this way because of the similarity of the data. Ward's method with the Euclidean distance measure allows for the identification of clusters based on the proximity of data points, facilitating the grouping of countries that exhibit similar characteristics and trends in their circular textile industry development.

The clustering analysis based on the provided data offers insights into the similarities and differences among countries in their circular textile industry development. It highlights countries that exhibit comparable patterns in terms of their trade activities, population, and economic indicators. Understanding these clusters can provide useful information for policymakers, industry stakeholders, and researchers to identify commonalities, share best practices, and foster collaboration in advancing the circular textile industry.

Moreover, in today's global market, products are often produced, purchased, disposed of, and recycled in different geographic locations, leading to a significant transfer of resources across the globe. High-level international policies, such as the Basel Convention (2018), have been established to regulate and prevent the transboundary movement and disposal of hazardous waste. However, the effective implementation of these policies has consistently posed challenges for both developed and developing countries (Qu et al., 2019). This highlights the interconnected nature of the circular textile industry and emphasises the critical importance of international collaboration and adopting resource optimisation strategies to address the complex and global nature of resource flows and waste management practices.

It is relevant to assess the existing research on circular textiles worldwide and compare it with the findings presented in this study. A database comparison of research articles was conducted using keywords such as circular economy, circular economy industry development, clustering, and the TOPSIS method. Most of the articles found employed qualitative research methodologies utilising the TOPSIS and clustering methods to evaluate the characteristics of circular textiles. However, a limitation observed in many studies was the lack of statistical data, relying mainly on literature reviews. One particular study examined the circular economy using the TOPSIS method to assess waste and identified ten strategies to provide optimal solutions for organisations. Among these strategies, the integration of CE design tools was found to be the most influential (Maliha et al., 2023). Another study analysed the network of companies in the textile industry using the clustering method, focusing on the textile companies with the highest connections (Sheresheva et al., 2022). Additionally, the research highlighted the challenges faced by the largest textile exporters, China and the European Union, emphasising the sustainability of textile reuse and recycling compared to incineration and landfill, with a particular emphasis on the benefits of reuse (Juanga-Labayen et al., 2022). These findings underscore the importance of international cooperation, promoting textile reuse, and exporting used textiles to economically disadvantaged countries.

In summary, the utilisation of the TOPSIS method in conjunction with Ward's merging method and the Euclidean distance measure in the clustering analysis significantly enhances our comprehension of the circular textile industry. This approach offers valuable insights into fostering sustainable practices, optimising resource efficiency, and facilitating collaboration among countries to advance a more circular and sustainable textile industry.

Conclusions

By analysing the literature, we can define the circular textile industry as a transformative approach that adopts a renewed economic business model. In this model, the focus is on reducing resources, inputs, emissions, and other energy losses by establishing a closed-loop system where materials circulate within a single chain. The principles of the circular economy are applicable to every aspect of the textile industry, making it imperative to take prompt action. Given the fashion industry's significant environmental impact and contribution to pollution, proactive measures are crucial. To drive circular textile industry development, the following key principles need to be considered: textile sorting,

biodegradation of textiles, textile refusal, rethinking textiles, textile recycling, reusing textiles, reducing textile use, and textile renovation.

The analysis of the circular textile economy shows that countries have not yet produced annual reports to assess the development of the circular textile economy. Therefore, in order to assess and further investigate the global situation, criteria have been selected that, based on the principles of the circular economy, would allow the evaluation of the main players in textiles and clothing. The main criteria chosen were as follows: exporters of second-hand clothing (USD billion), importers of second-hand clothing (USD billion), exporters of footwear and headgear (USD billion), importers of footwear and headgear (USD billion), exporters of textiles, (USD billion), importers of textiles (USD billion), population, total, GDP per capita (current, USD). Due to a lack of accuracy and data, the ten countries that are the leading players in textiles were assessed. The paper adopts a multi-criteria decision method, which ranked the countries according to the result obtained. Also, a hierarchical clustering Ward's clustering method was chosen, which groups countries into clusters based on similarity criteria.

The assessment of the circular textile economy, based on a set of criteria using the TOPSIS method, after ranking ten countries, shows the European Union is in first place, Malaysia in second place, and China in third place. The results of the clustering analysis using Ward's method with the Euclidean distance squared measure provide interesting insights into the grouping of countries based on the selected criteria. Cluster 1 consists of Vietnam, Turkey, the United Kingdom, Malaysia, and Hong Kong, China; Cluster 2 comprises Bangladesh and Indonesia; Cluster 3 consists of the European Union; Cluster 4 includes India and China. These countries might share similarities in certain aspects of their circular textile industry development based on the analysed criteria. Further exploration could shed light on the specific factors that contribute to their inclusion in this cluster. Overall, the clustering results provide a foundation for understanding the similarities and differences among countries in their circular textile industry development.

The literature analysis indicates that many sources related to the development of the circular textile industry are qualitative due to the lack of publicly available statistics for analysis. Assessing circular textiles faces challenges and information gaps, including the need for comprehensive data on resource efficiency, such as water and energy consumption, material waste, recycled inputs, and economic behaviour. Obtaining accurate and consistent data from stakeholders along the supply chain remains challenging. Additionally, tracking recycling and reuse rates requires reliable data on the volume of textiles recycled or reused, hindered by limited reporting and tracking systems. These challenges and information gaps present significant barriers to a comprehensive assessment and the progress of circular textiles. Future research should focus on improving data collection, enhancing transparency and traceability, and fostering collaboration to overcome these barriers and advance the circular textile industry.

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Annex

	Exporters of Used Clothing (2020) mln. Usd	Importers of Used Clothing (2020) mln. Usd	Exporters of Footwear and Headwear (Billion dollars)	Importers of Footwear and Headwear (Billion dollars)	Exporters of textiles, 2020 Billion dollars	Importers of textiles,2020 Billion dollars	Population, total	GDP per capita (current US$)
China	404	37,5	52,5	4,66	276	25,7	1,411,100.00	10,408.7
European Union	170685	936,9	45,13	63,57	179	738,7	447,479.49	34,191.8
Viet Nam	1,17	6,76	19,2	2,22	38,9	20,3	97,338.58	3,526.3
Bangladesh	0.000309	7,12	1,41	0,298	37,3	10,7	164,689.38	2,270.3
Turkey	52,5	29,5	0,938	0,55	28,5	9,29	84,339.07	8,536.4
India	64,2	93,9	2,44	0,863	29,7	6,27	1,380,004.39	1,933.1
Malaysia	56	105	206	0,976	3	5,14	32,366.00	10,412.3
United Kingdom	315	43,1	2,07	6,13	10	35,3	67,081.00	41,098.1
Hong Kong, China	7,78	5,78	0,574	0,05	4,94	10,4	7,481.00	46,101.0
Indonesia	1,62	20,3	5,34	0,971	11,9	7,7	273,523.62	3,870.6