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Mapping of the Circular Economy Implementation Challenges in the Fashion Industry: a Fuzzy-TISM Analysis

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Abstract

The fashion industry creates a large amount of pollution, making it one of the least environmentally friendly industries in the world with an ever-growing adoption of the linear fashion system “take-make-dispose” that continues to exploit scarce natural resources and energy. This advocate shifting to a circular economy to achieve sustainable production and consumption. However, numerous challenges are faced when introducing the principles of circular economy, obstructing the system transition. The ten challenges identified from the literature include poor material and energy efficiency, poor circular design, technological challenges, regulatory pressures, internal stakeholders’ pressures, financial pressures, insufficient human capital, poor management and leadership, lack of external collaborations, and consumer-related challenges. This research aims to identify the level of significance of the challenges identified from the literature to assist top management with formulating a strategy. Decisions will be made and prioritised based on the key challenges to ensure a successful and effective implementation of the circular economy in the fashion industry. To achieve the aim of this research, seven experts within both the circular economy and fashion context are interviewed. Fuzzy Total Interpretive Structural Modelling (Fuzzy-TISM) is used to arrange the challenges into a hierarchy-based model and to illustrate the interrelationship between these challenges. Also, Fuzzy MICMAC analysis is used to map and rank these challenges depending on their driving and dependence power. Based on the findings, regulatory pressures and poor management and leadership are the key challenges with the highest significance level. Therefore, successful and effective implementation of a circular economy requires a change in managerial strategies.

Keywords Circular economy · Fashion industry · Implementation challenges · Fuzzy-TISM · Fuzzy MICMAC analysis

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Introduction

There is no doubt that the fashion industry is amongst the world's most significant industries. Still, it is also amongst the highest contributors to environmental damage and social and ecological footprints [1, 2]. Not only does clothing play a crucial part in our daily lives, but a significant amount of the global workforce is based within the sector at over 300 million as of 2017, and consistently growing [3]. In the UK, the fashion industry has around 800,000 employees working in manufacturing, wholesale, retailing, and services, generating a revenue of over 100 billion pounds [4]. In Europe alone, fashion item manufacture employs approximately 1.7 million people and generates over €165 billion of income [5]. In 2021, the fashion industry's global revenue was about $1.5 trillion [6]. Therefore, it massively supports employment, especially in low-income countries, and significantly supports global economies.

However, the fashion industry alone consumes over 50% of the textiles available worldwide, comprising various non-renewable natural resources [3]. Moreover, the fashion industry processes across the value chain account for nearly 20% of global water waste and almost 10% of the world's carbon emissions per year [7, 8]. According to Atstja et al. [9], more than 95% of clothing materials can be recycled, but only 1% of them are recovered by the industry for reuse and recycling. In recent years, clothing production has increased by over 50%, and clothing usage has declined by over 40% [3]. Consequently, the fashion industry is facing a growing amount of textile waste, particularly with the rise of fast fashion, which increases the number of collections per year, lowers prices, and prompts quicker changes in styles and trends [10].

The rapid increase in the world's population and the rising environmental pressures and climate change are stimulating governments, organisations, and societies to work on conserving scarce natural resources [11]. Circular economy (CE) is one of the new approaches to address these issues. The most popular definition for the circular economy is provided by the Ellen MacArthur Foundation, which defines the circular economy as "the principles of designing out waste and pollution, keeping products and materials in use, and regenerating natural systems" [12]. Therefore, the circular economy advocates the shift from linear economies like the "take-make-dispose" approach to the "take-make-reuse" to address the threats and consequences of the linear fashion system [8, 13]. Moreover, the United Nations set 17 Sustainable Development Goals (SDGs). One way to fulfil them is to implement a CE, particularly SDG 12: "Responsible Consumption and Production", which emphasises efficient management and use of scarce natural resources and goods [10, 14, 15]. The CE is considered a systematic approach aiming to reduce waste from occurring in the first place and keep resources within the economy. This is done by re-distributing items' intrinsic value by reusing instead of dismissing them. However, the fashion industry must deal with challenges that obstruct the shift from a linear to a CE.

The efforts to explore these challenges have been growing in recent years due to the emerging nature of the CE in the fashion context. The existing research has proposed different categorizations to resolve the challenges of implementing a CE in the fashion industry. However, the current research lacks the information required at the early stages of the decision-making phase that identifies the level of significance for each challenge. This causes the arrival of further challenges within the implementation process. This research identifies the level of significance for several challenges identified from the literature to assist top management with formulating a strategy and making decisions for a successful and effective implementation. This research contributes to the gap in existing research by using the Fuzzy-TISM to identify the interrelationship between the challenges and to arrange these challenges into a hierarchy-based model. This helps to simply visualise the complex system of challenges and reveal direct and indirect impacts of each of the challenges identified from the literature. Fuzzy MICMAC will additionally analyse, map, and rank these challenges depending on their driving and dependence power. To achieve the aim of this paper and fill the research gap, the research is designed to address the following research questions:

1. What is the interrelationship between the challenges of implementing a CE in the fashion industry identified from the literature?
2. What is the significance level of the challenges for implementing a CE in the fashion industry identified from the literature?
3. What are the key challenges of implementing a CE in the fashion industry identified from the literature that need prioritising and addressing by management?

The paper aims to achieve its objectives and address the research questions throughout its six sections: “Introduction”, “Literature Review”, “Methodology”, “Results”, “Discussion”, and “Conclusion”.

Literature Review

Existing literature identifies various challenges to introducing a CE, and further research categorises these challenges into different categories. Table 1 provides an overview of reviewed sources that focus on the challenges of introducing a CE without a specific industry context. On the other hand, Table 2 illustrates an overview of the challenges reviewed from the literature focused on introducing a CE in the fashion industry context.

Based on the review of existing literature and research, this paper focuses on the challenges of introducing a CE in the fashion industry whilst also considering the challenges faced in other sectors when applicable. Therefore, ten main challenges of introducing CE in the fashion industry were identified, including *poor material and energy efficiency*, *poor circular design*, *technological challenges*, *regulatory pressures*, *internal stakeholders' pressures*, *financial pressures*, *insufficient human capital*, *poor management and leadership*, *lack of external collaborations*, and *consumer-related challenges* (Fig. 1). These challenges cover most areas and are discussed in detail in the following sub-sections.

Poor Material and Energy Efficiency

The fashion industry's transition to a CE poses several challenges. One is maintaining the quality and quantity of materials and energy efficiency whilst having the lowest possible environmental impact and highest value of materials [19]. The current linear fashion system adds to these challenges by increasing the number of collections per year, lowering prices, and prompting quicker changes in styles and trends [10]. Therefore, the linear fashion system has increased the use of non-renewable and unsustainable materials and energy in an unsustainable and uneconomic manner [20, 21].

However, the fashion industry's challenge concerning materials and energy is limited to the scarcity of resources, dictated by environmental impacts and climate change of current raw material production, and the poor understanding and management of the

Table 1 Overview of the challenges faced in introducing circular economy (without specific industry context)

Authors	Challenges
Kumar et al. [16]	15 challenges faced throughout the supply chain: (1) Insufficient legislation and control, (2) lack of governmental guidance and support, (3) risk of mismanagement, (4) poor waste management, (5) lack of management support, (6) short-term goals, (7) insufficient funds available for the industry, (8) inefficient execution of framework, (9) lack of skilled workforce, (10) employee resistance for change, (11) Lack of planning for the implementation and integration of CE and industry 4.0, (12) lack of understanding industry 4.0, (13) use of materials as energy, (14) poor resource quality, (15) insufficient market demand
Tura et al. [17]	Categorise the challenges into seven categories: (1) Environmental, (2) institutional, (3) economic, (4) social, (5) organisational factors, (6) supply chain, (7) technological and informational
Hina et al. [11]	Categorise the challenges into two categories: (1) Internal challenges: organisational strategies and policies, product design, internal stakeholders, financial challenges, collaborations, technological difficulties, and lack of viable resources (2) External challenges: supply chain-related challenges, environmental challenges, regulatory challenges, social and cultural challenges, economic challenges, and consumer-related challenges
García-Quevedo et al. [18]	Categorise the challenges into two categories (focused on European SMEs): (1) insufficient financial and human resources, and (2) the complexity of administrative obligations and legislations

Table 2 Overview of the challenges the fashion industry faces in introducing a CE

Authors	Challenges
Colucci and Vecchi [2]	Categorise the challenges into three categories: (1) operational challenges, (2) Technical challenges, and (3) customer-related issues
Abdelmeguid et al. [8]	Categorise the challenges into two categories: (1) Hard aspects: financial challenges, regulatory challenges, circular business model-related challenges, and pressures from stakeholders (2) Soft aspects: consumer-related challenges and green intellectual capital

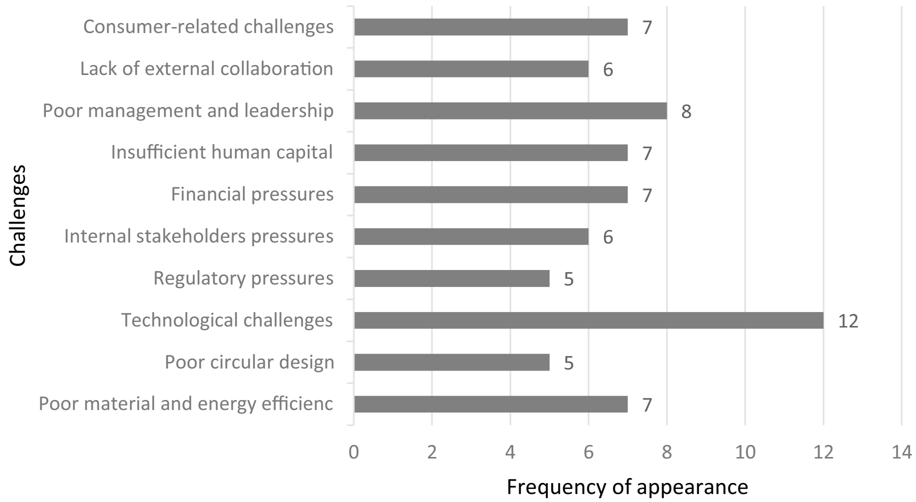


Fig. 1 The frequency of appearance of the ten challenges identified in the literature reviewed

current and potential material flow [22]. Although the extraction of raw materials is energy-intensive, there is still not enough attention given to the importance of utilising waste, making use of reusable, recycled materials, and biodegradable material to ease the flow and recovery of materials [22]. Moreover, some synthetic fibres require enormous amounts of energy and chemicals whilst generating toxic waste and polluting materials in their production, which cause environmental impacts and human health concerns [19]. Furthermore, by implementing circular strategies and activities, materials and energy can be used more efficiently, and production levels can be raised. However, this can lead to an increasing risk of circular rebound, which offsets the benefits of a circular economy [23].

Poor Circular Design

The circular design must redefine and reimagine products and services to improve waste management and support shifting to a CE. The design of circular systems should include strategies to extend the lifespan of products, such as swapping, renting, leasing, and repairing, as well as strategies to encourage circularity at the end of their useful lives, such as repairing, reusing, recycling, and remanufacturing [16, 20].

However, with fast fashion dominating the market, products are not designed to last for long or active use indicating poor circular design [24]. This is due to the fashion industry's competitive environment with a constantly changing market demand and customer preference, which pressures designers to rapidly create new styles and trends instead of focusing on innovative and efficient circular design [25]. Additionally, creating optimal circular products and services whilst keeping consumers' preferences in mind is often a challenge for the fashion industry. A circular and resource-efficient solution must be accompanied by the desired features, performance, and quality expected by their consumers to ensure an overall success [26].

Technological Challenges

The technology available in the fashion industry challenges CE implementation. This is because standard technologies used in the production process are designed to support fast-fashion business models, thereby designed to support high-scale and mass production at a lower cost and with shorter production cycles [2, 21]. Thus, circular economy business models are insufficiently supported by advanced and efficient technologies that run cost-effectively without compromising quality [8, 17].

A limited number of technologies are available to support the shift to a CE and overcome the issues caused by the currently available and used technologies [27]. These CE-oriented technologies must facilitate CE strategies such as optimising, remanufacturing, and regenerating resources [28]. CE-oriented technologies include sorting, recycling, and printing technologies, detection and separation of fibres and materials technology, material recovery, and waterless dying technologies [11, 16, 20]. Other sustainability-inspired technologies include additive manufacturing, cloud manufacturing, Cyber-Physical Systems (CPS), and the Internet of Things (IoT) [29]. These technologies could provide various circular qualities, including obtaining primary data that helps with decision-making and reverse logistics by monitoring real-time movements within the transportation systems, providing information about the availability of materials and sharing manufacturing resources, and estimating carbon emissions [16].

The limited availability of these technologies, accompanied by the challenge of strategic and efficient integration within the business models, and a fundamental lack of knowledge in their operation and implementation to resolve CE challenges, are some of the major barriers to a successful adoption [22].

. Furthermore, technological advancements could potentially lead to circular rebounds if not used effectively and efficiently [23].

Regulatory Pressures

In the fashion industry, regulations and legislation are seen as one of the most significant barriers to introducing a CE. Governments have the most control over how companies and retailers operate and play a crucial role for introducing a CE [8, 18]. Therefore, the transition needs to be complemented by supportive legal frameworks.

Insufficient regulations in some countries could encourage the outsourcing of production processes to benefit from fewer or weaker sustainable legislations and circular practices in place. It could potentially lead to unethical practices such as exploitation of the workforce and poor working conditions [30]. Furthermore, having insufficient regulations or legal obligations for consumers to support circular initiatives made within the industry could be very challenging for the industry to adopt a CE.

Challenging regulations and reduced taxes placed by the governments within the fashion industry can drive a successful transition to a CE. Therefore, governments can support the fashion industry through various ways, including implementing strict regulations and lowering taxes. However, governments around the world fail to implement efficient strategies that would help with waste minimisation, as well as fail to provide support for the complex administration requirements and high administration costs that act like a barrier when transitioning to a CE, particularly for SMEs [16, 18]. Additionally, there is insufficient governmental support and guidance to create a stream of textile waste derived from different companies, which hinders the opportunity for circular waste management at scale, [22].

Internal Stakeholders' Pressures

Collaboration and engagement amongst all internal stakeholders, including employees, managers, and owners, are required to introduce a CE in the fashion industry [7, 13]. Their collective action and effort are critical in planning and developing business strategies [31]. The involvement of all internal stakeholders increases constraints and pressures due to the different self-interests and needs of the various stakeholders [8, 16]. Also, internal stakeholders in the fashion industry need economic reasoning and benefits as an incentive to transition to a CE [32]. Therefore, it is very difficult to align and connect the goals of different internal stakeholders and meet their requirements, which makes the transition to a CE very challenging. However, the commitment of internal stakeholders alone is not enough. Commitment and engagement of external stakeholders, such as consumers, are also essential to achieve circularity in the fashion industry [13].

Financial Pressures

The fashion industry faces various financial pressures when transitioning to a CE [8]. This is usually due to limited financial means available, limited financial support provided, and high risk of misinvestment into the CE, particularly for SMEs and start-ups [16–18]. Also, the change requires many investments at the start to enable investments in the right CE-oriented technologies and infrastructure [33]. Moreover, the poor financial performance and difficulty in measuring and evaluating the efficiency of the circular business models hamper the transition's long-term environmental and social benefits [16]. This is because the CE is considered a new concept that implies uncertainty about its short-term profitability, and thereby, is usually not supported by financial markets [8, 34]. The fashion industry also faces the challenges of circular systems' costs and inefficiency, for instance, recycling or separating materials [35]. These higher costs and inefficiencies sometimes lead to a rise in the price of sustainable and circular fashion goods and services, affecting consumers' purchasing and product usage decisions as they are unwilling to pay more [35].

Insufficient Human Capital

Providing adequate and relevant training and knowledge to employees within the fashion industry is necessary to ensure that the resistance to change is minimised and increases the level of commitment to this change [36]. Also, it increases the ability to know more about sustainable materials and resources and the use of new technologies, circular strategies, and techniques [20, 37]. In addition, the involvement of employees in the decision-making process empowers the companies staff members, benefitting both the employees and the competitive advantage of the organisation.

Nevertheless, the fashion industry's lack of skilled and knowledgeable human capital causes a further challenge for CE introduction [8, 16]. As the fashion industry fails to recognise the crucial part that human capital plays in the manufacturing system and the overall life cycle of the system, it fails to consider the significant role it plays in organisational development and change, when implementing a CE [36]. Also, it fails to recognise the significance of imitable, non-substitutional, and rare human capital in achieving a competitive advantage [38, 39]. Therefore, organisations and brands are not paying much attention to allocating enough time and adequate finances to share knowledge, train and educate the workforce regarding circularity [18]. Consequently, there appears to be insufficient knowledge, skill set, and behaviour concerning the CE, management of environmental and sustainability concerns, and environmental protection [40]. This obstructs the ability of the fashion industry to transform into a CE.

Poor Management and Leadership

Management and leadership are critical factors for the introduction of circular strategies. Management and leadership shape the organisational culture, which plays a crucial role in organisational behaviour and the successful application of circular systems [37]. The shift to a CE within the fashion industry requires changes in the organisational culture, which may be threatening to some individuals and may be accompanied by high-risk aversion and high costs in the short-term [8, 34, 41]. Therefore, good leadership and management capabilities are essential for implementing fundamental changes within the industry [11, 42]. This helps in understanding the internal and external organisational issues and needs, as well as helping in considering the whole system and how it operates to support the introduction of a CE [41]. In addition, good management and leadership help understand the needs of the employees and boost motivation and development of the workforce to support the transition [11].

However, there is a lack of managerial and leadership skills required to distribute circular knowledge and adopt circular strategies, which usually leads to insufficient use of human capital and other organisational resources [8, 31]. This lack of effective management and leadership also leads to a lack of drive and motivation to implement circularity and a failure to raise awareness of the significance of transitioning to a CE system [8, 36]. Furthermore, poor management and leadership act like a barrier to initiating visions in the decision-making process and implementing actions, since it obstructs the ability to adopt the essential strategies in planning, organising, and controlling [36]. Therefore, poor management and leadership hinder the fashion industry's ability to transition to a circular economy.

Lack of External Collaborations

Collaboration networks within the fashion industry with external partners, including brands, retailers, suppliers, and governments, facilitate the sharing of knowledge and expertise, support the development of new environmental ideas and circular strategies, enable technological advancements and circular innovation, and reduce the costs of research and development [40]. In addition, collaboration networks encourage sharing materials, garments, services, tools, and other resources. Therefore, the value chain becomes more connected, and their vision is more aligned, facilitating the communication of best practices and introducing CE principles within industries [43].

However, the lack of external collaborations hinders the fashion industry's transition to a CE [8]. This is due to the lack of transparency stemming from a lack of trust and the incompatibility between partners across the value chain, in turn restricting the exchange of knowledge, expertise, and activities between collaboration networks [11]. This reduces the ability to reduce costs, develop new ideas, reduce the risks associated with long-term investments and the opportunity of collaborating with the government [44]. External collaboration also relies on three supporting factors: challenges from the external environment (regulations, society, and expectations), challenges from the competitive environment (suppliers, competitors, consumers, and intermediates), and the search for the competitive advantage (cost and differentiation qualities and features) [45]. Therefore, the absence or insufficiency of these three driving factors could act as a barrier to external collaboration and restrict its supporting opportunities in introducing circularity in the fashion industry.

Consumer-Related Challenges

Based on Berberyan et al. [46], there are variables related to the product, such as price, quality, availability and accessibility, product design, and ethical identification. In comparison, the variables related to the consumers include personal interests, norms, habits, convenience, social desirability bias, and perception. Usually, variables related to the product are the ones that could be managed. As variables related to consumers are more difficult to predict and control due to the conflicting external behaviours regarding the purchase, use, and disposal of products or services within the fashion industry which creates circularity dilemmas [8, 47].

The attitude-behaviour gap is one of the main consumer-related challenges. There has been a massive gap between understanding the need for ethical clothing and circular products, services to tackle environmental concerns, and consumers' purchase, usage, and disposal behaviour [48]. For example, consumers first identify the price when purchasing. Yet circular and sustainable products and services tend to be more expensive to compensate for the higher costs encountered throughout the production process. This is referred to as a circular premium, and it acts as a challenge since it advocates a high risk of losing existing consumers who may not accept this increase in price [49]. Although circular strategies within the fashion industry could be communicated at a larger scale, through initiatives such as enhanced marketing mechanisms and platforms to educate consumers, and promote awareness amongst them, this still relies on consumers' mindsets and behaviours that are hard to anticipate and manage [16, 17, 20].

Methodology

To achieve the aim of this research, Fuzzy Total Interpretive Structural Modelling (Fuzzy-TISM) is used to deduct a structured model to illustrate the relationship between the challenges, and Fuzzy MICMAC analysis is used to map and rank these challenges based on their driving and dependence power. The driving power in this research refers to a higher level of significance, independence, and influence of some of the challenges on others, thereby helping to successfully address other challenges and implement a CE in the fashion industry [50, 51]. In contrast, dependence power in this research refers to the challenges that rely on others when being addressed to achieve a successful implementation and have minor or no influence on other challenges [50, 51].

Fuzzy-TISM is a qualitative research tool and structured approach based on collecting data from a limited number of experts within the research criteria, which lie in the fashion context of this research, using focus groups, questionnaires, or interviews [52]. The experts do not need to have any previous knowledge of the underlying method. Furthermore, Fuzzy-TISM is the fuzzy extension of the ISM, which is a pairwise comparison methodology for identifying and summarising relationships between variables that define a problem or a challenge [51]. However, it has been updated to include the interpretation of each relationship by qualitative considerations on a 0 to 1 scale to show the direction of the relationship and the degree of influence [53].

The research approach used to achieve the objectives of this paper is an inductive approach. This means that the theoretical ideas and the model created are derived from the data collected from interviews. Therefore, the philosophical position underpinning this research is interpretivism because the research focuses on the experts' subjective experiences and interpretations of the world, hence highly dependent on the experts' lived experiences, insights, and real-life situations [55].

This paper adapts the Fuzzy-TISM approach suggested by *Khatwani* (2015). However, the steps have been slightly modified. Therefore, eight steps of Fuzzy-TISM are adopted in this paper, noting that Step 1 and Step 2 are completed before data collection, and the results build on these two steps. The eight steps are as follows (Fig. 2) [50]:

Step 1: Start of Decision-making Process

This step involves setting the research goals and committing the decision-making process to achieving these goals. Therefore, deciding how to gather the information and knowledge required to achieve the research objective. For this research, the responses of 7 researchers, academics, and industry experts in implementing the CE in the fashion industry are collected through in-depth interviews (Table 3).

Step 2: Selection of Criteria

This step involves establishing a set of criteria. For this research, the literature was reviewed to identify a set of challenges associated with circular economy implementation in the fashion industry. The challenges of implementing a circular economy in the fashion industry identified from the literature are as follows:

1. *Poor material and energy efficiency (C1):* The use of non-renewable materials and energy in an unsustainable and non-economic manner and/or the use of toxic materials and energy [20, 21].
2. *Poor circular design (C2):* Having difficulty reimagining and reinventing products and services supporting the CE. For instance, lacking the ability and the capacity to include strategies to extend the lifespan of products, such as swapping, renting, leasing, and repairing products, as well as strategies to encourage circularity at the end of their useful lives, such as repairing, reusing, recycling, and remanufacturing [16, 20].
3. *Technological challenges (C3):* Poor level of advanced and efficient technologies that run cost-effectively without comprising the quality [8, 17].
4. *Regulatory pressures (C4):* The regulations and legislations that affect how the companies in the fashion industry operate. For example, lack of governmental support, insufficient legislation and control, complex administration requirements, chemical requirements, and legal obligations [8, 18, 22].
5. *Internal stakeholder pressures (C5):* The pressures exerted by employees, managers, shareholders, owners, and management, and the difficulty of aligning their goals industry [7, 13].

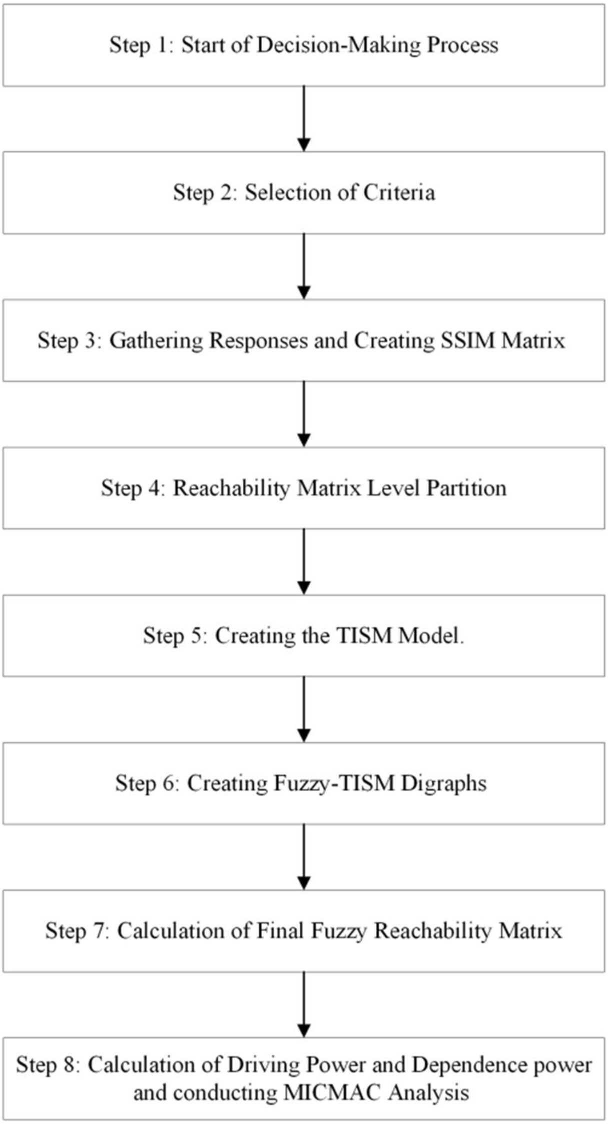


Fig. 2 The eight steps of Fuzzy-TISM [50]

6. *Financial pressures (C6):* Circular business models in the fashion industry have been hindered by the lack of financial resources, support, and evaluation mechanisms [16–18].
7. *Insufficient human capital (C7):* Insufficient understanding and inadequate behaviour amongst employees regarding the circular economy, environmental protection, and environmental and sustainability management [8, 36, 40].
8. *Poor management and leadership (C8):* Poor managerial capabilities and leadership skills shape the organisational culture, which is crucial in successfully distributing and applying knowledge regarding circular strategies [8].
9. *Lack of external collaborations (C9):* The fashion brands and retailers lack collaboration with external partners (i.e., brands, retailers, and suppliers) on sustainable and

Table 3 Experts' profiles

Job title	Years of experience
Circular economy programme and research manager	6
CEO and co-founder of a sustainable and circular fashion brand	20
CEO and co-founder of a circular fashion brand	4
Co-founder of a sustainable and circular fashion courses and training provider	10
Circular project manager	8
CEO and co-founder of circular fashion brand	20
Senior research associate in sustainable luxury	18

circular strategies, limiting their opportunities to unite their visions, improve their connectivity, and support their commitment to the transition [8, 43].

10. *Consumer-related challenges (C10):* Difficulty in anticipating and managing the decisions of consumers regarding the purchase, use, and disposal of products or services within the fashion industry [2, 46].

Step 3: Gathering Responses and Creating SSIM Matrix

The responses about the pairwise relationship between the challenges are collected from the seven experts through interviews and used to complete the initial SSIM matrix for each expert [56]. The experts are asked to choose one of four following symbols (V, A, X, and O) to indicate the pairwise relationship and the direction of the relationships between the challenges, followed by a combination of the five linguistic terms (Very high, High, Low, Very low, No) to indicate the degree of influence/impact of the challenges [52]. Therefore, the experts have four response options:

i **V:** To establish that challenge *i* influences/impacts challenge *j* but not vice versa, followed by Very high (VH), High (H), Low (L), or Very low (VL). For example, V (VH) or V(H) or V(L) or V(VL).

ii **A:** To establish that challenge j influences/impacts challenge *i* but not vice versa, followed by Very high (VH), High (H), Low (L), or Very low (VL).

iii X: To establish that challenges i and j influence/impact each other, followed by (Very high (VH), High (H), Low (L), or Very low (VL) for each direction. For example, X (VH, L) or X (H, VH).

iv **O:** To establish that there is no relationship between challenges *i* and *j*, followed by No influence (No). For example, O (No).

Step 4: Reachability Matrix Level Partition

In this step, the reachability matrix is partitioned into different levels. For example, based on Singh et al. [51], the reachability set is the variable itself and other variables it may help achieve (based on the rows). The antecedent set is the variable itself and the other variables that may help achieve it (based on the columns). The intersection set is the common variables between reachability and the antecedent sets.

Step 5: Creating the TISM Model

In this step, a defuzzified TISM digraph is developed to visualise the hierarchy-based model showing the inter-relationship between the challenges and the direct and indirect impact of each challenge during the implementation of a CE within the fashion industry.

Step 6: Creating Fuzzy-TISM Digraphs

In this step, all responses collected from the interviews will be combined in an aggregated SSIM matrix using fuzzy linguistic terms. Moreover, Fuzzy-TISM digraphs are developed using simple arrows to visualise the relationship between the challenges.

Step 7: Calculation of Final Fuzzy Reachability Matrix

In this step, the linguistic terms are replaced by the fuzzy linguistic values first proposed by Li [57] and shown in Table 4. Therefore, *N* is replaced by (0.0, 0.0, 0.25); VL is replaced by (0.0, 0.25, 0.50); *L* is replaced by (0.25, 0.50, 0.75); *H* is replaced by (0.50, 0.75, 1.0); and VH is replaced by (0.75, 1.0, 1.0).

Step 8: Calculation of Driving Power and Dependence Power and Conducting MICMAC Analysis

In this step, the aggregated fuzzy reachability matrix is generated from the Fuzzy SSIM completed in the previous step. The fuzzy reachability matrix's columns and rows are summed up to calculate the driving and dependence power. Then, the crisp value required for Fuzzy MICMAC analysis is determined using the following five equations derived from Khatwani et al. [50]:

Step 1: Determine $L = \min\left(l_k\right); R = \max(u_k); K = 1, 2, \ldots nand \Delta = R - L$, then use Eq. 1 to determine each of the alternatives.

$$x_{lk} = \frac{\left(l_k - L\right)}{\Delta}, X_{mk} = \frac{m_k - L}{\Delta}, X_{uk} = \frac{u_k - L}{\Delta} \tag{1}$$

Step 2: Use Eqs. 2 and 3 to calculate normalised values for the left score (l_s) and the right score (R_s).

Table 4 Fuzzy linguistic scale [57]

Linguistic description	Notation	Triangular fuzzy number	Influence scope
No influence	(0.0, 0.0, 0.25)	*N*	0
Very low influence	(0.0, 0.25, 0.50)	VL	1
Low influence	(0.25, 0.50, 0.75)	*L*	2
High influence	(0.50, 0.75, 1.0)	*H*	3
Very high influence	(0.75, 1.0, 1.0)	VH	4

$$X_k^{ls} = \frac{X_{mk}}{(1 + X_{mk} - X_{lk})} \tag{2}$$

$$X_k^{rs} = \frac{X_{uk}}{(1 + X_{uk} - X_{mk})} \tag{3}$$

Step 3: Use Eq. 4 to calculate the normalised crisp value.

$$X_k^{crisp} = \left[X_k^{ls} \times \left(1 - X_k^{ls}\right) + X_k^{rs} \times X_k^{rs}\right] / [1 - X_k^{ls} + X_k^{rs}] \tag{4}$$

Step 5: Use Eq. 5 to calculate the crisp value for B_k

$$B_k^{crisp} = L + X_k^{crisp} \times \Delta \tag{5}$$

Results

Step 3: Gathering Responses and Creating SSIM Matrix

The aggregated initial SSIM matrix is derived based on the highest frequency of occurrence for the linguistic terms and is shown in Table 5. The table shows that all challenges influence/impact one another in one or both directions and that none are unrelated.

Step 4: Reachability Matrix Level Partition

To generate a defuzzified reachability matrix, only the direction of the relationship between the challenges is considered. Therefore, only the four symbols used in the initial SSIM matrix are considered and replaced by 1 or 0. The V is replaced by 1, A is replaced by 0, X is replaced by 1, and O is replaced by 0, as shown in Table 6. The driving power is the count of all challenges within the reachability set (based on the rows), hence the challenge itself and other challenges which it may help to address. The dependence power is the count of the challenges in the antecedent set (based on the columns), hence the challenge itself and all other challenges which it may help in addressing it.

Furthermore, levels of partitioning are conducted based on the reachability, antecedent, and intersection sets, as represented in Tables 7, 8, 9, and 10. Table 7 shows the first

Table 5 Initial aggregated SSIM matrix

	C10	C9	C8	C7	C6	C5	C4	C3	C2	C1
C1 Poor material and energy efficiency	X(H, H)	X(L, VH)	A(VH)	A(VH)	A(VH)	A(L)	A(VH)	A(VH)	X(L, VH)	
C2 Poor circular design	X(VH, H)	X(VH, VH)	A(H)	A(H)	A(H)	A(H)	A(VH)	A(H)		
C3 Technological challenges	X(H, H)	A(VH)	A(H)	A(VH)	X(H, VH)	X(H,H)	A(VH)			
C4 Regulatory pressures	V(H)	V(VH)	X(L,H)	V(L)	X(H, L)	X(L,L)				
C5 Internal stakeholders' pressures	X(L, VL)	X(H, L)	X(L, VH)	X(VH, H)	X(H, H)					
C6 Financial pressures	X(H, H)	X(H, L)	X(H, VH)	X(H, VH)						
C7 Insufficient human capital	V(H)	X(H, H)	X(VH, VH)							
C8 Poor management and leadership	V(H)	X(VH, L)								
C9 Lack of external collaborations	V(H)									
C10 Consumer-related challenges										

iteration, where poor material and energy efficiency (C1), circular design (C2), and consumer-related challenges (C10) are found at level 1. This indicates that C1, C2, and C10 would not help address any of the other challenges below their level. Table 8 represents the second iteration, where technological challenges (C3), internal stakeholders' pressures (C5), and financial pressures (C6) are found at level 2. Table 9 shows the third iteration, where insufficient human capital (C7), poor management and leadership (C8), and lack of external collaborations (C9) are found at level 3. Finally, Table 10 represents the fourth iteration where regulatory pressures (C4) are placed at level 4. Therefore, this indicates that C4 help in directly or indirectly addressing all other challenges.

Step 5: Creating the TISM Model

Moreover, Fig. 3 represents the TISM Diagram developed to visualise the relationship between the challenges through the constructed hierarchy-based model. The solid one-ended arrow illustrates the relationship of one challenge with another in one direction, whilst the dotted double-ended arrows show the interrelationships between one challenge and another. The challenges in Fig. 3 are represented in 4 levels based on the levels concluded in Step 4.

At the bottom-level challenge of the model is the regulatory pressures (C4), which indicates the key challenge that requires the most attention managerial attention at the early stages of strategy formulation and decision-making for a successful and effective implementation of a circular economy in the fashion industry. Whereas the top-level challenges of the hierarchy are poor material and energy efficiency (C1), circular design (C2), and consumer-related challenges (C10), which indicate that they require the least managerial attention due to their lowest level of significance according to the TISM model. Therefore, the levels help with grouping those challenges. As seen in the model, all challenges have direct or indirect interrelationships, which shows the relevance of all the challenges identified from the literature and how they impact each other bringing in the need to understand their complex system.

Moreover, all challenges on the same levels are interconnected and impact each other in both directions, which means that challenges on the same level have the same impact on one another. However, this does not mean they have the same significance level because their relationship with other challenges on higher and lower levels should also be considered in making those observations. For example, consumer-related challenges (C10) is on level 4 and interconnected with the other challenges on the same level and with all challenges on level 3, where challenges have higher significance and impact levels. This means that consumer-related challenges (C10) could influence and get influenced by higher significance challenges, showing its higher significance level compared to the other two challenges at the same level. Another example is technological challenges (C3) appears to have a lower significance level in comparison to internal stakeholders' pressures (C5) and financial pressures (C6) despite being on the same level. technological challenges (C3) can only influence the other two challenges on the same level and the challenges on the higher level, hence, with a lower significance level. Therefore, this gives the other two challenges, internal stakeholders' pressures (C5) and financial pressures (C6), a higher significance level due to their interconnection with the challenges on level 2.

Furthermore, poor management and leadership (C8) is shown to be one of the key challenges with a higher level of significance in comparison to insufficient human capital (C7) and poor and lack of external collaborations (C9), which are on the same level. This is

Table 6 Defuzzified reachability matrix

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	Driving power
C1 Poor material and energy efficiency	1	1	0	0	0	0	0	0	1	1	4
C2 Poor circular design	1	1	0	0	0	0	0	0	1	1	4
C3 Technological challenges	1	1	1	0	1	1	0	0	0	1	6
C4 Regulatory pressures	1	1	1	1	1	1	1	1	1	1	10
C5 Internal stakeholders' pressures	1	1	1	1	1	1	1	1	1	1	10
C6 Financial pressures	1	1	1	1	1	1	1	1	1	1	10
C7 Insufficient human capital	1	1	1	0	1	1	1	1	1	1	9
C8 Poor management and leadership	1	1	1	1	1	1	1	1	1	1	10
C9 Lack of external collaborations	1	1	1	0	1	1	1	1	1	1	9
C10 Consumer-related challenges	1	1	1	0	1	1	0	0	0	1	6
Dependence Power	10	10	8	4	8	8	6	6	8	10	

Table 7 First iteration of the final defuzzified reachability matrix

Variable	Reachability set	Antecedent set	Intersection set	Level
C1	1,2,9,10	1,2,3,4,5,6,7,8,9,10	1,2,9,10	1
C2	1,2,9,10	1,2,3,4,5,6,7,8,9,10	1,2,9,10	1
C3	1,2,3,5,6,10	3,4,5,6,7,8,9,10	3,5,6,10	
C4	1,2,3,4,5,6,7,8,9,10	4,5,6,8	4,5,6,8	
C5	1,2,3,4,5,6,7,8,9,10	3,4,5,6,7,8,9,10	3,4,5,6,7,8,9,10	
C6	1,2,3,4,5,6,7,8,9,10	3,4,5,6,7,8,9,10	3,4,5,6,7,8,9,10	
C7	1,2,3,5,6,7,8,9,10	4,5,6,7,8,9	5,6,7,8,9	
C8	1,2,3,4,5,6,7,8,9,10	4,5,6,7,8,9	4,5,6,7,8,9	
C9	1,2,3,5,6,7,8,9,10	1,2,4,5,6,7,8,9	1,2,5,6,7,8,9,10	
C10	1,2,3,5,6,10	1,2,3,4,5,6,7,8,9,10	1,2,3,5,6,10	1

Table 8 Second iteration of the final defuzzified reachability matrix

Variable	Reachability set	Antecedent set	Intersection set	Level
C3	3,5,6	3,4,5,6,7,8,9	3,5,6	2
C4	3,4,5,6,7,8,9	4,5,6,8	4,5,6,8	
C5	3,4,5,6,7,8,9	3,4,5,6,7,8,9	3,4,5,6,7,8,9	2
C6	3,4,5,6,7,8,9	3,4,5,6,7,8,9	3,4,5,6,7,8,9	2
C7	3,5,6,7,8,9	4,5,6,7,8,9	5,6,7,8,9	
C8	3,4,5,6,7,8,9	4,5,6,7,8,9	4,5,6,7,8,9	
C9	3,5,6,7,8,9	4,5,6,7,8,9	5,6,7,8,9	

because poor management and leadership (C8) are interconnected with regulatory pressures (C4) and thereby can influence and get influenced by one another. Therefore, having that direct interrelationship with regulatory pressures (C4), which according to the model, is the key challenge that needs the most managerial attention, makes poor management and leadership (C8) one of the challenges with the highest level of significance. Additionally,

Table 9 Third iteration of the final defuzzified reachability matrix

Variable	Reachability set	Antecedent set	Intersection set	Level
C4	4,7,8,9	4, 8	4, 8	
C7	7,8,9	4, 7,8,9	7,8,9	3
C8	4, 7,8,9	4, 7,8,9	4,7,8,9	3
C9	7,8,9	4, 7,8,9	7,8,9	3

Table 10 Fourth iteration of the final defuzzified reachability matrix

Variable	Reachability set	Antecedent set	Intersection set	Level
C4	4	4	4	4

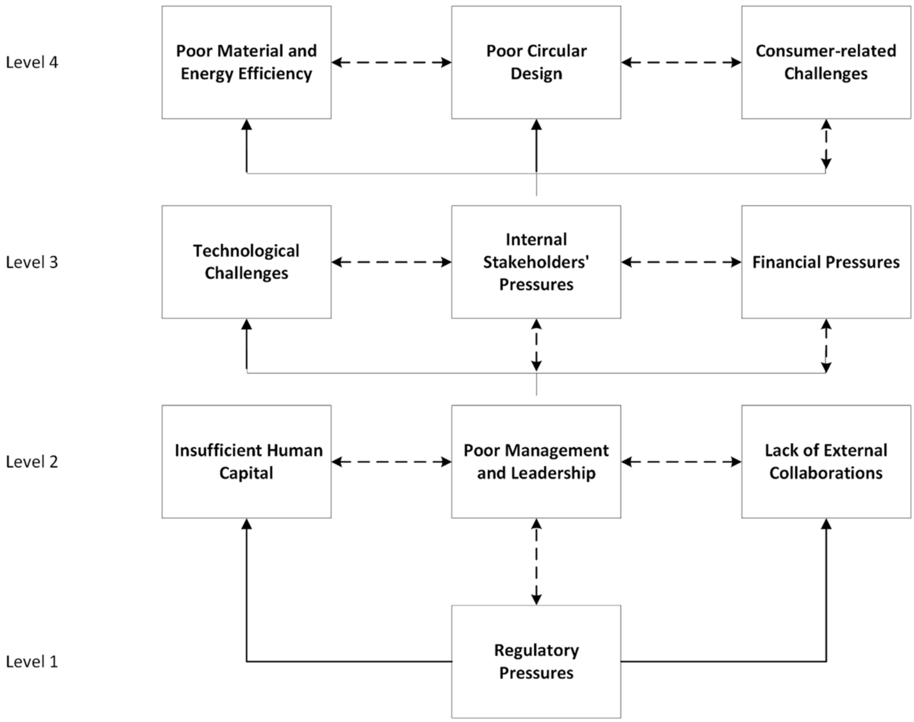


Fig. 3 TISM Model

insufficient human capital (C7) appears to have higher significance than lack of external collaborations (C9) since it influences the challenges in level 3 in one direction and does not get influenced by them, which makes it a more stable challenge than lack of external collaborations (C9) to be addressed to gain more effective results despite being on the same level.

Step 6: Creating Fuzzy-TISM Digraphs

Table 11 Final reachability matrix using fuzzy linguistic terms

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
C1 Poor material and energy efficiency		L	No	No	No	No	No	No	L	H
C2 Poor circular design	VH		No	No	No	No	No	No	VH	VH
C3 Technological challenges	VH	H		No	H	H	No	No	No	H
C4 Regulatory pressures	VH	VH	VH		L	H	L	L	VH	H
C5 Internal stakeholders' pressures	L	H	H	L		H	VH	L	H	L
C6 Financial pressures	VH	H	VH	L	H		H	H	H	H
C7 Insufficient human capital	VH	H	VH	No	H	VH		VH	H	H
C8 Poor management and leadership	VH	H	H	H	VH	VH	VH		VH	H
C9 Lack of external collaborations	VH	VH	VH	No	L	L	H	L		H
C10 Consumer-related challenges	H	H	H	No	VL	H	No	No	No	

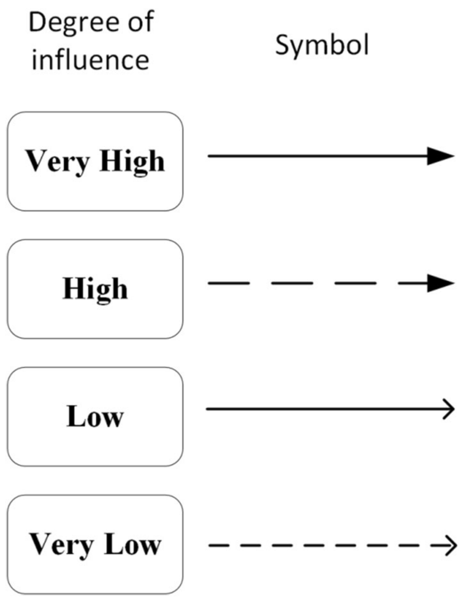


Fig. 4 Symbols for representing the fuzzy relationship between the challenges

The initial aggregated SSIM matrix is transformed into the final reachability matrix using linguistic terms and based on the highest frequency of occurrence, as shown in Table 11.

The symbols for representing the fuzzy relationship between the challenges are shown in Fig. 4. Using these symbols, the Fuzzy-TISM diagraphs of the ten challenges are generated and are shown in Table 12.

Step 7: Calculation of Final Fuzzy Reachability Matrix

The linguistic terms are then replaced by the fuzzy linguistic triangular numbers, as shown in Table 13.

Step 8: Calculation of Driving Power and Dependence power and conducting MICMAC Analysis

As represented in Table 14, all the columns and rows are summed to calculate the fuzzy values of driving and dependence power. The crisp values of driving and dependence power are calculated using the five equations mentioned in the "Methodology" section. Furthermore, based on the crisp values of driving power (y-axis) and dependence power (x-axis), the Fuzzy MICMAC analysis is derived as represented in Fig. 5.

Firstly, regulatory pressures (C4) and poor management and leadership (C8) lie within the "Drivers" cluster, as both have strong driving power and weak dependence power. Therefore, they have the highest influence over all other challenges and very little or no dependence on other challenges. Thus, the MICMAC analysis displays these two challenges as the key ones with the highest level of significance requiring the most managerial attention, especially at the early decision-making stage for successful and effective implementation results. This somewhat validates the TISM model considering that the regulatory pressures (C4) is placed at level 1 and has the highest significance level. Additionally, it has an interconnection (in both directions) with poor management and leadership (C8) located at level 2, indicating the relationship that both challenges have and their high significance. However, according to MICMAC analysis, both challenges should be placed in level 1 and treated as key challenges. In fact, poor management and leadership (C8) appear to have higher driving power than regulatory pressures (C4).

Secondly, technological challenges (C3), internal stakeholders' pressures (C5), financial pressures (C6), insufficient human capital (C7), and lack of external collaborations (C9) lie within the "linkage" cluster, as these challenges have strong driving and dependence power. This means these challenges are unstable because any action on them will influence others and have a feedback effect on themselves. These challenges are placed in levels 2 and 3 on the TISM model, but poor management and leadership (C8) is not being mapped in the same cluster. Hence, this slightly conflicts with the TISM model. Furthermore, seeing insufficient human capital (C7) on the borderline of the "drivers" cluster validates the findings of the TISM model, indicating the high significance of this challenge compared to the other challenges in the same cluster. Also, seeing technological challenges (C3) on the borderline of the "dependent" validates its less significance than the other challenges in the same cluster.

Thirdly, poor material and energy efficiency (C1), circular design (C2), and consumer-related challenges (C10) lie within the "dependent" cluster, as these challenges have weak driving power and strong dependence power. These are the same challenges found at level 4 on the TISM Model. Therefore, the MICMAC analysis validates that they are highly reliant and dependent on other challenges. This means that they are driven by other factors with higher significances level.

Finally, no challenges lie within the "autonomous" cluster. Thus, none of the challenges have weak driving and dependence power. Also, none of the challenges are considered isolated from the system since they have little or no influence or relationship with other challenges. This has already been noticed in the initial aggregated SSIM matrix. Moreover, this validates that all challenges identified from the literature and analysed in this research have a direct or indirect relationship.

Discussion

Several interesting findings were drawn from the TISM model (Fig. 3) and Fuzzy-MICMAC analysis (Fig. 5).

Firstly, regulatory pressures and poor management and leadership do not lie on the same level in the TISM Model, as shown in Fig. 6, illustrating that regulatory pressures are ranked at level 1. Therefore, it is the key challenge that influences all other challenges

Table 12 Fuzzy-TISM digraphs of all challenges influencing others using the symbols from Fig. 4 to show all fuzzy linguistic terms

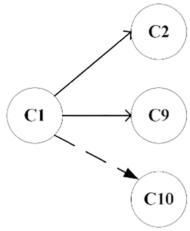
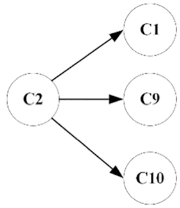
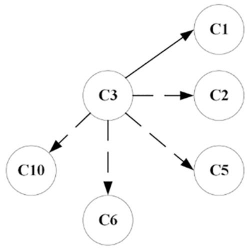
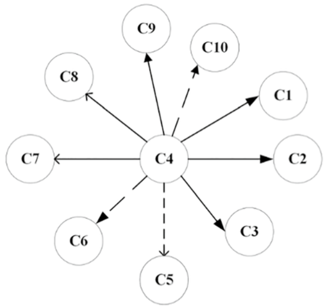
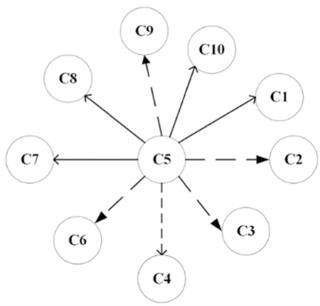
Challenge	Diagraph
C1 has low influence on C2 and C9, and high influence on C10	
C2 has very high influence on C1, C9, C10	
C3 has very high influence on C1, and high influence on C2, C5, C6 and C10	
C4 has very high influence on C1, C2, C3, C9, high influence on C6 and C10, low influence C7 and C8, and very low influence on C5	
C5 has low influence on C1, C7, C8 and C10, high influence on C2, C3, C6 and C9, and very low influence on C4	

Table 12 (continued)

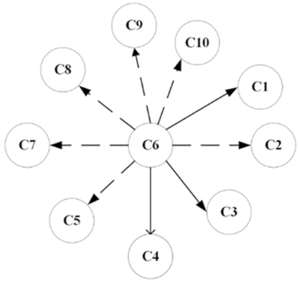
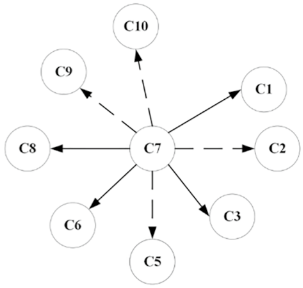
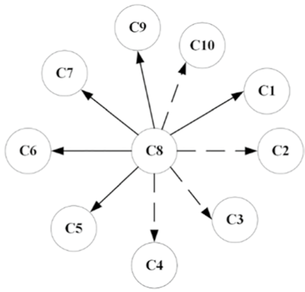
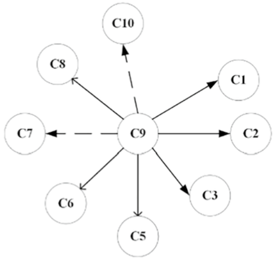
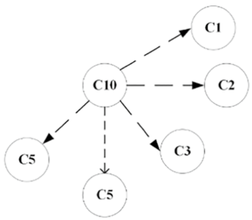
C6 has very high influence on C1 and C3, high influence on C2, C5, C7, C8, C9 and C10, and low influence on C4	
C7 has very high influence C1, C3, C6 and C8, and high influence on C2, C5, C9 and C10	
C8 has very high influence on C1, C5, C6, C7 and C9, and high influence on C2, C3, C4 and C10	
C9 has very high influence on C1, C2, C3, high influence on C7 and C10, and low influence on C5, C6 and C8	
C10 has high influence on C1, C2, C3 and C5, and very low influence on C5	

Table 13 Fuzzy reachability matrix using fuzzy linguistic values

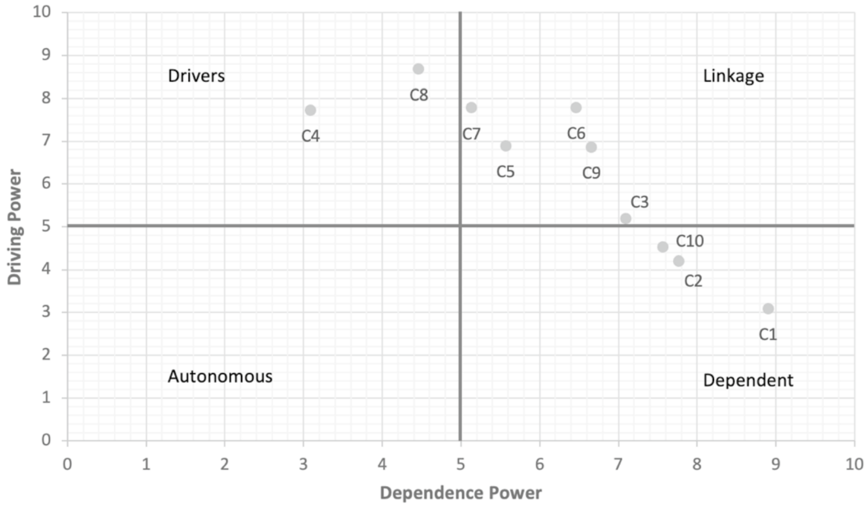
	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
C1 Poor material and energy efficiency	(1, 1, 1)	(0.25, 0.50, 0.75)	(0.0, 0.0, 0.25)	(0.0, 0.0, 0.25)	(0.0, 0.0, 0.25)	(0.0, 0.0, 0.25)	(0.0, 0.0, 0.25)	(0.0, 0.0, 0.25)	(0.25, 0.50, 0.75)	(0.50, 0.75, 1)
C2 Poor circular design	(0.75, 1, 1)	(1, 1, 1)	(0.0, 0.0, 0.25)	(0.0, 0.0, 0.25)	(0.0, 0.0, 0.25)	(0.0, 0.0, 0.25)	(0.0, 0.0, 0.25)	(0.0, 0.0, 0.25)	(0.75, 1, 1)	(0.75, 1, 1)
C3 Technological challenges	(0.75, 1, 1)	(0.50, 0.75, 1)	(1, 1, 1)	(0.0, 0.0, 0.25)	(0.50, 0.75, 1)	(0.50, 0.75, 1)	(0.0, 0.0, 0.25)	(0.0, 0.0, 0.25)	(0.0, 0.0, 0.25)	(0.50, 0.75, 1)
C4 Regulatory pressures	(0.75, 1, 1)	(0.75, 1, 1)	(0.75, 1, 1)	(1, 1, 1)	(0.25, 0.50, 0.75)	(0.50, 0.75, 1)	(0.25, 0.50, 0.75)	(0.25, 0.50, 0.75)	(0.75, 1, 1)	(0.50, 0.75, 1)
C5 Internal stakeholders' pressures	(0.25, 0.50, 0.75)	(0.50, 0.75, 1)	(0.50, 0.75, 1)	(0.25, 0.50, 0.75)	(1, 1, 1)	(0.50, 0.75, 1)	(0.75, 1, 1)	(0.25, 0.50, 0.75)	(0.50, 0.75, 1)	(0.25, 0.50, 0.75)
C6 Financial pressures	(0.75, 1, 1)	(0.50, 0.75, 1)	(0.75, 1, 1)	(0.25, 0.50, 0.75)	(0.50, 0.75, 1)	(1, 1, 1)	(0.50, 0.75, 1)	(0.50, 0.75, 1)	(0.50, 0.75, 1)	(0.50, 0.75, 1)
C7 Insufficient human capital	(0.75, 1, 1)	(0.50, 0.75, 1)	(0.75, 1, 1)	(0.0, 0.0, 0.25)	(0.50, 0.75, 1)	(0.75, 1, 1)	(1, 1, 1)	(0.75, 1, 1)	(0.50, 0.75, 1)	(0.50, 0.75, 1)
C8 Poor management and leadership	(0.75, 1, 1)	(0.50, 0.75, 1)	(0.50, 0.75, 1)	(0.50, 0.75, 1)	(0.75, 1, 1)	(0.75, 1, 1)	(0.75, 1, 1)	(1, 1, 1)	(0.75, 1, 1)	(0.50, 0.75, 1)
C9 Lack of external collaborations	(0.75, 1, 1)	(0.75, 1, 1)	(0.75, 1, 1)	(0.0, 0.0, 0.25)	(0.25, 0.50, 0.75)	(0.25, 0.50, 0.75)	(0.50, 0.75, 1)	(0.25, 0.50, 0.75)	(1, 1, 1)	(0.50, 0.75, 1)
C10 Consumer-related challenges	(0.50, 0.75, 1)	(0.50, 0.75, 1)	(0.50, 0.75, 1)	(0.0, 0.0, 0.25)	(0.0, 0.25, 0.50)	(0.50, 0.75, 1)	(0.0, 0.0, 0.25)	(0.0, 0.0, 0.25)	(0.0, 0.0, 0.25)	(1, 1, 1)

Table 14 Final fuzzy reachability matrix of the seven experts with fuzzy and crisp values of the driving and dependence power of challenges

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	Driving power	Crisp value
C1 Poor material and energy efficiency	(1, 1, 1)	(0.25, 0.50, 0.75)	(0.0, 0.0, 0.25)	(0.0, 0.0, 0.25)	(0.0, 0.0, 0.25)	(0.0, 0.0, 0.25)	(0.0, 0.0, 0.25)	(0.0, 0.0, 0.25)	(0.25, 0.50, 0.75)	(0.50, 0.75, 1)	(2, 2.75, 5)	3.088
C2 Poor circular design	(0.75, 1, 1)	(1, 1, 1)	(0.0, 0.0, 0.25)	(0.0, 0.0, 0.25)	(0.0, 0.0, 0.25)	(0.0, 0.0, 0.25)	(0.0, 0.0, 0.25)	(0.0, 0.0, 0.25)	(0.75, 1, 1)	(0.75, 1, 1)	(3.25, 4, 5.5)	4.1904
C3 Technological challenges	(0.75, 1, 1)	(0.50, 0.75, 1)	(1, 1, 1)	(0.0, 0.0, 0.25)	(0.50, 0.75, 1)	(0.50, 0.75, 1)	(0.0, 0.0, 0.25)	(0.0, 0.0, 0.25)	(0.0, 0.0, 0.25)	(0.50, 0.75, 1)	(3.75, 5, 7)	5.1876
C4 Regulatory pressures	(0.75, 1, 1)	(0.75, 1, 1)	(0.75, 1, 1)	(1, 1, 1)	(0.25, 0.50, 0.75)	(0.50, 0.75, 1)	(0.25, 0.50, 0.75)	(0.25, 0.50, 0.75)	(0.75, 1, 1)	(0.50, 0.75, 1)	(5.75, 8, 9.25)	7.7216
C5 Internal stakeholders' pressures	(0.25, 0.50, 0.75)	(0.50, 0.75, 1)	(0.50, 0.75, 1)	(0.25, 0.50, 0.75)	(1, 1, 1)	(0.50, 0.75, 1)	(0.75, 1, 1)	(0.25, 0.50, 0.75)	(0.50, 0.75, 1)	(0.25, 0.50, 0.75)	(4.75, 7, 9)	6.8824
C6 Financial pressures	(0.75, 1, 1)	(0.50, 0.75, 1)	(0.75, 1, 1)	(0.25, 0.50, 0.75)	(0.50, 0.75, 1)	(1, 1, 1)	(0.50, 0.75, 1)	(0.50, 0.75, 1)	(0.50, 0.75, 1)	(0.50, 0.75, 1)	(5.75, 8, 9.75)	7.7848
C7 Insufficient human capital	(0.75, 1, 1)	(0.50, 0.75, 1)	(0.75, 1, 1)	(0.0, 0.0, 0.25)	(0.50, 0.75, 1)	(0.75, 1, 1)	(1, 1, 1)	(0.75, 1, 1)	(0.50, 0.75, 1)	(0.50, 0.75, 1)	(6, 8, 9.25)	7.7736
C8 Poor management and leadership	(0.75, 1, 1)	(0.50, 0.75, 1)	(0.50, 0.75, 1)	(0.50, 0.75, 1)	(0.75, 1, 1)	(0.75, 1, 1)	(0.75, 1, 1)	(1, 1, 1)	(0.75, 1, 1)	(0.50, 0.75, 1)	(6.75, 9, 10)	8.6784

Table 14 (continued)

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	Driving power	Crisp value
C9 Lack of external collaborations	(0.75, 1, 1)	(0.75, 1, 1)	(0.75, 1, 1)	(0.0, 0.0, 0.25)	(0.25, 0.50, 0.75)	(0.25, 0.50, 0.75)	(0.50, 0.75, 1)	(0.25, 0.50, 0.75)	(1, 1, 1)	(0.50, 0.75, 1)	(5, 7, 8.5)	6.8512
C10 Consumer-related challenges	(0.50, 0.75, 1)	(0.50, 0.75, 1)	(0.50, 0.75, 1)	(0.0, 0.0, 0.25)	(0.0, 0.25, 0.50)	(0.50, 0.75, 1)	(0.0, 0.0, 0.25)	(0.0, 0.0, 0.25)	(0.0, 0.0, 0.25)	(1, 1, 1)	(3, 4.25, 6.5)	4.5216
Dependence power	(7, 9.25, 9.75)	(5.75, 8, 9.75)	(5.5, 7.25, 8.5)	(2, 2.75, 5)	(3.75, 5.5, 7.5)	(4.75, 6.5, 8.25)	(3.75, 5, 6.75)	(3, 4.25, 6.25)	(5, 6.75, 8.25)	(5.5, 7.75, 9.75)		
Crisp value	8.9037	7.7722	7.0941	3.0904	5.5704	6.464	5.1364	4.4668	6.6578	7.5661		



(C1) Poor Material and Energy Efficiency	**(C2)** Circular Design	**(C3)** Technological Challenges	**(C4)** Regulatory Pressures	**(C5)** Internal Stakeholders' Pressures
(C6) Financial Pressures	**(C7)** Insufficient Human Capital	**(C8)** Poor Management and Leadership	**(C9)** Lack of External Collaborations	**(C10)** Consumer-related Challenges

Fig. 5 Fuzzy MICMAC analysis

and the starting point for addressing the challenges and implementation efforts. This confirms the massive control that governments have over companies (including management and leadership), retailers, and consumers, and is consistent with the findings from literature. This indicates the critical role that governments play in the transition to a CE within the fashion industry [8, 18]. Although poor management and leadership is ranked at level 2 amongst other challenges, the findings entail that it is the challenge that is the second most critical for review. Therefore, it needs to be provided with a high degree of attention and addressed effectively. The TISM model implies that this challenge is interlinked with regulatory pressures, showing that poor management and leadership can influence and get influenced by regulatory pressures. The literature reviewed shows the influence of regulatory pressures on poor management and leadership. Still, despite its importance and complexity, it fails to consider the impact of poor management and leadership on regulatory pressures. Hence, the findings of this research contribute to this gap. Moreover, the findings illustrate that poor management and leadership is directly and indirectly linked to all other challenges. This demonstrates that management and leadership are crucial for positive organisational change, managing high costs and risks, understanding and motivating employees, and planning, organising, and controlling resources [11, 36, 42].

Furthermore, the Fuzzy-MICMAC analysis maps the regulatory pressures and poor management and leadership as drivers, as shown in Fig. 3. According to the interviews, regulatory pressures affect all other challenges. An interesting example made by one of the experts was that licenses must be obtained to allow waste collection, transportation, and handling because a producer is designated to make a particular product and would need a different license to sell waste. At the same time, companies must justify what is bought, produced, and wasted, and if waste is recognised as a secondary raw material, then this justification might be impacted. Furthermore, most experts explained that fashion companies have a more top-down approach. For example, a few experts mentioned that managers and leaders brief employees, including designers, about the actions that need to be done and the ways of implementing these actions. This shows that poor management and leadership have a strong driving force as it affects the strategies formulated and decisions made at a very early stage concerning all other challenges. This entails that regulatory pressures and poor management and leadership shape the rest of the complex system, as they can influence other challenges and have low dependence on other challenges. Therefore, both challenges are crucial to the success of a CE implementation in the fashion industry and maximising its beneficial results.

Secondly, the TISM model shows that poor management and leadership, lack of external collaborations, and insufficient human capital are ranked at level 2. This contributes to the existing research since the literature reviewed indicates the role of government in initiating external collaborations but does not consider the role of government in addressing the challenge of having insufficient human capital. Furthermore, collaborations help share knowledge, ideas, techniques, materials, and resources, which help improve human capital and the growth of the organisations within the industry. However, sufficient human capital is still necessary for the collaboration, as without it, this collaboration would not be possible. This is because employees should have the knowledge and skill set required for applying circularity. Although very little was found in the literature on associating lack of external collaborations and insufficient human capital, Todeschini et al. somehow support the findings of this research by suggesting that external collaborations rely on three supporting factors: external environmental pressures, competitive environmental pressures, and the search for a competitive advantage [45].

Thirdly, the following challenges that need to be addressed are financial pressures, internal stakeholders' pressures, and technological challenges, ranked at level 3 on the TISM model. The literature reviewed focuses on the financial pressures occurring due to the lack of financial means, support, and uncertainty surrounding profitability [8, 16, 34]. This research adds that financial pressures are thought to rely on the economy and the company's size. For instance, big companies in low-income countries generate a lot of revenue, which massively impacts the economy. Therefore, good leadership and management regulations could be adjusted so that these companies do not move elsewhere with fewer taxes or lower costs. The findings and literature still agree that financial pressures are a linkage challenge. This is because financial pressures are obstructing the transition to a CE, and at the same time, the transition to a CE creates financial pressures. Also, financial pressures could cause multiple effects depending on the economy and the company's size. For internal stakeholders' pressures, the literature reviewed explains that internal stakeholders would support the implementation of CE strategies and have positive effects when there is an economic incentive and when their goals are aligned [8, 16, 32]. This is supported by the findings classifying internal stakeholders' pressures as a linkage challenge because stakeholders' pressures could work with or against the transition to a CE based on the factors highlighted in the literature.

Moreover, the Fuzzy-MICMAC analysis maps technological challenges (C3), internal stakeholders' pressures (C5), financial pressures (C6), insufficient human capital (C7), and lack of external collaborations (C9) within the "linkage" cluster, hence requiring careful treatment since any change could lead to multiple effects on other challenges and themselves. Therefore, each of the challenges falling in the "linkage" cluster influences and gets influenced by other challenges in different ways that cannot be anticipated. The TISM model allocates these challenges falling in the "linkage" cluster to levels 2 and 3 and considers them being in the middle levels of the hierarchy with multiple effects. An example from the interviews is that although technological advancement could positively help circularity through various ways, including accepting and separating different fibres, it could also lead to increased production, negatively affecting the CE. As the literature demonstrates, technological challenges obstruct the transition to a CE since up-to-date, cost-effective, and efficient technologies support CE business models without compromising quality [8, 17]. Nevertheless, technological advancements could also lead to circular rebound if not used effectively and efficiently, demonstrating its linkage effect and consistency with the literature [23].

Finally, poor material and energy efficiency (C1), circular design (C2), and consumer-related challenges (C10) are ranked at level 4 on the TISM model. They are mapped within the "dependent" cluster in the Fuzzy-MICMAC analysis. These are the least significant challenges with the lowest priority and are more likely to be influenced by other challenges, not vice versa. In particular, poor material and energy efficiency and poor circular design, because these two challenges are only interconnected with challenges on the same level but do not influence or impact any other challenges from the below levels. According to the literature, circular design usually originates from market demands and preferences [25]. However, this research shows that most challenges influence poor circular design, specifically poor management and leadership, and regulatory pressures.

For poor material and energy efficiency, the findings and the literature somehow agree on this challenge as a result of poor management. However, the literature adds that this challenge could arise from the scarcity of resources arising from environmental impact and climate change, which could be hard to manage even by addressing all other challenges [22]. Furthermore, the findings of this research show that this challenge could be managed by addressing other challenges. For instance, most experts highlighted that consumers are at the bottom as they usually go for the given trends and options. Providing them with various circular options will reduce the challenges associated with their purchasing, usage, and disposable behaviour. Another expert also added that the price of the products does not influence the consumers purchasing decision because the same consumer could pay a lot more to buy a designer product. Hence it depends more on the trends and attractiveness of the products. This is in contrary to the existing literature that entails that consumer-related challenges have a significant impact on the transition to a CE and that these challenges cannot be managed or anticipated [16, 17, 20].

Managerial implications

This research identified the significance level and key challenges that top management and decision-makers must prioritise and address to support their understanding and implementation efforts. This paper shows that the management must adhere to regulations and legislation because regulatory pressure is one of the most vital factors affecting other challenges of CE implementation. However, it is not only about creating regulations but how the management implements them to increase the positive impact of the transition towards a CE. For instance, management in large enterprises may be forced to change regulations to support their CE initiatives.

Managers and leaders affect organisational culture. Therefore, the managers and leaders must have the knowledge, capabilities, and skills to implement real change, respond to the industry's needs, and find solutions and alternatives when needed. Management must also efficiently and effectively use the organisations and brand' resources, including human resources. Furthermore, management must create a flexible, adaptable, and motivated culture built on communication and collaboration across the supply chain. In addition, management needs to raise awareness of the importance of this transition and overcome the resistance to change. Moreover, management needs to consider CE principles at very early stages to base their decisions and formulate their strategies based on those principles. For instance, decisions about materials, prices, risks, and profit margins need to be considered at early stages depending on the principles and context of the application.

Therefore, it should be noted that management should focus on dealing with regulatory pressures as this challenge is at a higher level of influence, hence of greater significance. Then, the following challenges that need to be considered are poor management and leadership, lack of external collaborations, and insufficient human capital, as these challenges lie on the same level and need to be addressed by the management to overcome all other challenges at the other levels directly or indirectly.

Policy Implications

Implementing a CE in the fashion industry heavily depends on government regulations and legislation. As the findings of this research show, regulatory pressures are the key challenge faced in the transition to a CE. Hence addressing those regulatory pressures could help overcome all other challenges directly or indirectly. Many aspects concerned with the transition, including approvals, material and energy efficiency levels, and emissions allowed, are set following the regulations. Therefore, governments must change existing regulations and provide legal frameworks and policies supporting CE implementation. Governments could enforce strict and standardised regulations making CE principles a legal requirement. Managers and leaders follow and implement these policies and regulations to enable the transition to a CE. Governments could provide their support in various ways. For example, governments could reduce administration costs and requirements as well as lower taxes. Governments could also offer incentives to increase collaborations between parts of the supply chain or various organisations/brands.

Furthermore, governments could support waste minimisation strategies by providing access to textile waste and giving permission to collect this waste from other organisations/brands and use it as a resource stream. This reduces the challenges faced due to the lack of collaboration and helps address other challenges. For example, governments could encourage training and development of the workforce to improve their knowledge and skills regarding the CE, enabling them to implement new techniques and use advanced technologies required in that transition. Additionally, governments could set a cap on the price of products according to their specifications and/or the production levels to avoid, to ensure that managers and leaders implement strategies that would not exploit consumers or resources. Therefore, indirectly encourage consumers to choose circular services or products and avoid circular rebound and premiums.

Conclusion

This research aims to identify the level of significance of the challenges identified in the literature to assist top management with formulating a strategy and making decisions. These choices are based on the key challenges that require the most attention for a successful and effective implementation. To achieve the aim of this research, research questions were established to direct, identify, and fill the research gap, and populate the TISM model and MICMAC analysis diagrams which are deducted from the research findings.

Existing literature and research were used to identify the ten challenges of introducing a CE in the fashion industry used in this paper, including poor material and energy efficiency, poor circular design, technological challenges, regulatory pressures, internal stakeholders' pressures, financial pressures, insufficient human capital, poor management and leadership, lack of external collaborations, and consumer-related challenges.

The TISM model is a key step that demonstrates that all challenges identified from the literature are interrelated and directly or indirectly influence one another. The ranking of the challenges identified is as follows.

- Level 1: Regulatory pressures
- Level 2: Poor management and leadership, insufficient human capital, and lack of external collaborations
- Level 3: Technological challenges, internal stakeholders' pressures, and financial pressures
- Level 4: Poor material and energy efficiency, poor circular design, and consumer-related challenges

Level 1 has the highest significance level, and level 4 has the lowest. Therefore, identifying regulatory pressures is the key challenge that requires the most managerial attention.

The Fuzzy MICMAC analysis mapped technological challenges, internal stakeholders' pressures, financial pressures, insufficient human capital, and lack of external collaborations within the "linkage" cluster. This shows that addressing those challenges directly should be avoided unless necessary due to their instability, which may lead to more challenging factors or less effective implementation results. Moreover, Poor Material and energy efficiency, poor circular design, and consumer-related challenges are mapped within the "dependence" cluster. This indicates that these challenges have the least significance, in line with the TISM model, as they are likely to be addressed indirectly. Also, directing the implementation efforts to these challenges may not lead to the most successful and effective results. Finally, regulatory pressures and poor management and leadership are mapped within the "drivers" cluster. Therefore, according to MICMAC analysis, these are the key challenges with the highest significance level.

This research contributes to existing research in various ways. Firstly, this research is the first research to use Fuzzy-TISM to identify the interrelationship between the challenges and to arrange these challenges into a hierarchy-based model This helps in the simple visualisation of a complex system of challenges and reveals the direct and indirect impact, as well as the level of significance of the challenges. Secondly, this is the first research to use Fuzzy MICMAC analysis to map and rank these challenges depending on their driving and dependence power to validate and analyse the TISM model developed. Thirdly, the findings demonstrate that poor management and leadership significantly influence regulatory pressures, not just vice versa, as illustrated in the existing literature, which elaborates on the significance of both challenges for a successful and effective transition. This is because regulatory pressures and poor management and leadership are the key challenges that directly or indirectly influence other challenges and therefore need the most managerial attention for a successful and effective implementation. Finally, contrary to the existing literature, the research findings indicate the insignificance of directing measures or strategies to address the challenges at level 4. This includes consumer-related challenges since they are usually addressed indirectly whilst tackling the other challenges.

The limitation of this research is that data was collected through interviews with individuals rather than focus groups due to the experts' time and availability restrictions. This limited the opportunity to allow all experts involved in the research to communicate their opinions and different perspectives from their experiences and agree on the pairwise relationship of the challenges rather than basing this relationship on the highest frequency of occurrence throughout the interviews. This has also limited the opportunity to have an insightful justification for the agreed relationship between the challenges.

Future research should aim to collect data from experts using focus groups instead to reach a contextual pairwise relationship between the challenges identified from the literature. This will help avoid or overcome the risk of misinterpretation of the data collected. Furthermore, the TISM model and MICMAC analysis are based on the subjective knowledge and experience of the experts participating in the research. Therefore, future research could consider empirically testing the results of this research. Finally, future research could explore possible ways of addressing the key challenges concluded in this research. However, the research context, location of the brands/ organisations, demographics, and the culture they operate in should all be considered when planning future research, as these factors will significantly affect the results and findings.

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Data Availability Not authorised to share or publish identifiable personal data or materials.

Code Availability Not applicable.

Declarations

Ethics Approval This research was approved by the Cranfield University Research Ethics System (CURES). (Ethics approval reference: CURES/15947/2022).

Consent to Participate Verbal informed consent was obtained prior to the interviews.

Consent for Publication Verbal informed consent for publication of this research was obtained prior to the interviews, noting that the participation in the interviews was voluntary and identities were kept anonymous.

Competing Interests The authors declare no competing interests.

References

1. Armstrong CM, Niinimäki K, Kujala S, Karell E, Lang C (2015) Sustainable product-service systems for clothing: exploring consumer perceptions of consumption alternatives in Finland. J Clean Prod 97:30–39. https://doi.org/10.1016/j.jclepro.2014.01.046
2. Colucci M, Vecchi A (2021) Close the loop: evidence on the implementation of the circular economy from the Italian fashion industry. Bus Strategy Environ 30(2):856–873. https://doi.org/10.1002/bse.2658
3. Ellen MacArthur Foundation (2017) Fashion and the circular economy. https://www.ellenmacarthurfoundation.org/explore/fashion-and-the-circular-economy. Accessed 24 Mar 2021
4. Office for National Statistics (2020) Employment in the fashion industry in London - Office for National Statistics. https://www.ons.gov.uk/businessindustryandtrade/business/activitysizeandlocation/adhocs/11367employmentinthefashionindustryinlondon. Accessed 07 Aug 2022
5. European Commission (2022) Textiles and clothing industries. https://single-market-economy.ec.europa.eu/sectors/fashion/textiles-and-clothing-industries_it. Accessed 30 Mar 2022
6. Smith P (2022) Global apparel market - statistics & facts | Statista. https://www.statista.com/topics/5091/apparel-market-worldwide/#topicHeader__wrapper. Accessed 07 Aug 07
7. World Economic Forum (2021) Five big bets for the circular economy in Africa. [Online]. Available: www.aceaafrica.org
8. Abdelmeguid A, Afy-Shararah M, Salonitis K (2022) Investigating the challenges of applying the principles of the circular economy in the fashion industry: a systematic review'. Sustain Prod Consum 32:505–518. https://doi.org/10.1016/j.spc.2022.05.009
9. Atstja D, Cudečka-Puriņa N, Vesere R, Abele L, Spivakovskyy S (2021) 'Challenges of textile industry in the framework of Circular Economy: Case from Latvia', in *E3S Web of Conferences*. EDP Sciences. https://doi.org/10.1051/e3sconf/202125501014
10. Vehmas K, Raudaskoski A, Heikkilä P, Harlin A, Mensonen A (2018) Consumer attitudes and communication in circular fashion. J Fash Mark Manag 22(3):286–300. https://doi.org/10.1108/JFMM-08-2017-0079
11. Hina M, Chauhan C, Kaur P, Kraus S, Dhir A (2022) Drivers and barriers of circular economy business models: where we are now, and where we are heading. J Clean Prod (333). https://doi.org/10.1016/j.jclepro.2021.130049
12. Ellen MacArthur Foundation (2012) The circular economy in detail. https://www.ellenmacarthurfoundation.org/explore/the-circular-economy-in-detail. Accessed 27 Jun 2021
13. Ki CW, Park S, Ha-Brookshire JE (2021) Toward a circular economy: Understanding consumers' moral stance on corporations' and individuals' responsibilities in creating a circular fashion economy. Bus Strategy Environ 30(2):1121–1135. https://doi.org/10.1002/bse.2675
14. United Nations (2016) Sustainable development goals. https://www.un.org/sustainabledevelopment/blog/2015/12/sustainable-development-goals-kick-off-with-start-of-new-year/. Accessed 22 Mar 2022
15. Gabriel M, Luque MLD (2020) Sustainable development goal 12 and its relationship with the textile industry. In: Gardetti MA, Muthu SS (eds) The UN sustainable development goals for the textile and fashion industry, Singapore: textile science and clothing technology, Springer, [Online]. Available: http://www.springer.com/series/13111
16. Kumar P, Singh RK, Kumar V (2021) Managing supply chains for sustainable operations in the era of industry 4.0 and circular economy: analysis of barriers. Resour Conserv Recycl 164. https://doi.org/10.1016/j.resconrec.2020.105215
17. Tura N, Hanski J, Ahola T, Ståhle M, Piiparinen S, Valkokari P (2019) Unlocking circular business: A framework of barriers and drivers. J Clean Prod 212:90–98. https://doi.org/10.1016/j.jclepro.2018.11.202
18. García-Quevedo J, Jové-Llopis E, Martínez-Ros E (2020) Barriers to the circular economy in European small and medium-sized firms. Bus Strategy Environ 29(6):2450–2464. https://doi.org/10.1002/bse.2513
19. Pathak R, Endayilalu A (2019) Circular economy: a perspective of ethiopian textile sector 1: 11
20. Dissanayake G, Weerasinghe D (2021) Towards circular economy in fashion: review of strategies, barriers and enablers. Circ Econ Sustain. https://doi.org/10.1007/s43615-021-00090-5
21. CM Ostermann, LS da Nascimento, FK Steinbruch, D Callegaro-de-Menezes (2021) Drivers to implement the circular economy in born-sustainable business models a case study in the fashion industry. Revista de Gestão 28(3):223–240. https://doi.org/10.1108/rege-03-2020-0017
22. Sandvik IM, Stubbs W (2019) Circular fashion supply chain through textile-to-textile recycling. J Fash Mark Manag 23(3):366–381. https://doi.org/10.1108/JFMM-04-2018-0058

23. Zink T, Geyer R (2017) Circular economy rebound. J Ind Ecol 21(3):593–602. https://doi.org/10.1111/jiec.12545
24. Khamisani N (2021) Evolving the fashion design process for multiple lives and users. Fash Pract 13(3):351–375. https://doi.org/10.1080/17569370.2021.1973229
25. Gazzola P, Pavione E, Pezzetti R, Grechi D (2020) Trends in the fashion industry. The perception of sustainability and circular economy: a gender/generation quantitative approach. Sustainability (Switzerland) 12(7):1–19. https://doi.org/10.3390/su12072809
26. Koszewska M (2018) Circular economy - challenges for the textile and clothing industry. Autex Res J 18(4):337–347. https://doi.org/10.1515/aut-2018-0023
27. Ghisellini P, Cialani C, Ulgiati S (2016) A review on circular economy: the expected transition to a balanced interplay of environmental and economic systems. J Clean Prod 114:11–32. https://doi.org/10.1016/J.JCLEPRO.2015.09.007
28. Jesus A, Mendonça S (2018) Lost in transition? Drivers and barriers in the eco-innovation road to the circular economy. [Online]. Available: www.sussex.ac.uk/spru/research/swpsSSRN:http://www.ssrn.com/link/SPRU-RES.htmlIDEAS:ideas.repec.org/s/sru/ssewps.html. Accessed: 03 Aug 2022
29. ABLS de Jabbour, CJC Jabbour, MG Filho, D Roubaud (2018) Industry 4.0 and the circular economy: a proposed research agenda and original roadmap for sustainable operations. Ann Oper Res 270:273–286. https://doi.org/10.1007/s10479-018-2772-8
30. Turker D, Altuntas C (2014) Sustainable supply chain management in the fast fashion industry: An analysis of corporate reports. Eur Manag J 32(5):837–849. https://doi.org/10.1016/j.emj.2014.02.001
31. Riva F, Magrizos S, Rubel MRB (2021) Investigating the link between managers' green knowledge and leadership style, and their firms' environmental performance: the mediation role of green creativity. Bus Strategy Environ. https://doi.org/10.1002/bse.2799
32. Sas I, Thoney KA, Joines JA, King RE, Woolard R (2015) Reverse logistics of US carpet recycling. In: Choi TM, Cheng TCE (eds) Sustainable fashion supply chain management, Switzerland: Springer International Publishing, 2015, pp. 3–30. [Online]. Available: http://www.springer.com/series/13081
33. Jansson D, Sjöbohm V (2022) The circular fashion economy: a case study on the role of unsold apparel in circular strategies. KTH Industrial Eng Manag, Stockholm
34. Torstensson LA (2016) Internal barriers for moving towards circularity- an industrial perspective. Master of Science Thesis, KTH, Sweden
35. de Hugo A, de Nadae J, da Lima RS (2021) Can fashion be circular? A literature review on circular economy barriers, drivers, and practices in the fashion industry's productive chain. Sustainability (Switzerland) 13(21) MDPI. https://doi.org/10.3390/su132112246
36. Sawe FB, Kumar A, Garza-Reyes JA, Agrawal R (2021) Assessing people-driven factors for circular economy practices in small and medium-sized enterprise supply chains: Business strategies and environmental perspectives. https://doi.org/10.1002/bse.2781
37. Claxton S, Kent A (2020) The management of sustainable fashion design strategies: an analysis of the designer's role. J Clean Prod 268: 122112. https://doi.org/10.1016/j.jclepro.2020.122112
38. Asante R, Agyemang M, Faibil D, Osei-Asibey D (2022) Roles and actions of managers in circular supply chain implementation: a resource orchestration perspective. Sustain Prod Consum 30:64–76. https://doi.org/10.1016/j.spc.2021.11.028
39. Bag S, Yadav G, Dhamija P, Kataria KK (2021) Key resources for industry 4.0 adoption and its effect on sustainable production and circular economy: an empirical study. J Clean Prod 281. https://doi.org/10.1016/j.jclepro.2020.125233
40. Wang CH, Juo W (2021) An environmental policy of green intellectual capital: green innovation strategy for performance sustainability. Bus Strategy Environ, p. bse.2800. https://doi.org/10.1002/bse.2800
41. Bertassini AC, Ometto AR, Severengiz S, Gerolamo MC (2021) Circular economy and sustainability: the role of organisational behaviour in the transition journey. Bus Strategy Environ. https://doi.org/10.1002/bse.2796
42. Ritzén S, Sandström GÖ (2017) Barriers to the circular economy - integration of perspectives and domains', in *Procedia CIRP*, Elsevier BV, 7–12. https://doi.org/10.1016/j.procir.2017.03.005
43. Global Fashion Agenda (2018) 2020 circular fashion system commitment- status report
44. Triguero Á, Cuerva MC, Sáez-Martínez FJ (2022) Closing the loop through eco-innovation by European firms: circular economy for sustainable development. Bus Strategy Environ. https://doi.org/10.1002/BSE.3024
45. Todeschini BV, Cortimiglia MN, de Medeiros JF (2020) Collaboration practices in the fashion industry: environmentally sustainable innovations in the value chain. Environ Sci Policy 106:1–11. https://doi.org/10.1016/j.envsci.2020.01.003

46. Berberyan Z, Jastram SM, Freidman BA (2018) Drivers and obstacles of ethical fashion consumption', in Eco-friendly and fair: fast fashion and consumer behaviour, Routledge 36–48
47. D'adamo I, Lupi G Piergiuseppe Morone, Settembre-Blundo D (2022) Environmental science and pollution research towards the circular economy in the fashion industry: the second-hand market as a best practice of sustainable responsibility for businesses and consumers 1. https://doi.org/10.1007/s11356-022-19255-2
48. Auger P, Devinney TM (2007) Do what consumers say matter? The misalignment of preferences with unconstrained ethical intentions. J Bus Ethics 76(4):361–383. https://doi.org/10.1007/s10551-006-9287-y
49. D'adamo I, Lupi G (2021) Sustainability sustainability and resilience after COVID-19: a circular premium in the fashion industry. https://doi.org/10.3390/su13041861
50. Khatwani G, Singh SP, Trivedi A, Chauhan A (2015) Fuzzy-TISM: a fuzzy extension of TISM for group decision making. Glob J Flex Syst Manag 16(1):97–112. https://doi.org/10.1007/s40171-014-0087-4
51. Singh RK, Garg SK, Deshmukh SG (2007) Interpretive structural modelling of factors for improving the competitiveness of SMEs. Singapore Manag Rev Global J Flexible Syst Manag IIMB Manag Rev 2(4):423–440
52. Bolaños R, Fontela E, Nenclares A, Pastor P (2005) Using interpretive structural modelling in strategic decision-making groups. Manag Decis 43(6):877–895. https://doi.org/10.1108/00251740510603619
53. Sushil R (2012) Interpreting the interpretive structural model. Global J Flexible Syst Manag 13(2) 87–106. https://doi.org/10.1007/S40171-012-0008-3
54. Bryman A (2012) Social research methods, 4th edn. Oxford University Press, New York, United States of America
55. Saunders M, Lewis P, Thornhill A (2019) Research methods for business students, 8th edn. Pearson Education, New York
56. Attri R, Dev N, Sharma V (2013) 'Interpretive Structural Modelling (ISM) approach: an overview. [Online]. Available: www.isca.in
57. Li R-J (1999) 'Fuzzy method in group decision making', *PERGAMON*. Comput Math Appl 38:91–101

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Mapping of the circular economy implementation challenges in the þÿfashion industry: a fuzzy TISM

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