Mitigating climate change risks by adopting emerging technologies: A contextual comparative exploration of fast fashion supply chains

Abstract

Empirical research suggests that the fast fashion (FF) industry is a major contributor to global climate change. Fast fashion supply chains (FFSCs) are inherently complex due to the multiplicity of processes, locations, and stakeholders involved. This research explores the key climate risks, response strategies, and application of emerging technologies in the comparative context of developing and developed countries. Institutional theory was used as a theoretical lens, and the research data was collected by using expert interviews from industry experts in Pakistan and United Kingdom. The analysis shows numerous climate risks posed by FFSC at multiple tiers, ranging from raw materials to the retailing of products. The FF industry in Pakistan is more focused on meeting the needs of UK fashion brands by adopting global frameworks to reduce their greenhouse gas emissions. Including, using sustainable materials, and adopting changes according to the environmental standards and renewable energy due to coercive, normative, and mimetic pressures. In contrast, coercive and mimetic pressures forcing UK fashion companies to address regulatory and economic challenges and deals with persistent organisational and cultural issues including fast changing customer requirements. To mitigate climate risks, companies in both contexts are adopting emerging technologies such as AI-based analytics, internet of things, automation, blockchain and digital traceability based solutions, and 3D printing. However, they face challenges such as high initial costs, human capital gaps, and data integration issues. To mitigate these challenges, companies in both contexts are adopting strategies such as technology-business alignment, collaboration with technology partners and multiple stakeholders, pilot testing of new technologies, cultural transformation, and structural changes.

1 Introduction

Climate change is one of the most pressing issues of the 21st century, posing a significant threat and exposing the vulnerabilities of humanity and planet earth (Millward-Hopkins et al., 2023). Climate change is causing considerable harm to property and businesses while severely disrupting the production and operations of many firms. The frequency and severity of climate-related risks, such as extreme weather events, have surged by 83% between the periods 1980-1999 and 2000-2019, creating substantial risks to individuals, businesses, and global economies (UNDRR, 2020). The poorest nations are expected to suffer the most from the consequences of climate change. By 2050, the global cost of climate-related damages, including impacts to property, agriculture, human health, and infrastructure, is projected to range between $1.7 trillion and $3.1 trillion annually (Bennett, 2023). For instance, recent wildfires in Los Angeles are preliminarily estimated to have caused economic losses and damages totalling $250 billion (AccuWeather, 2025). Thus, comprehending the policy and strategies associated with coping with climate change is imperative for international business and management scholars (Howard-Grenville et al., 2014). In addition, effective addressing of the grand challenges resulting from the ongoing climate change necessitate the collaborative efforts by various stakeholders such as policy-makers, firms, local communities (Reid and Toffel, 2009).

Fast fashion industry is known as one of the major contributors to environmental issues (Rafi-ul-Shan et al., 2024). Globally, the $1.3 trillion FF industry employs more than 300 million people along the value chain and cotton production alone accounts for almost 7% of all employment in some low-income countries (The Ellen MacArthur Foundation, 2025). In the past two decades, global fibre production has experienced significant growth, nearly doubling from 58 million tons in 2000 to 116 million tons in 2022. Projections indicate that this upward trend will persist, with production expected to reach 147 million tons by 2030 (Textile Exchange, 2023). Retail sales in textile, clothing, and footwear stores in Great Britain have grown since 2005, reaching approximately £52.6 billion in 2023 (Statista, 2025). The fashion industry is the second-biggest consumer of water and is responsible for 2-8% of global carbon emissions (Sadowski et al., 2021). Around 85% of textiles end up in landfills each year and washing certain types of clothing releases substantial amounts of microplastics into the ocean (UNECE, 2018). Thus, there is a growing awareness and demand from multiple stakeholders to design sustainable FFSCs. Furthermore, growing environmental catastrophise caused by climate change such as intensive heat waves, melting glaciers and rising water levels, wildfires, hurricanes and flooding highlight the criticality of climate risk (Akter et al., 2024). Sustainable supply chain management has evolved significantly yet significant knowledge gaps remain in our understanding of climate change risks and response strategies from contextual and comparative analytical perspectives (Ghadge et al., 2020; Er Kara et al., 2021; Kazancoglu et al., 2022).

The extant empirical research predominantly focused on the buying firm's perspective situated in developed countries, with limited attention given to upstream supply chain partners, located in developing countries (Huq and Stevenson, 2020; Rafi-ul-Shan et al., 2024). Empirical research suggest that most of the environmental and social issues in FFSCs are due to unsustainable practices at upstream levels (Khan et al., 2024). Mainly, due to lack of transparency, visibility, control and increased complexity of globally dispersed and fragmented production and manufacturing operations. The significant environmental impact of current unsustainable operational practices in the FF industry highlight the need to adopt sustainable industrial methods and emerging innovative technologies (Rafi-ul-Shan et al., 2024). Thus, to enhance our understanding of climate risks, this research incorporated the developed-developing country FFSC perspective. Such comparative and contextual analysis provided a more holistic view for managing climate risks and implementing sustainable practices across the FFSCs (Ghadge et al., 2020; Ostermann et al., 2021; Alam et al., 2023; Rafi-ul Shan et al., 2020).

The extant empirical research has highlighted the role of emerging technologies such as AI-based analytics, Internet of Things (IoTs), automation, blockchain and digital traceability-based solutions, and 3D printing in FFSCs (Jain et al. 2022; Tam and Lung, 2023; Akter et al., 2024). For example, for trend identification and demand forecasting (Kim et al., 2022; Rafi-ul-Shan et al., 2024); Managing risks (Sharma et al., 2022); collaboration, coordination and integration (Todeschini et al., 2020; Rafi-ul-Shan et al., 2020); resilience (Akter et al., 2024; Bin Makhashen et al., 2020); sustainability (Perez-Batres et al., 2014; Ghadge et al., 2020; Kazancoglu et al., 2022); size and fitting to reduce returns (Wünsche and Fernqvist, 2022; Szozda, 2023). However, despite these vital contributions the role of emerging technologies in mitigating climate risks from a comparative and contextual industrial perspective remains yet unknown. It is imperative to explore the role of ETs in mitigating climate risks in a volatile and unpredictable marketplace such as fast fashion (Rafi-ul-Shan et al., 2024). Furthermore, FF industry can benefit from the adoption and implementation of emerging technologies (e.g., AI-powered climate service innovations, AI-based analytics, internet of things, automation, blockchain and digital traceability-based solutions, and 3D printing) to improve both environmental sustainability and market performance (Akter et al., 2024). Thus, highlighting the importance of emerging technologies for sustainable production, sustainable supply chain design and promoting sustainable consumption (Chandy et al., 2023).

The extant empirical research have investigated various aspects of fast fashion supply chains. For example, sustainable practices within FFSCs for better understanding of operational complexities (e.g., Rafi-ul-Shan et al., 2018; Huq and Stevenson, 2020; Caldarelli et al., 2021, Alam et al., 2023). A stream of research also focused on the role of emerging technologies to mitigate climate change impact of fashion industry (e.g., Birtwistle et al. 2006; Jain et al. 2022; Huynh 2022; Colucci and Vecchi 2024; Akter et al. 2024; Agrawal et al. 2021; Saha et al. 2021; Salmi and Kaipia 2022). However, despite this growing body of studies, substantial gaps remain in understanding how sustainable practices are implemented in FFSCs across different regional contexts. Most of the studies focus on the developed world, limiting their applicability to the emerging or less-developed world where institutional environments, climate vulnerabilities, and technological capabilities differ markedly (Kazancoglu et al., 2022; Huynh, 2022). Similarly, exiting empirical research has also highlighted the role of various institutional forces which shape strategic decision-making and response strategies in fashion supply chains. While institutional theory has been applied to supply chain contexts (e.g., Huq and Stevenson, 2018; Akbar and Deegan, 2021), its use in explaining how coercive, normative, and mimetic pressures shape FFSC climate-risk responses remains limited (Nath et al., 2021). This highlights the need for a comparative developed-developing comparative exploration to understand how institutional environment influences the adoption of sustainable practices for climate-risk mitigation. To address the existing research gap, this study seeks to answer the following questions.

RQ1: What are the key climate risks posed by FFSC operations in a developed-developing country context?

RQ2: How are FSC firms in developed-developing countries managing their climate risks?

RQ3: How can emerging technologies help FF firms operating in developed-developing countries manage their operational climate risks?

This study carried out a structured review of the extant empirical research to identify the primary climate risks posed by FFSC operations, along with their associated challenges and mitigation strategies. The research data was collected using semi-structured interviews and analysed by employing thematic analysis. The study has made several contributions to the knowledge domain. First, it answers the call for more empirical research on climate change and its associated risks in the supply chain management discipline (Sharma et al., 2022; Colucci and Vecchi, 2024). Second, the comparative analysis of developed-developing country FFSCs contributes to enhancing the understanding of key climate risks, challenges and strategies to mitigate such risks. A comparative developed-developing country lens is essential for an end-to-end comparative and contextual analysis. Similarly, most of the existing studies focus on the developed world at downstream levels of FFSCs, making is difficult to generalise findings to the emerging or less-developed world, where institutional environments, climate vulnerabilities, and technological capabilities differ markedly due to contextual specificities (Wren, 2022).

Third, this research has applied Institutional Theory (IT) to explore the role of emerging technologies for climate risk mitigation. Thus, this study provides new insights and deepens our understanding of how the institutional environment can shape decision-making and organisational behaviour for technology adoption for climate change risk mitigation. Consequently, making original contributions by exploring contrasting experiences across developed-developing fashion markets, enhancing relevance and applicability of research findings (Mammadov and Wald, 2025). Fourth, this research has explored the role of emerging technologies, which is a growing empirical research interest in the SCM discipline (Papamichael et al., 2023; Radanliev and De Roure, 2023; Rafi-ul-Shan et al., 2024) but is often overlooked in the context of FFSCs and climate change risks. Fifth, this research also made important managerial contributions by identifying key climate risks, challenges and response strategies including the use of emerging technologies to mitigate key climate risks under diverse institutional pressures.

The remainder of this paper is structured as follows. In the next section, we present a review of the extant empirical research on climate change risk, emerging technologies and institutional theory.

Section three begins with the research methodology and discusses the research settings. Section four offers the findings of the study. Lastly, section five describes the conclusion and implications.

2. Literature Review

2.1 Climate Risks and Fast Fashion Industry

The fast fashion industry significantly impacts environmental sustainability due to its global scale and intensive resource utilisation (Ghadge et al., 2020; Saha et al., 2024). The production processes, particularly dyeing, drying, and finishing, are resource-intensive and generate substantial environmental harm (Schmutz and Som, 2022). The industry's reliance on external partners for outsourcing of raw material and production add further complexity, lack of visibility and control leading to substantial sustainability issues such as Rana Plaza incident in Bangladesh (Rafi-ul-Shan et al., 2024). This necessitates effective supply chain management balancing competitiveness with sustainability responsibility (Saha et al., 2021). Companies face increasing pressure to adopt sustainability initiatives due to heightened public scrutiny regarding labour conditions and environmental impacts (Perez-Batres et al., 2014, Todeschini et al., 2020; Saha et al., 2021).

Growing interest in environment friendly and socially responsible products and services indicate that consumer preferences are shifting towards sustainability beyond mere style and price considerations (Holtström et al., 2019; Hartley et al., 2022). A significant percentage of consumers have expressed interest in ethical consumption and the environmental impact of products, thus creating opportunities for sustainable companies (Zhang and Dong, 2021; Mohr et al., 2022). Similarly, various strategies are employed by firms operating within the fashion industry to achieve environmental sustainability such as utilising organic fibres that minimise chemical use, reusing and recycling materials, implementing clean technologies, obtaining green certifications, and enhancing product traceability throughout the SC (e.g., Sadowski et al., 2021; Kim et al., 2022; Abbate et al., 2023; Colucci and Vecchi, 2024).

The UN member agencies and various environmental organisations have developed comprehensive frameworks to address and mitigate the environmental degradation caused by industrial and commercial activities (United Nations Environment Management Group, 2023). Among the most influential is the Greenhouse Gas (GHG) Protocol established by the World

Resources Institute (WRI) and the World Business Council for Sustainable Development (WBCSD), which introduced a tripartite categorisation of emissions known as Scope 1, Scope 2, and Scope 3 (World Resources Institute, 2025). Scope 1 emissions refer to the direct greenhouse gas emissions from sources owned or controlled by an organisation, such as fuel combustion in company-owned vehicles or manufacturing facilities. Scope 2 emissions encompass indirect emissions from the generation of purchased electricity, steam, heating, or cooling consumed by the reporting company. Scope 3 emissions are the most expansive and difficult, covering all other indirect emissions that occur in a company's value chain, including upstream and downstream activities such as raw material procurement, transportation, waste disposal, and product use. Companies can better understand the full extent of their environmental impact and identify targeted strategies for decarbonisation with the adoption of this framework (SAP, 2024; National Grid, 2024).

Incorporating emissions taxonomy is essential to grounding sustainability studies within contemporary climate accountability practices (Schütze and Stede, 2024). Despite an increasing trend in adoption of these frameworks, companies in the FF industry find it challenging to collect information and the required data from upstream and downstream SCs operations and partners. Consequently, most focusing on short-term actions, making it difficult to achieve net-zero emissions in the coming decades (Matuszak-Flejszman et al., 2024; Talyka et al., 2024). Moreover, collaboration among stakeholders including suppliers, manufacturers, retailers, and consumers is essential for achieving meaningful progress in sustainability initiatives (De Brito et al., 2008). Thus, while there is a growing acknowledgment of the importance of sustainable practices in FFSC, significant gaps remain in understanding how these practices can be effectively implemented across diverse contexts (Sandvik and Stubbs, 2019; Huynh, 2022).

2.2 Emerging Technologies in FF industry

Emerging or innovative technologies, defined as existing technologies assembled and used in an innovative and creative manner, or newly developed incremental or disruptive technologies, to maximise value for business and humanity by enhancing accessibility, affordability and convenience (Rafi-ul-Shan et al., 2024). Emerging technologies play a crucial role in shaping agile and integrated FFSCs, enabling rapid trend recognition and ensuring product availability within narrow market windows. Fashion brands increasingly deploy tools such as wearables, robotics, and immersive technologies, like virtual and augmented reality, to enhance both in-store and online experiences, promoting inclusivity, convenience, and personalisation (Huang et al., 2019; Serrano et al., 2022). These technologies also assist in aligning purchasing decisions with consumer preferences and sustainability values, reducing product returns and associated waste through improved size and fit (Wünsche and Fernqvist, 2022; Szozda, 2023).

Beyond customer engagement, technological integration boosts SC transparency, productivity, and responsiveness by facilitating data-driven decisions and automating key functions (Ahmad et al., 2020; Szozda, 2023). Emerging technologies such as AI, IoT and blockchain are transforming production systems into smart factories, while simultaneously supporting financial risk management and fraud prevention (Pham et al., 2022). However, despite these benefits, the adoption of emerging technologies remains complex due to challenges like privacy concerns, resource constraints, stakeholder fragmentation, and technological unpredictability (Govindan et al., 2021; Duong et al., 2023). The effective implementation of emerging technologies requires strategic alignment and supportive organisational ecosystems to harness the full transformative potential of these innovative emerging technologies (Alam et al., 2023).

2.3 Institutional Theory

Institutional theory is an instrumental framework for understanding how the external pressures stemming from social, political, and economic factors influence organisational strategies and decision-making processes for the purpose of legitimising their practices in the eyes of their stakeholders (Perez-Batres et al., 2014; Liedong and Frynas, 2018; Purkayastha and Filatotchev, 2023). DiMaggio and Powell (1983) identified three types of isomorphic pressure: *coercive, mimetic,* and *normative*. Coercive pressures arise when organisations face formal and informal demands from other entities they depend on, such as governments, and may push manufacturing companies to adopt sustainable practices and technologies to meet environmental standards (Rafi-Ul-Shan et al., 2020). In uncertain environments with unclear objectives, mimetic pressures drive organisations to imitate successful counterparts (Nath et al., 2021). Mimetic pressures occur when companies strive for better performance by emulating their competitors' best practices. Lastly, businesses are pressured to meet the expectations of their professional networks due to normative pressure where the need to adhere to industry norms and societal expectations leads to normative isomorphism (Huq and Stevenson, 2020; Posadas et al., 2023).

The adoption of sustainability practices in FFSCs in response to social and environmental pressures from various stakeholder groups is primarily explained by institutional forces (Pedersen and Gwozdz, 2014; Khan et al., 2024). Diverse stakeholders influence companies to reduce negative external damages, like pollution, while increasing positive initiatives such as charity (Zhu et al., 2016). Simultaneously, a multitude of new environmental labels, sustainability certifications, standards, and multi-stakeholder initiatives have forced companies to internalise their externalities (Pedersen and Gwozdz, 2014). Consequently, this has led companies to recognise the strategic value of responding to stakeholder concerns to strengthen their competitive position (Zhu et al., 2016). Institutional theory has been used as the theoretical lens in various studies in the fashion industry. For instance, Huq and Stevenson (2020) explored the coercive, mimetic, and normative pressures felt by suppliers to adopt socially sustainable practices, revealing that horizontal collaboration among buyers is a crucial coercive pressure. Nath et al. (2021) reported that coercive pressures on first and second tier service providers are greater than the mimetic and normative pressures to integrate sustainability. Scheiber (2015) examined the spread of the code of conduct in the German apparel industry, revealing that NGO pressure is the primary driving force. Thus, institutional theory offers a comprehensive framework for analysing how external pressures influence organisational behaviour, particularly regarding sustainability-related issues.

In Summary- The above review makes it evident that climate change risk management in the FF industry is not only a technological or operational challenge but a deeply institutional one. FFSCs are subject to increasingly complex climate risks which demand urgent organisational responses, particularly in developed–developing country contexts where production is frequently outsourced (Huq et al., 2014; Ghadge et al., 2020). Similarly, FFSCs face intensifying institutional pressures in the form of regulatory mandates, stakeholder expectations, and broader societal norms, which collectively shape the legitimacy and sustainability expectations placed upon them (DiMaggio and Powell, 1983; Huq and Stevenson, 2020). Emerging technologies offer powerful tools to meet these demands by enhancing SC visibility, transparency, responsiveness, evidence-based decision-making, and environmental impact mitigation (Ahmad et al., 2020). However, as the literature on institutional theory underscores, the companies' ability to adopt such technologies is itself influenced by the very pressures that motivate climate action (Zhu et al., 2016; Nath et al., 2021). In this way, institutional forces not only drive organisational behaviours but shape the pathways through which technological innovation is mobilised in the pursuit of environmental legitimacy and resilience (Feng et al., 2022). This conceptual intersection offers a compelling rationale for the use of IT to explore how firms in FFSCs use emerging technology to mitigate climate risks.

Structured Review of the Empirical Research

This research conducted a structured review of the empirical research to identify developments in the extant empirical research over the course of the last two decades (2003-2023) regarding key climate risks, management strategies and challenges. The structured review was conducted in four phases following the guidelines proposed by Denyer and Tranfield (2009). *Phase I* was related to setting the research objectives and designing keywords and search strings. The main objectives of the structured review were to identify the status of climate change and the use of technology in the FFSCs literature, to identify the key climate risks in the FFSC literature, and to identify climate change risk mitigation strategies and challenges. We then applied Boolean logic to design key search strings (see Appendix 1). The key words and search strings were then discussed within the research team and an industry expert for validity and triangulation purposes to achieve enhanced research quality and transparency (Miles et al., 2014).

Phase II was concerned with ensuring quality and transparency in the data collection and finalising the research papers by providing a detailed description and trackability of the review processes (Miles et al., 2014). Emerald Insight, ScienceDirect, and Web of Science academic databases were used to search for research papers which index high quality peer reviewed empirical papers including holistic bibliographic data and detailed abstracts (Rafi-Ul-Shan et al., 2018; Khan et al., 2018). Thus, ensuring the robustness and better organisation, access and analysis of the research data and results. *Phases III* and *IV* are concerned with searching and screening the research papers and analysis for their relevance to the research subject areas. The inclusion and exclusion criteria proposed by Newbert (2007) were applied to enhance the research rigour by including research papers written in English, published from 2003-2023, and containing the chosen keywords in the title, abstract, or introduction.

The applied structured review approach helped us to finalise the 111 papers discussing our research specific subject areas, satisfying the inclusion and exclusion criteria. Figure 1 shows the yearly research trends and relevant journals. Similarly, Table 1 shows the climate and emerging technology risks, Table 2 highlights the status of climate change and fashion technologies literature, and Tables 3 and 4 highlight the strategies for and challenges to climate change risk management in the fashion literature, respectively.

Fig 1: Publications Per Year & Journals

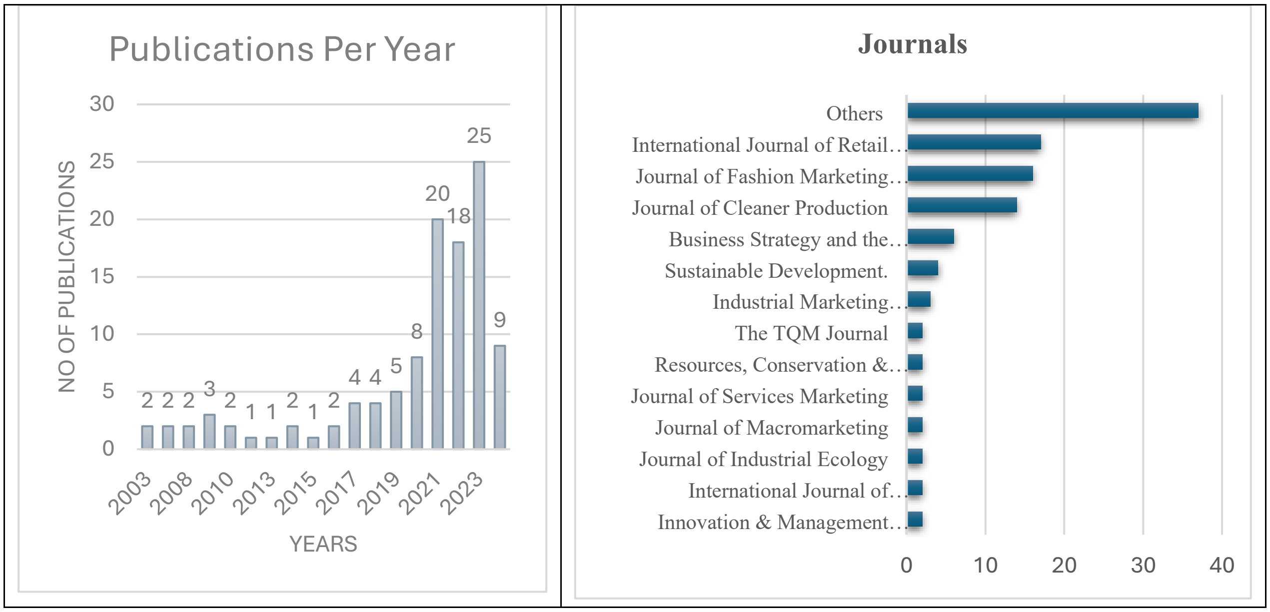

Table 1: Climate and emerging technology risks

Risks	Sources
Environmental	
Risk of contamination	Jain et al. (2022), Huynh (2022)
Waste risk	Brydges et al., (2023), Jain et al. (2022)
Climate risk	Colucci and Vecchi (2024) , Akter et al. (2024)
Carbon footprint	Salo et al. (2020), Millward-Hopkins et al., (2023)
COVID-19	Alam et al. (2023), Colucci and Vecchi (2024)
Scarcity of resources	Alam et al. (2023)
Operational	
SC Disruption risk	Sharma et al., (2022)
Legal and Reputational risks	Saha et al., (2024), Akter et al., (2024)
Regulatory risk	Hartley et al. (2022), Saha et al., 2024)
On/off contractual relations	Oxborrow and Brindley (2014), Bressanelli et al. (2022)
Frequent changes in mgt. body	Alam et al. (2023)
Lack of training and employee motivation	Maware and Parsley (2022), Alam et al. (2023)
Less authority to employee	Alam et al., (2023)
Lack of top management commitment	Jia et al., (2020), Kazancoglu et al, (2022), Alam et al. (2023)
Leak of collaboration and communication	Hartley et al., (2022), Wünsche and Fernqvist, (2022)
Procurement criteria	Oxborrow and Brindley (2014) , Alhola et al. (2019)
Technology & Information	
Outdatedness	Oxborrow and Brindley (2014), Salmi and Kaipia (2022)
Lack of data manipulations and quality	Agrawal et al., (2021), Hartley et al. (2022)
Limited circular designs	Hartley et al. (2022), Huynh (2022), Brydges et al. (2023)
Lacking ability to deliver high quality and low cost circular products	Hartley et al. (2022)
Limit of circular supply streams	Hartley et al. (2022) Kazancoglu et al.(2022), Jia et al. (2020)
Lack of technical know-how & adaptability	Sharma et al (2022), Alam et al. (2023)
Complex implementation process	Maware and Parsley (2022)
Lack of data protection	Oxborrow and Brindley (2014)
Emerging technology malfunctioning	Alam et al. (2023)
Market	
Low virgin material prices	Hartley et al. (2022)
Lacking Opportunistic competition	Hartley et al. (2022)
Lacking standardisation	Hartley et al. (2022) Maware and Parsley (2022)
Lack of understanding of the market	Oxborrow and Brindley (2014)
Social & Govt	
Trustworthiness	Oxborrow and Brindley (2014)

Lacking consumer awareness and interest	Hartley et al. (2022), Abbate et al. (2023)
Lack of government support policies	Kazancoglu et al. (2020), Abbate et al. (2023), Alam et al. (2023)
Hesitant company culture	Hartley et al. (2022) Maware and Parsley (2022),
Resistance to change due to fear of unemployment	Ahmad et al (2020), Alam et al. (2023)
Financial	
High upfront investment costs	Hartley et al. (2022), Kazancoglu et al. (2022) , Alam et al. (2023)
Limited funding for circular business models	Oxborrow and Brindley (2014), Hartley et al. (2022)
Inadequate Capital Investment	Maware and Parsley (2022) , Alam et al. (2023)
Unclear understanding of economic benefit	Alam et al. (2023)
No involvement of informal bodies	Alam et al. (2023)

Table 2: The Status of Climatic Change and Fashion Technologies Literature

Methodology & Data Collection	Core focus	Centric view of data	Applied Theory
Qualitative (54%)	**Climate change (52%)**	Asia (10%)	Resource dependence theory, OLI paradigms, Network theory, Stakeholder theory, Institutional theory, Game theory, Dynamic capability theory, Circular Economy theory, Design theory, Management theory, Graph theory,.
Case Study (35%)	*Circular economy (53%)*	Europe (44%)	
Conceptual (15%)	*Circular economy business models (7%)*	Global (32%)	
Delphi Approach (2%)	*Disruptive exogenous event (7%)*	N-America (7%)	
Document Analysis (7%)	*Life cycle perspective (7%)*	Oceania (1%)	
Focus Group (3%)	*Sustainable Fashion System (10%)*	S America (5%)	
Literature Review (13%)	*Sustainable innovation (9%)*		
Interviews (25%)	**Technology Application (48%)**		
Observation (7%)	*3D printed technology (7%)*		

Quantitative (38%)	*Augmented reality (7%)*		
Experiment (31%)	*Blockchain (7%)*		
Life cycle assessment (10%)	*Omnichannel (7%)*		
Questionnaire (64%)	*RFID (7%)*		
Mixed Method (8%)	*Technological advancements (11%)* *Others (30%)*		

The structured review shows that the majority of studies focus on in-depth, exploratory analysis, while quantitative research plays a substantial yet secondary role. (e.g., Oxborrow and Brindley, 2014; Huynh, 2022; Hartley et al., 2022; Kazancoglu et al., 2022; Abbate et al., 2023). This indicates a strong preference for qualitative approaches to explore the inherent complexities in the subject domain, even though quantitative methods like questionnaires are a critical tool for structured data gathering (e.g., (Alam et al., 2023; Akter et al., 2024). Mixed methods, while promising, have not yet gained widespread adoption (e.g., Bressanelli et al., 2022; Shou and Domenech, 2022). The extant empirical research emphasises a shift towards using technology as a key driver for combating climate change and fostering sustainability in the FF industry.

Most of the research is centred on technological advancements and applications (48%) and climate change (52%), signifying their critical role in transforming the FF industry. The geographical distribution of the research on climate change and technology in the fashion industry provides valuable insights into the regional focus and highlights areas with significant research gaps. The extant empirical research landscape is predominantly focused on developed economies, particularly Western markets, while developing and least-developed regions remain underrepresented (e.g., Alhola et al., 2019; Hartley et al., 2022; Abbate et al., 2023). This highlights an urgent need for academic efforts to bridge this gap, particularly for the purpose of understanding the intersection of climate change and technology in the fashion industry in regions with limited resources but a significant global impact. Addressing this imbalance will be critical for fostering equitable and effective solutions across the global fashion industry. The finalised empirical papers highlight several prominent theories frequently applied in research, including Dynamic Capability

Theory, Circular Economy Theory, Theory of Reasoned Action, Diffusion of Innovation Theory, and various Management Theories (e.g., Huynh, 2022; Khan et al., 2024; Lee and Fiore, 2024).

Table 3: Strategies of Climate Risk

Strategies	Sources
AI Applications	Tupikovskaja-Omovie and Tyler (2020), Akter et al. (2024)
Circular Strategies	Alhola et al. (2019), Holtström et al.(2019), Sandvik and Stubbs (2019), Salo et al. (2020), Ostermann et al. (2021), Saha et al. (2021), Salmi and Kaipia, (2022), Bressanelli et al. (2022), Hartley et al. (2022), Schmutz and Som, (2022), Shou and Domenech (2022), Luoma et al. (2022), Papamichael et al. (2023), Huynh (2022), Abbate et al. (2023), Colucci and Vecchi (2024)
Digitalisation Transformation Strategies	Fernie et al. (2010), Sandvik and Stubbs (2019), Huang et al.(2019), Tupikovskaja-Omovie and Tyler (2020), Salo et al. (2020), Agrawal et al. (2021), Huynh (2022), Hartley et al. (2022), Papamichael et al. (2023)
Formation of Novel Business Ecosystems	Fernie et al. (2010), Salmi and Kaipia (2022), Kazancoglu et al. (2022), Huynh (2022), Abbate et al. (2023), Brydges et al. (2023),
Information Sharing	Agrawal et al. (2021), Lee and Fiore (2024)
Innovation	Saha et al. (2021), Salmi and Kaipia (2022), Schmutz and Som (2022), Huynh (2022), Alam et al. (2023)
Product-orientation	Salmi and Kaipia (2022), Oguntegbe et al. (2023)
QR Strategies	Birtwistle et al. (2006), Fernie et al. (2010), Huynh, (2022)
Quick Response Strategies	Birtwistle et al. (2006)
Rental of Garments	Holtström et al. (2019), Huynh (2022)
Sensing Capability	Salmi and Kaipia (2022)
Strategic Collaborations	Saha et al. (2021), Salmi and Kaipia (2022), Schmutz and Som (2022), Huynh (2022), Oguntegbe et al. (2023)
Sustainability Practices	Salo et al. (2020), Saha et al. (2021), Oguntegbe et al. (2023), Alam et al. (2023), Millward-Hopkins et al. (2023), Colucci and Vecchi (2024)(Diddi et al., 2019)
Waste Management	Saha et al. (2021), Salo et al., (2020), Schmutz and Som (2022), Papamichael et al. (2023)

Table 4: Challenges of Climate Change

Challenges	Sources
Eco-innovation	Oxborrow and Brindley (2014), Salo et al., (2020), Alam et al. (2023), (Abbate et al., 2023), Akter et al. (2024)
Implementation of a Circular Economy	Colucci and Vecchi (2024), Ostermann et al. (2021), Jia et al. (2020), Jain et al., (2022), Hartley et al. (2022), Kazancoglu et al., (2022), Schmutz and Som (2022), Luoma et al. (2022), Huynh, (2022), Saha et al. (2021)
Lack of Collaboration	Abbate et al., (2023), Akter et al. (2024), Kazancoglu (2020), Jia et al., (2020)
Lack of Government Support	Saha et al. (2021), Alam et al. (2023)
Lack of Resources	Jia et al. (2020), Huynh (2022), Schmutz and Som (2022), Alam et al. (2023)
New Business Models	Salmi and Kaipia, (2022)
Operational Challenges	Jia et al. (2020)
Prediction of Regulatory and Technological Development	Kazancoglu et al. (2020), Salmi and Kaipia (2022)
Product Design and Manufacture	Kazancoglu et al. (2020), Jia et al. (2020)
Rapid Technological Growth	Fernie et al., (2010), Oxborrow and Brindley (2014), Holtström et al. (2019), Oguntegbe et al. (2023), Alam et al. (2023)
Scalability Challenges	Colucci and Vecchi (2024)
Sustainability and Ethical Challenges	Fernie et al. (2010), Ostermann et al. (2021), Shou and Domenech (2022), Luoma et al.(2022), Saha et al. (2021), Oguntegbe et al. (2023)
Transparency	Fernie et al. (2010), Luoma et al. (2022)

3 Research Methodology

3.1 Research Methods

This research adopted an exploratory qualitative inductive approach (Miles et al., 2014). The research data was collected by conducting semi-structured expert interviews with industry experts (Bogner et al., 2018). Expert interviews have been a widely discussed qualitative method in political and social research since the early 1990s, and are used to explore or collect data about a specific field of interest. Meuser and Nagel (2009) described the expert interview method as a qualitative interview based on a topical guide, focusing on the expert's knowledge, which is broadly characterised as specific knowledge in a certain field of action. Experts are considered knowledgeable on a particular subject and are identified by virtue of their specific knowledge, community position, or status (Kaiser, 2014). For the contextual analysis of developed-developing country FFSC climate risk mitigation, this research selected Pakistan as a developing country and UK as a developed country. Pakistan is well known for its vertically integrated fashion manufacturing and the UK for its design and retail (Husain et al., 2024). This dual country approach strengthens the study by contrasting experiences across developed and emerging markets. Thus, enhancing the relevance and applicability of the findings in diverse cultural and geographical settings (Mammadov and Wald, 2025).

3.2 Data Collection

This study adopted purposive sampling (Kazancoglu et al., 2020) to collect data from FFSC managers in the operational areas of operations, sourcing, logistics, SC, risk and sustainability management, production, IT and technology operations. To collect the research data from Pakistan, we explored the taxpayers' directory of Pakistan and selected the top 50 exporting companies of 2023-24 in the Pakistani fashion industry. The research team used their personal contacts to approach target respondents in the UK fashion industry. Experts in both countries were contacted through emails with follow-up telephone calls. Finally, 10 managers from Pakistan and 15 from the UK fashion industry showed their willingness to collaborate as part of this project. The interviews were conducted using Microsoft Teams which were recorded with the respondents' permission and lasted 50 minutes on average. The interviews were later transcribed and verified with the respondents to enhance data reliability (Yin, 2018). Efforts were made to triangulate the interview data to improve reliability and validity (Miles et al., 2014). Secondary data was reviewed from archival records, the respondents' company websites, and existing databases from various relevant industry sources.

3.3 Data Analysis

This research adopted qualitative content analysis and thematic analysis to analyse the interviews and documentary data using the coding scheme (Open, Axial and Selective coding) proposed by Strauss and Corbin (1998). The interview transcripts and document data were de-constructed into the initial codes for the purpose of open coding which led to axial coding. Subsequently, the individual codes were regrouped based on their similarities and differences in relation to the sub-themes. The research team analysed and extensively discussed the open and axial codes to identify and remove any discrepancies for greater inter-reliability and credibility (Rafi-ul-Shan et al. 2020). In the selective coding, the sub-themes were selected based on pattern matching and were combined to form the major themes such as the role of emerging technologies to mitigate climate change risks in FFSCs. Subsequently, the summary of the major themes was reported to the interviewees for validation purposes. The analysis process was conducted in the *Atlas.ti* software for simplification and better structuring to abstract and organise the useful information, whereas social constructionism was applied to interpret the major findings (Miles et al., 2019).

The qualitative content analysis enabled the exploration of the key climate change risks (RO1) of FFSC in both the UK and Pakistan. Thematic analysis was then used to develop the major themes on the key risk mitigation strategies for climate change risks (RO2) and the role of emerging technologies to mitigate the climate change risks in FFSCs (RO3). To ensure research rigour, Yin's (2018) guidelines were followed to assess the qualitative research quality through trustworthiness, which includes credibility, transferability, dependability, and confirmability. Due to the exploratory nature of this research, generalisability cannot be claimed, as is typical in quantitative studies (Rafi-ul-Shan et al., 2020). However, the approach to transferability can be divided into the intended practical and theoretical contributions, with the former being primarily context-specific, while the theoretical contribution derived from the discussion has broader analytical generalisability (Yin, 2018). The following Table 5 summarises quality measures and actions taken.

Table 5: Summary of the Actions Taken to Ensure Research Rigour

Measure	Purpose	Action Taken
Confirmability	Confirmability assurance of the integrity of the findings based on the data	Data collected from experts in the companies

	(interpretations, constructions, assertions, facts etc.)	
Credibility	Matching the constructed realities of the respondents to those presented by the evaluator	Multiple respondent types and data sources were used to triangulate emergent findings
Dependability	Trackable variance and transparency	Atlas.ti software used for coding Interview quotations, coding scheme elaborated on
Transferability	Specifying the context of scope in which the research findings can be generalised	Theoretical sampling of 10 companies in the sector of study Provided a thick description of the research process

4 Findings

4.1 Key Climate Risks

The respondents of this research argued that the industry is cognisant of climate challenges due to various pressures from a diverse set of stakeholders. Respondents explained that the key climate risks can be categorised into risks related to *operations, SC, and overall risks* (Prod-Mgr-9). Risks from operations include the high energy consumption in manufacturing processes such as cutting, sewing, dyeing and finishing which leads to significant greenhouse gas emissions (GHG) from fossil fuel-based electricity. Similarly, the dyeing and finishing processes require large volumes of water, contributing to water scarcity and pollution. Textile production generates substantial waste, including fabric scraps, chemical waste, and packaging, which can contribute to environmental pollution and contribute to GHG emissions. Similarly, the use of chemicals in the dyeing and finishing processes can release harmful pollutants into the air and water, impacting human health and the environment.

While explaining the SC-related risks, SC-Mgr-2 mentioned that *"SC in our industry is very complex because we multiple inter-dependent operations, activities and partners at upstream and downstream tiers of our SC"*. The respondents from both countries further mentioned that the key climate risks posed by the different operations of their SC partners begin with raw material production which is cotton cultivation. It involves water and chemical in an intensive process.

Similarly, synthetic fibre has a high reliance on fossil fuels for production, leading to significant GHG emissions. Respondents from the UK also mentioned that they consider their suppliers' operations, including their own energy consumption and waste generation. The UK companies also pay close attention to the logistics and transportation part following production, including the GHG emissions from the trucks, ships, and airplanes transporting raw materials and finished goods across long distances. Respondent highlighted the overall risks in the SC as consisting of "*GHG emissions across the entire value chain, water scarcity and pollution, air and soil pollution due to chemical discharges, waste disposal, and transportation emissions, and biodiversity loss*" (Sus-Mgr-6). The following Table 6 provides categories of key climate risks in both countries, as well as a brief description of their relevance to the SCOPE framework.

Table 6: Key Climate Risks of Relevance to the SCOPE Framework

Country	Climate Change Risk Category	Risk Description	Relevance to SCOPEs	Respondents' Quotations
Pakistan	Emissions from Production	Emissions from on-site boilers or generators, company-owned vehicles, leaked refrigerants	SCOPE 1	*"Our company's earlier reliance on thermal electricity/diesel generators and ageing boilers was a major hurdle. We're investing in renewables and advance technologies to cut direct emissions, but the transition is costly and slow."* (Ops-Mgr-5)
Pakistan	Emissions / Pollution from Operations, Transportation, Waste and Disposal	Emissions from purchased electricity, logistics, textile waste management, raw material production, suppliers' transportation	SCOPE 2, SCOPE 3	*"Over time energy mix in our country shifted to thermal power which increases emissions. We need better logistics and recycling systems to address SC impacts."* (Sus-Mgr-6)
UK	Energy Consumption at Retail Level	Emissions at the retail level	SCOPE 1, SCOPE 2	*"Our stores' lighting and heating systems consume significant energy. We're trailing LED upgrades and renewable energy contracts to reduce our direct and electricity-related emissions."* (Ops-Mgr-20)
UK	Supplier's Operations, Logistics	Production of apparel at the contractual partners' premises as well as logistics	SCOPE 2, SCOPE 3	*"Our reliance on overseas suppliers for FF means high emissions from their electricity use and air freight. We're pushing for greener practices, but coordination across borders is challenging."* (SO-Mgr-13)
UK	Textile Waste and Disposal	Textile waste disposal causing methane and CO2 emissions	SCOPE 3	*"Textile waste crisis, with clothes piling up in landfills or incinerated abroad, is a hidden carbon bomb. Initiatives are needed to overcome this challenge."* (Sus-Mgr-21)
UK	Overconsumption and Carbon Emissions	Washing/drying-related emissions	SCOPE 3	*"Customers buying and washing cheap clothes frequently drive massive emissions. We're educating them on low temperature washing to cut their carbon footprint."* (Ops-Mgr-20)
UK	Water Pollution from Consumer Use	Microplastic release into UK waterways	SCOPE 3	*"Microplastics from synthetic garments are polluting our rivers. We're exploring fabrics with lower shedding rates and promoting eco-friendly washing solutions."* (QC-Mgr-18)

The respondents mentioned the use of Scope 1, 2, and 3 frameworks to categorise and measure greenhouse gas (GHG) emissions as a part of the GHG protocol. In the context of the FFSCs especially at the production level, these scopes are helpful to understand and manage the environmental impact of the companies. Respondents described these scopes as *"very comprehensive and broad-based measures in conceptualising and management of climate risks in our industry* (OL & Sus-Mgr-1). *Scope 1* emissions are the direct emissions that occur from sources owned or controlled by the company. The respondents from both countries, agreed that the fashion industry has a significant environmental footprint due to its global nature and extended SC operations. Thus, understanding Scope 1, 2, and 3 emissions is a helpful framework for combating climate change challenges and reducing the environmental impact of the FF industry. Respondents also explained that the application of these frameworks is helpful in, "*identifying the hotspots in reducing emissions, setting science-based targets, engaging suppliers, and bringing transparency in the company's operations"* (Sus-Mgr-4). A positive development in a developing economy's context is that most of the respondents, especially from the companies which are engaged in business relationships with the Western retails have adopted such frameworks already. These companies are prioritising environmental impact in their operations, as one of the respondents added that "*our company prioritises eco-friendly practices because this is expected by our customers globally."* (Ops-Mgr-3).

4.2 Climate Change Risk Management Practices

Our research respondents were aware of the seriousness of the challenges posed by the climate risks and are managing these challenges with the help of various initiatives. The following Table 7 summarises various initiatives being adopted by the fashion industry in both countries. The initiatives taken by producers in Pakistan are internal in nature to manage the risks related to energy, water conservation, waste reduction, and chemical management. However, the key driver comes from the demand side of their SC partners in developed countries, for example, "*we do this, a lot of these things because our customer wants to see us doing all this*" (Sus-Mgr-4). In the UK, the major themes that emerged are internal cultural and data-related challenges, and investment in systems and processes due to the regulatory and stakeholder drivers.

The respondents from the UK fashion industry found themselves more concerned by the climate risks posed by their SC partners as the industry involves a complex network of partners both upstream and downstream. In this regard, various respondents explained that a broader stakeholder-based approach is useful to create synergy and to achieve a common goal. As a respondent discussed the importance of this issue by highlighting that, *"SC strategy must have a built-in climate risk management component apart from other components, and this is what we are doing"* (SC-Mgr-10).The key initiatives that emerged from the analysis of interviews include suppliers' engagement in climate risk management processes, efforts towards transparency in the SCs through data and the use of technologies, sustainable sourcing of material, collaboration with stakeholders, and investment recovery initiatives adopted by companies to various degrees in both, developing and developed contexts. The following table 7 provides a comparative analysis of such initiatives.

Table 7 Climate Change Risk Management Practices – Comparative Analysis

Country	Dimension	Initiatives
Pakistan	Energy	Implementing energy-efficient equipment (e.g., high-efficiency lighting, energy-efficient machinery). Utilising renewable energy sources (e.g., solar power, wind power).
	Water conservation	Reducing water usage in dyeing and finishing processes. Implementing water-efficient technologies (e.g., water recycling systems, closed-loop water systems).
	Waste reduction	Minimising fabric waste through efficient cutting techniques and utilising fabric scraps for other products. Implementing waste segregation and recycling programs.
	Chemical management	Using environmentally friendly and less harmful chemicals Implementing robust chemical management systems to minimise spills and emissions.
United Kingdom	Data and organisational culture	Recoding environmental data and establishing cultural initiatives for sustainable culture.
	Investing in systems	Investing in technologies and sustainable production and operations management systems.
	Structural changes	Setting up information and communication streams and enhancing internal and external integration for environmental risk management Supplier and customer collaboration
	Long-term orientation	Making an element of corporate strategy part of performance measurement
Common in Both Countries	Supplier engagement	Collaborating with suppliers to set and achieve environmental targets. Conducting regular environmental audits of supplier facilities. Providing training and support to suppliers on environmental best practices.
	SC transparency	Mapping and assessing the environmental impacts of all key suppliers. Communicating environmental expectations to all suppliers.
	Sustainable sourcing	Sourcing from suppliers with strong environmental and social performance records. Prioritising the use of sustainable materials (e.g., organic cotton, recycled polyester, alternative sources).

	Collaboration with stakeholders	Establishing relationships with the government; environmental organisations SC partners, customers
	Investment recovery (more prevalent in the UK)	Establishing relationships with SC partners and competitors for investment recovery

4.4 Key Drivers to Manage Climate Risks

The respondents were asked questions regarding the key drivers of managing climate-related risks in their companies to understand their perspective regarding these challenges. The analysis shows that most companies have a set of motivations that can be summarised as brand reputation, regulatory compliance, cost savings, competitive advantage, risk mitigation, and visionary leadership. These drivers can be associated with various pressures including competitive and dynamic business, legislative pressures, normative pressures, and mimetic pressures. The following table 8 highlights key findings regarding drivers to managing climate risks including institutional pressures.

Table 8: Key Drivers to Manage Climate Risks

Drivers	Description	Pressures	Pakistan	UK	Representative Quotations
Brand Reputation	Maintaining a positive brand image and meeting the consumer demand for sustainable products.	Normative, Contractual Obligations, Customers	High	High	*"Sustainability boosts our brand's appeal to eco-conscious UK buyers."* (*Prod-Mg*r-9). *"Green credentials are now vital to retain customers.*" (De-Mgr-16).
Regulatory Compliance	Meeting increasingly stringent environmental regulations (mostly from the demand side).	Coercive	Low domestic High international	High domestic	*"UK clients demand strict compliance, but local rules lag."* (Ops-Mgr-3). *"We face tough UK laws pushing us to cut emissions."* (SC-Dir-12).
Cost Savings	Increasing energy costs leading to renewable sources.	Coercive, Mimetic	High	Medium	*"Renewables cut costs and nowadays everyone is going towards solar energy*" (Sus-Mgr-6). *"Energy savings are a bonus, but increasing regulation drives us"* (Ops-Mgr-20).
Competitive Advantage	Differentiating the company from its competitors by demonstrating strong environmental performance.	Mimetic	High	High	*"Eco-friendly practices secure UK contracts"* (Sus-Mgr-4). *"Sustainability sets us apart in a crowded market*" (SO-Mgr-13).
Risk Mitigation	Reducing the financial and reputational risks associated with meeting customer and consumer requirements and climate change.	Coercive, Mimetic	Medium to High	High	*"Climate risks threaten our UK exports; we must adapt"* (SC-Mgr-7). *"Ignoring sustainability risks our reputation"* (Pu-Mgr-17).
Visionary Leadership	Visionary philosophy of the leadership.	Normative	Low	High	*"Sustainability is secondary to meeting UK orders"* (Ops-Mgr-5). *"Our vision is a circular fashion future"* (SC-Mgr-11).
Business Proposition	To attract customers and gain an early mover advantage.	Mimetic	Low	High	*"Early sustainability moves are not our focus yet."* (Ops-Mgr-5). *"Being first in eco-fashion draws new clients."* (SC-Dir-12).

The UK and Pakistani FF industry exhibits distinct motives and pressures driving sustainability adoption, shaped by their respective roles in the global SC and varying institutional contexts. In the UK, high coercive pressures stem from stringent domestic environmental regulations and the consumer demand for sustainable products. Consequently, propels motives like regulatory compliance and safeguarding brand reputation, as highlighted by respondents "*compliance with (UK) laws and consumer expectations force us to prioritise green practices"* (SC-Dir-12). Competitive advantage and business proposition motives are equally strong, driven by mimetic pressures to differentiate through early-mover sustainability initiatives. Visionary leadership also plays a significant normative role, with UK firms leveraging sustainability as a strategic vision to mitigate reputational risks.

In contrast, Pakistani FF industry faces high international coercive pressures for cost and regulatory compliance, particularly from UK retailers enforcing environmental standards, yet a low domestic regulatory drive due to weaker local frameworks. Cost savings are a prominent motive, driven by coercive and mimetic pressures to adopt renewable energy due to rising energy costs, while competitive advantage is pursued through the mimetic adoption of sustainable practices to retain UK contracts, as a business proposition. As highlighted by a respondent *"The UK clients demand eco-standards pushing us to adopt renewables to stay competitive"* (SC-Mgr-10). However, visionary leadership and business proposition motives remain weak, reflecting the limited domestic market incentives and a focus on meeting external demands.

4.5 Key Challenges of Managing Climate Risks

Often there is a gap between strategy formulation and strategy implementation, thus, the analysis of expert interview data also enabled us to explore key challenges related to climate risks and their management. Among these key challenges, the most prominent are related to the data collection and measurement of the activities that come within the domain of the Scope 3 framework. As one respondent highlighted, "*Scope 3 activities are most challenging for us, because it is a complex network with too many nodes and connections"* (Sus-Mgr-6). Similarly, another respondent, termed it as a "*complex and challenging system"* (Ops-Mgr-8). Key challenges to managing climate risks also overlapped in both countries. The analysis of the key challenges in both countries and the ways the companies are addressing them have been summarised in the following Table 9:

Table 9 Key challenges in managing climate risks and their management

Key Challenge	Country	Description	Management Practices	Representative Quotations
Data Collection and Measurement	Pakistan-UK	Difficulty collecting accurate and comprehensive data on emissions across the entire SC (especially in Scope 3)	Implementing robust data management systems and collaborating with suppliers to improve data collection (using technology)	*"Our international clients demand emissions data, but our systems lag"* (Sus-Mgr-4). *"Tracking Scope 3 emissions across our SC is tough; we're investing in digital platforms for better data*" SO-Mgr-13).
Supplier Engagement	Pakistan-UK	Engaging and motivating suppliers to adopt sustainable practices	Offering incentives to suppliers, providing technical assistance, and building strong relationships	*"We are building the capacities to push suppliers towards sustainability"* (SC-Dir-12). *"UK incentives help, but local barriers slow progress"* (OL-Sus-Mgr-1).
Cost of Implementation	Pakistan	High upfront costs for implementing sustainable technologies	Exploring financing options, such as green loans and grants	*"Green tech is expensive; we're seeking loans to bridge the gap"* (Ops-Mgr-3).
Lack of Standardisation	Pakistan	Lack of standardised methodologies for measuring and reporting environmental performance	Following internationally recognised standards and frameworks (e.g., GHG Protocol)	*"Adopting global standards like GHG Protocol is key for UK compliance"* (SC-Mgr-2).
Increased Disruptions, Risks, and Uncertainties	Pakistan-UK	This does not allow sufficient time to design proactive strategies for corporate climate risk management (CCRM)	Setting up early warning systems by developing communication and information sharing streams and building partnering relationships	*"Disasters risks disrupt our orders; we need better forecasting tools"* (SC-Mgr-10). *"SC shocks require stronger supplier partnerships"* (SC-Mgr-19).
Current Economic Situation	UK	Increased inflation, recession, and high borrowing costs pose major challenges for CCRM. This also promotes the consumer preference for savings over spending on fashion	Focusing on building partnering relationships with customers and initiatives for strong brand image development	*"Economic pressures push consumers to save, so we're strengthening our eco-brand to retain loyalty"* (Ops-Mgr-20).
Consumer Attitude and Behaviour	UK	Consumer preference for FF but a demand for environmentally sustainable products. Social media complicates narrowing the	Use of ICT and big data analysis to learn and manage consumer expectations, create	*"Social media drives green demands; we use data to align with consumer values"* (Pu-Mgr-17).

		gap between attitude and behaviour	awareness, and respond to emerging issues	
Retailer/Customer Practices	UK	Last-minute order changes, cancellations, and pressure for technology and capacity investments, plus design contributions without repeat order guarantees, hinder CCRM	Senior management and leadership involvement in managing customer expectations, early engagement, and collaboration with customers	*"Erratic orders strain our sustainability goals"* (SO-Mgr-13).

In the UK context, some variations were also found that are context specific, such as stagnation in organisational culture as SC-Mgr-19 mentioned: "*demographic factors associated with fashion manufacturing industry employees is making the companies stagnant to change their culture"* for sustainable operations design. A senior expert pointed towards the *"challenge of organisational structural challenges"* (Ops-Mgr-20) including waste due to bureaucracy, and the lack of information sharing and communication. Similarly, De-Mgr-16 highlighted the *"contrasting consumers' attitude"* that relates to showing an interest in sustainability while their buying behaviour is contrary to that. Respondents also mentioned that an important challenge is the "*lack of knowledge, expertise, and finances due to economic factors such as high interest rates, operating costs and overall complexities and uncertainties associated with the SCs"* (QC-Mgr-22). Companies are struggling to manage these challenges through the various initiatives of change management programs for the purpose of cultural and structural transformations, strengthening data and information systems, and building partnerships.

4.6 Emerging Technologies: Adoption, Purpose, and Related Challenges

The respondents were asked questions regarding how emerging technologies are being adopted and utilised, as well as the challenges encountered by their companies. While variations exist in the technology adoption and its application, the following table 10 highlights technologies that were mostly adopted by their companies.

Table 10: Emerging Technologies adapted by FFSCs for Climate Risk Mitigation

Emerging Technologies	Country	Purpose	Level of Adoption	Representative Quotations
AI-Powered Predictive Maintenance	Pakistan	Predict equipment failures to reduce downtime and emissions	Low: Limited to large mills due to high costs	*"AI cuts downtime, but costs are a barrier"* (Prod-Mgr-9).
	UK	Forecast demand and maintain warehouse equipment to reduce emissions	High: Widely used in retail logistics	*"AI streamlines our warehouses, cutting energy use"* (G&S-25).
IoT Sensors	Pakistan	Monitor water and energy use in production to optimise resources	Low: Adopted by advanced mills, limited by infrastructure	*"IoT helps us save water and energy"* (Prod-Mgr-9).
	UK	Track inventory and energy use in warehouses for efficiency	High: Common in large retailers	*"IoT optimises stock, reducing waste"* (SC-Mgr-11).
Blockchain Technologies	Pakistan	Enhance SC transparency for sustainable sourcing	Low: Early stages, cost and standardisation issues	*"Blockchain ensures clients trust our cotton sourcing"* (Sus-Mgr-6).
	UK	Trace garment origins to meet consumer sustainability demands	Medium: Piloted by some firms	*"Blockchain builds trust in our green claims"* (Sus-Mgr-21).
Robotics and Automation	Pakistan	Automate cutting and sewing for speed and precision	Low: Used by large firms, capital-intensive	*"Robots speed up export orders, but investment is steep"* (SC-Mgr-10).
	UK	Streamline warehouse operations for rapid fulfillment	High: Widespread in retail distribution	*"Automation ensures fast delivery with less energy"* (LO-Mgr-15).
RFID	Pakistan	Track inventory and ensure quality control in production	Medium: Growing in larger exporters	*"RFID reduces errors in shipments"* (SC-Mgr-7).
	UK	Real-time inventory tracking and theft prevention	High: Standard in major retailers	*"RFID keeps our stock accurate, cutting waste"* (G&S-14).
Advanced Barcodes	Pakistan	Cost-effective inventory and shipment tracking	High: Widely used due to low cost	*"Barcodes are simple but effective for tracking orders"* (SC-Mgr-2).
	UK	Basic inventory tracking and point-of-sale efficiency	High: Universal in retail	*"Barcodes remain reliable for stock management"* (Ops-Mgr-20).
EDI	Pakistan	Facilitate real-time order and inventory communication with UK retailers	Medium: Used by large exporters, limited by infrastructure	*"EDI speeds up order processing"* (Ops-Mgr-8).
	UK	Enable seamless supplier communication for rapid order fulfillment	High: Standard across retail	*"EDI ensures quick supplier coordination"* (SC-Mgr-19).
3D Printing	Pakistan	Prototype designs and produce accessories with less waste	Low: Niche, limited by cost and scalability	*"3D printing cuts waste, but it's costly"* (Ops-Mgr-8).
	UK	On-demand production of accessories to reduce overproduction	Low: Experimental, used in premium lines	*"3D printing lets us produce locally, saving emissions"* (De-Mgr-16).

In the UK's context, due to the continuous advancement of ICT, there is the enhanced application of RFID, Barcodes, and EDIs. These technologies offer enhanced capabilities for tracking and managing goods throughout the SC. Similarly, ICT continues to rapidly evolve, driven by innovations in cloud computing, big data analytics, artificial intelligence, and the Internet of Things. EDI also remains dynamic, with ongoing advancements in data exchange standards and the increasing adoption of cloud-based platforms. Our research participants argued that *"by leveraging ICT, the fashion industry can optimise logistics, minimise waste, and enhance efficiency, ultimately contributing to a more sustainable and climate-resilient future"* (SC-Mgr-10). Respondents also maintained that *"the rapid evolution of ICT in the UK has led to significant advancements in our use of RFID, barcodes, and EDI. These technologies are crucial for optimising our SC, improving efficiency, and ultimately enhancing our ability to meet the growing demand for sustainable and ethical fashion"* (SO-Mgr-13).

The respondents in both countries mentioned that emerging technologies have the significant potential to mitigate climate risks within the fashion industry. Improved inventory visibility and demand forecasting, facilitated by ICT, enables optimised transportation routes, minimising fuel consumption and associated emissions, for example, "*ICT streamlines our logistics, cutting emissions from transport*" (Ops-Mgr-20). The real-time tracking of goods further enhances logistics efficiency by identifying and avoiding unnecessary transportation as mentioned by our respondents "*tracking shipments for UK orders avoids wasteful routes*" (Ops-Mgr-5). Furthermore, these technologies play a crucial role in reducing waste. Accurate inventory tracking minimises overproduction and stockouts, preventing the accumulation of unsold goods. Our respondents highlighted that "*precise forecasting stops excess stockpiling up*" (SC-Mgr-23) and "*ICT cuts overproduction for our international clients, reducing waste*" (Prod-Mgr-9). Enhanced communication and collaboration fostered by ICT streamline processes across the SC minimises waste at various stages. Finally, ICT empowers increased operational efficiency. The automation of tasks through technologies like robotics and AI reduces energy consumption and resource use. Notably, blockchain technology, enhances the traceability of materials, enabling the sourcing of sustainable and ethically produced materials.

The most important reasons given by the respondents regarding the adoption of these technologies are economic and competitive advantage such as demands by the Western brands. Our analysis also identified technology adoption drivers such as differentiation, improving operational governance, efficiency and cost reduction, sustainability and informed data-driven decision-making. As mentioned by our Pakistani respondent "*technologies like AI and blockchain meet UK client demands, cut costs, and enhance sustainability, strengthening our market edge and operations"* (SC-Mgr-7). Similarly, a UK manager noted "*adopting ICT and robotics drives efficiency, support eco-goals, and sharpens our competitive position through data-driven governance* (LO-Mgr-15). It can be inferred that the adoption and application of emerging technologies can play a vital role in the climate change-related risk mitigation. Similarly, these technologies, if used appropriately, can support companies in their quest for competitive advantage by improving overall operational and strategic efficiency and effectiveness. As one respondent summed it up, *"innovative technologies definitely add value when it is aligned with the business strategy"* (SC-Mgr-7).

However, there are always challenges associated with the adoption of technology. In this regard, the most common challenges highlighted by our respondents in are the high initial costs associated with technology acquisition, human resources (skills gap), integration and the maintenance of the various data sources, and data security. Similarly, a sub-theme in the interviews was to explore the best practices or strategies that companies have adopted to overcome the technology adoption and implementation challenges. In this regard, the best practices adopted by companies in both countries are summarised in the following Table 11:

Table 11: Best practices for technology adoption in both countries

Pakistan	Representative Quote	United Kingdom	Representative Quote
Developing a comprehensive technology strategy to align technology investments with overall sustainability goals.	*"Technologies need to be aligned with business operations"* (Ops-Mgr-5). *"In our industry, technologies are continuously evolving but we adopt technologies when it can add value to our business"* (Prd-Mgr-9).	Cultural changes for technology adoption and implementation.	*"The industry is facing the grand challenge of aging workforce which makes it difficult to adapt"* (Ops-Mgr-20).
Pilot-testing new technologies to evaluate the effectiveness of new technologies before widespread implementation.	*"Adopting a new technology needs to be tested first. Many companies faced issues in this regard"* (SC-Mgr-10).	Organisational investment-technologies, training and development.	*"Investing in the right technologies, like AI-powered predictive analytics and automation, is not just an expense; it's a strategic investment in our long-term sustainability and competitiveness" (*G&S-14). *"We recognise that continuous training and development for our workforce is crucial to effectively leverage these new technologies and drive sustainable change"* (LO-Mgr-15).
Data integration from various sources to gain a holistic view of environmental performance.	*"Integrating data from various sources, such as production records, energy consumption data, and supplier information, is crucial for gaining a holistic understanding of our environmental impact"* (OL & Sus-Mgr-1).	Cooperation and collaboration with technology suppliers, developers, trainers and guidelines providers.	*"Building strong partnerships with technology suppliers, developers, and training providers is essential for staying ahead of the curve and accessing the latest innovations"* (Sus-Mgr-21).
Collaboration with technology providers to develop and implement innovative solutions.	*"Active collaboration with technology providers is essential to develop and implement innovative solutions that address our specific sustainability challenges"* (SC-Mgr-7).	Cooperation with SC partners and competitors.	*"We actively engage with our SC partners to encourage the adoption of sustainable practices and share best practices for climate risk mitigation" (*Pu-Mgr-17). *"While competition is inevitable, we also recognise the value of collaborating with competitors on industry-wide initiatives to address shared environmental challenges" (*QC-Mgr-18).
		Seeking guidelines from government and open market.	*"We actively seek guidance from government agencies and industry associations to ensure we are complying with all relevant regulations and best practices"* (De-Mgr-16).
		Structural changes in the organisation for better business-technology alignment to manage climate risks as part of the corporate strategy.	*"Integrating climate risk management into our core business strategy requires a fundamental shift in how we operate, from top to bottom"* (SC-Dir-12).

4.7 Effectiveness of Emerging Technologies for Mitigating Climate Risks

In response to the effectiveness of emerging technologies, the majority of the respondents recommended the adoption of emerging technologies such as AI-powered Predictive Maintenance due to its high potential for energy savings and reduced downtime. The respondents also mentioned the effectiveness of IoT sensors which enable real-time data collection and decision-making, leading to significant improvements in resource efficiency. A Pakistani manager noted*, "AI maintenance and IoT sensors cut energy use and optimise production for international orders, but integration is key"* (Sus-Mgr-6). Similarly, a UK manager stated, *"Predictive AI and IoT boost efficiency and reduce emissions, provided they align with our green goals"* (SC-Mgr-19). Additionally, their perception was that any technology that is not well-integrated into existing operations or that lacks sufficient data to support effective decision-making is the least effective. Consequently, this led us towards the earlier perspective that there should be an alignment between technology and the business purpose, in this case, climate risk mitigation.

Table 12: Effectiveness of Emerging Technologies for Mitigating Climate Risks

Emerging Technologies	Country	Purpose	Effectiveness/Role in Climate Risk Mitigation	***Representative Quotations***
AI-Powered Predictive Maintenance	Pakistan-UK	Predict equipment failures to reduce downtime	High potential for energy savings and reduced downtime, lowering Scope 1 and 2 emissions; requires integration with operations for effectiveness	*"AI maintenance saves energy but needs better integration"* (Ops-Mgr-3). *"AI cuts downtime, aligning with our green goals"* (Ops Mgr-20).
IoT Sensors	Pakistan-UK	Real-time monitoring of resource use	Enables data-driven resource efficiency, reducing Scope 3 emissions; effectiveness depends on data quality and system integration	*"IoT tracks water use, but data gaps limit impact"* (Sus-Mgr-4). *"IoT optimises stock, cutting emissions"* (Sus-Mgr-21).
Predictive Analytics	Pakistan-UK	Forecast demand accurately	Reduces overproduction and stockouts, minimising Scope 3 emissions; depends on data quality	*"Analytics helps meet international order without waste"* (Prod-Mgr-9). *"Demand forecasting cuts excess, aiding green goals"* (Pu-Mgr-17).
Rapid Prototyping and On-Demand Production	Pakistan-UK	Production on-demand to reduce lead times	Minimises overproduction and transport needs, reducing Scope 3 emissions; requires alignment with business operations	*"Prototyping cuts waste for orders, but costs are high"* (SC-Mgr-7). *"On-demand production reduces excess stock"* (SO-Mgr-13).
Personalised Production	Pakistan-UK	Enable mass customisation	Reduces large inventories and waste, lowering Scope 3 emissions; needs robust data integration	*"Customization aligns with UK demands, but data is key"* (Ops-Mgr-5). *"Personalised lines cut waste, meeting green demands"* (SC-Mgr-11).
Circular Economy Models	Pakistan-UK	Design recyclable and reusable products	Facilitates sustainable production, reducing Scope 3 waste-related emissions; requires operational alignment	*"Recyclable designs meet global demand"* (Sus-Mgr-6). *"Circular models boost our sustainability"* (QC-Mgr-22).

The respondents' perceptions of emerging technologies highlight their potential to mitigate climate risks in the FF industry, offering insights into strategic sustainability advancements such as rapid prototyping and on-demand production. Consequently, reducing lead times, minimising overproduction, reducing waste and transportation needs. Personalised production can enable mass customisation, reducing the need for large inventories and minimising waste. Circular economy models facilitate the design and production of products that are easily recycled and reused. Predictive analytics allow for the forecasting of demand more accurately, reducing the risk of overproduction and stockouts. Leveraging these technologies, FF firms can significantly reduce their environmental impact, improve their sustainability performance, and build more resilient and sustainable business models.

5 Discussion

Our research findings suggest differences in the nature of climate risks in the FF industry supply chains, ranging from the sourcing of the raw material to production and retailing and implies greater operational, upstream and downstream, integration to reduce these risks (Wren, 2022). The SC literature support our finding that there is a significant contextual gap in the climate change risks from the upstream levels of FFSCs (Huq et al., 2014; Perez-Batres et al., 2014; Kazancoglu et al., 2020; Saha et al., 2021; Alam et al., 2023; Saha et al., 2024). For examples, Huq et al., (2014) reported that the ready-to-wear fashion manufacturers in Bangladesh face immense sustainability pressures from their Western counterparts. Similarly, Rafi-ul-Shan et al., (2020) also highlighted the importance of operational integration into fashion supply chains for sustainability. Similarly, the analysis of this research reveals that due to pressure from brands, regulators and consumers (Feng et al., 2022), several companies in developing countries have defined their science-based targets such as net zero by 2050 with the goal of reducing their operational climate risks. To achieve these targets, companies have adopted frameworks to address Scopes 1, 2, and 3 to address this complex challenge (Giannakis and Papadopoulos, 2016; McMaster et al., 2020; World Resources Institute, 2025).

The findings of this research support existing literature (World Resources Institute, 2025) that while Scope 1 and Scope 2 related activities are relatively manageable, the activities in the Scope 3 domain are more complex and challenging for the FF industry to manage (Matuszak-Flejszman et al., 2024). Similarly, 75% of FF industry emissions stem from upstream Scope 3 activities in the

FFSC, thus, improving energy efficiency by collaborating with suppliers and adopting sustainable practices is important (Matuszak-Flejszman et al., 2024; Talyka et al., 2024). Products must be designed with durability, sustainability, and repairability in mind to extend product life and reduce waste (Jain et al., 2022; Brydges et al., 2023). Logistics should be optimised as well to reduce transportation emissions, including consolidating shipments (Sharma et al., 2022; Matuszak-Flejszman et al., 2024). Some of the key aspects of the climate change challenges in FFSCs are the accessibility, availability and quality of data and its measurability from upstream and downstream supply chain operations in the FF industry (Agrawal et al., 2021; Hartley et al., 2022). In the UK FF industry, the major themes that emerged are internal cultural and data-related challenges, and investment in systems and processes due to the regulatory and stakeholder drivers (Govindan et al., 2021; Khan et al., 2023).

The FF industry has embraced innovative technologies (for example blockchain technology) to varying degrees based on the overall business strategies of the companies and their associated costs (Rafi-Ul-Shan et al., 2024). Most of the companies have adopted energy related technologies (energy production and energy efficient equipment) to cater to the Scope 1 and Scope 2 related science-based targets. They are facing more challenges in the Scope 3 domain where innovative technological adoption is the key to addressing said challenges (Pham et al., 2022;Duong et al., 2023). This study find that companies in the UK and Pakistani FF industry have adopted several emerging technologies such as AI-based analytics, internet of things, automation, blockchain and digital traceability based solutions, and 3D printing (e.g., Agrawal et al., 2021; Huynh, 2022; Shou and Domenech, 2022; Kazancoglu et al., 2022; Lyu et al., 2023; Duong et al., 2023; Rafi-Ul-Shan et al., 2024). However, there are challenges related to cost of adoption, skills gaps, and data integration and maintenance due to the wide scope of the Scope 3 domain (Radanliev and De Roure, 2023). Similarly, for successful adoption, several initiatives are proposed such as developing a strategy for technology and business objectives alignment, pilot testing, and data integration and collaboration with the technology partners to enhance human capital as it can add value in the utilisation of innovative technologies (Pham et al., 2022; Rafi-ul-Shan et al., 2024).

In the Pakistani fashion industry, there is a complex interplay of coercive, normative, and mimetic pressures with respect to climate risks and their management (Trevino et al., 2008; Alexander, 2012). The coercive pressures are composed of multiple forces including government regulations and environmental laws such as compliance related to pollution control, waste disposal, and energy consumption (e.g., The Gazette of Pakistan, 1997; APTMA, 2022). There is also adherence to labour laws related to workplace safety and environmental conditions, and meeting the requirements of the trade regulations and standards set by international bodies (e.g., REACH regulations in the EU). Another pressure is from international brands to comply with their sustainability standards and certifications such as Global Organic Textile Standard and Fair Wear Foundation. There is also limited extant investor and financial institution pressure to incorporate environmental, social, and governance (ESG) factors into business operations (Ahmad et al., 2024).

The *normative pressures* in the Pakistani context include industry best practices, and pressure from industry associations and professional bodies to adopt sustainable practices and participate in industry initiatives. This also includes pressure from NGOs and civil society groups advocating for environmental and social responsibility and ethical considerations, which is consistent with previous research (Pedersen and Gwozdz, 2014; Nath et al., 2021). In contrast, mimetic pressures on the FF industry in the Pakistan are composed of imitating the strategies and best practices of best-in-class companies to gain a competitive advantage. Additionally, benchmarking with the industry leaders or differentiating from their competitors by adopting best in industry strategies is a strong pressure for many firms in the industry (Posadas et al., 2023). Furthermore, seeking guidance and adopting recommendations from consulting firms specialised in sustainability and environmental management and following the lead of influential companies are also part of mimetic pressures (Nath et al., 2021).

In the UK FF industry, coercive, normative, and mimetic pressures significantly shape sustainability motives, driving the strategic responses to climate risks (Rafi-ul-Shan eta l., 2020). Coercive pressures, stemming from stringent domestic environmental regulations and consumer expectations. Consequently, forcing firms to prioritise regulatory compliance and risk mitigation (Haq and Stevenson, 2020) as firms face mandates to reduce the various types of emissions. Normative pressures, driven by the societal demand for ethical consumption, elevate brand reputation and visionary leadership. Thus, managers emphasising the need for a positive green image and circular economy vision to align with consumer values (Nath et al., 2021; Posadas et al., 2023). Mimetic pressures drive the competitive advantage and business proposition motives as firms emulate industry leaders to gain early-mover advantages in eco-fashion, differentiating themselves in a crowded market. Thus, they leverage motives like cost savings and competitive differentiation to navigate climate risks, although economic constraints temper the adoption of costly renewable energy solutions (Zhu et al., 2016; Posadas et al., 2023).

Some of the key considerations that emerged from the analysis of our research data are the *interplay of pressures*, as these pressures often interact and overlap (Trevino et al., 2008; Alexander, 2012; Rafi-ul-Shan et al., 2020). For example, a company may initially adopt sustainable practices due to coercive pressure (e.g., government regulations or demand by the client company) but then find that these practices also improve their reputation and attract more customers (normative and mimetic pressures). Thus, key actions taken by companies are the outcomes of a complex interplay of these varying pressures (Rafi-ul-Shan et al., 2020). Delineating them from each other is not an easy proposition. For example, companies initially started looking for renewal sources of power generation due to the increasing electricity prices of the government (*coercive)*. However, later, a lot of companies adopted it due to mimetic and normative pressures (Dhillon et al., 2022).

In terms of contextual factors, the specific nature and intensity of these pressures vary depending on the size and location of the company, the specific segment they occupy, and the overall economic and social context of Pakistan (Dhillon et al., 2022). For example, companies which have long-term strategic partnerships with Western brands have been prioritising and strategising climate change related risks and its management compared with companies which operate locally or that have partnered with non-Western brands. Despite these pressures, some companies resist adopting sustainable practices due to factors such as cost, the skills gap, and resistance to change within the organisation (Govindan et al., 2021; Khan et al., 2023; Radanliev and De Roure, 2023). Governance mechanisms such as sustainability standards, reporting and auditing requirements, capability-building initiatives, and technology diffusion are designed and enforced by client companies, cascading across borders to shape supplier behavior (Rafi-ul-Shan et al., 2018; 2024 and Perry et al., 2015). However, the effectiveness of these mechanisms is mediated by institutional differences between developed and developing contexts (Rafi-ul-Shan et al., 2020).

In the UK, strong regulatory frameworks, normative expectations from consumers and civil society, and mimetic pressures from industry peers reinforce governance arrangements (Rafi-ul-

Shan eta l., 2020). Lead firms operate within an institutional environment that legitimizes and amplifies sustainability initiatives, resulting in proactive adoption of climate-risk mitigation practices (Rafi-ul-Shan 2020). Suppliers and partners in this context are incentivised to comply not only to meet contractual obligations but also to maintain legitimacy within a highly institutionalised environment (Huynh, 2022), Oguntegbe et al., 2023; Huq et al., 2014). In contrast, in Pakistan, governance mechanisms are received within a weaker regulatory environment and more fragmented institutional horizon (Khan et al., 2024). Here, supplier adoption of sustainability practices is driven less by domestic institutional pressures and more by external demands from international clients, rising energy costs, and competitive pressures (Khan et al., 2024; Dhillon et al., 2022). Standards and auditing requirements imposed by lead firms are often perceived as compliance obligations. This highlights the complex interplay between global governance arrangements and local institutional conditions, where suppliers' responses are shaped by both external mandates and local economic realities (Ahmad et al., 2020; Feng et al., 2022).

This comparative analysis advances our understanding of institutional theory by showing how regulative, normative, and mimetic pressures vary from across contexts, and how these variations condition organisational responses to climate risks (Dhillon et al., 2022 and Khan et al., 2024). It also extends debates on value-chain governance by demonstrating that governance mechanisms do not travel uniformly across borders, instead, their diffusion and effectiveness are mediated by institutional environments (Rafi-ul-Shan et al., 2020). Lead firms play a pivotal role in transmitting sustainability practices, but the outcomes depend on how local institutions enable or constrain adoption (Khan et al., 2024). Lead firms are increasingly diffusing technologies such as digital traceability systems, energy-efficient production processes, and advanced monitoring tools across their supply chains. In the UK, these technologies are integrated into broader sustainability strategies, supported by regulatory and normative pressures (Rafi-ul-Shan et al., 2024). In Pakistan, adoption is more incremental, often driven by cost considerations and external client requirements (Khan et al., 2024; Dhillon et al., 2022). This suggests that technology diffusion is itself a governance mechanism, but one whose uptake is conditioned by institutional differences. Aligning technology adoption with both global governance arrangements and local institutional realities is therefore critical for achieving meaningful climate resilience in fast fashion supply chains (Alam et al., 2023; Rafi-Ul-Shan et al., 2020; 2024).

6 Conclusion

The fast fashion industry is known for its environmental impact due to unsustainable production and consumption practices and heavy reliance on natural resources (Rafi-ul-Shan et al., 2024). The aim of this research was to explore the role of emerging technologies in mitigating climate risks in the fast fashion industry. This study carried out a contextual comparative analysis of the UK and Pakistan fashion industry. Findings of this research suggest that FF industry is prone to diverse climate risks from its upstream and downstream supply chain operations. For example, emissions from production and manufacturing, transportation, energy consumption at the retail level, textile waste and disposal, overconsumption and water pollution (Sadowski et al., 2021; Papamichael et al., 2023; Abbate et al., 2023). The identified climate risks are broadly classified in the extant empirical research as Scope 1, Scope 2, and Scope 3 risks (World Resources Institute, 2025). Among these risks, in both countries, more complexity was found in the Scope 3 related risks, which fall outside the domain of the firms' boundaries (Matuszak-Flejszman et al., 2024).

From the production perspective, more emphasis was on renewal energy, water conservation, waste reduction and chemical management. In the UK context, the practices are more inclined towards recoding data and transforming organisational culture, introducing structural changes and developing long term orientation for strategising climate change mitigation (Rafi-Ul-Shan et al., 2024). Some commonalties in practice include further emphasis required towards supplier engagement, enhancing SC transparency, and sustainable sourcing (Ahmad et al., 2020; Szozda, 2023). The key drivers to manage climate risks in both countries are brand reputation, regulatory compliance, competitive advantage through cost savings, differentiation and early movers' advantage, financial and reputational risk mitigation, and visionary leadership at the firm level (Saha et al., 2024; Akter et al., 2024).

However, the nature and intensity of the institutional pressures shaping climate risk responses differs (Huq and Stevenson, 2020). In the UK context, firms are under higher coercive and normative pressures for regulatory compliance, cost management and risk mitigation and protecting brand reputation (Akbar and Deegan, 2021; Rafi-ul-Shan et al., 2020). Pakistani firms face more coercive pressures from international brands (APTMA, 2022) but weak local regulation and, thus, focusing on cost savings and competitive advantage with limited visionary leadership (Nath et al., 2021). Similarly, it can be argued that in developed economies, regulatory, normative, and mimetic forces exert a strong influence, driving firms toward proactive sustainability practices (Hartley et al., 2022; Abbate et al., 2023). In contrast, firms in developing countries are primarily responding to external demands from international clients and economic pressures such as rising energy costs, with institutional forces playing a more complex and indirect role (Hug and Stevenson, 2020; Nath et al., 2021; Khan et al., 2024).

Importantly, our research highlights the growing adoption of emerging technologies such as IoTs, AI predictive maintenance, blockchains, 3D printing, advanced barcodes (Akter et al., 2024). These technologies are helping in relation to managing operational efficiencies and sustainability goals through automation, reducing downtime, monitoring energy and water consumption, tracking inventories, enhancing SC transparency, and improving stakeholder engagement (Rafi-Ul-Shan et al., 2024). UK firms have an advantage in terms of an the early adoption of emerging technologies compared with Pakistani firms due to developed-developing countries variations (Salmi and Kaipia, 2022). However, Pakistani firms are also adopting emerging technologies due to the aforementioned institutional pressures (Papamichael et al., 2023; Khan et al., 2024). This dual-context analysis addresses a critical gap in the extant literature (Wren, 2022; Alam et al., 2023), which has largely examined climate risk and sustainability practices in isolation, either within developed or developing settings (Alhola et al., 2019; Hartley et al., 2022; Abbate et al., 2023)), or focusing narrowly on upstream or downstream SC components (Huq and Stevenson, 2020; Rafi-ul-Shan et al., 2024: 2020).

By integrating contextual and comparative analysis of upstream and downstream FF industry supply chains, our study offers a more holistic and nuanced understanding of the role of emerging technologies in climate risk management (Colucci and Vecchi, 2024; Mammadov and Wald, 2025). Our findings suggest that aligning technological adoption with institutional dynamics and organisational strategy is essential for achieving meaningful sustainability outcomes (Feng et al., 2022). Similarly, pilot testing new technologies before widespread implementation, data integration, and collaboration with technology providers are also vital elements that are a part of achieving success in utilising emerging technologies for climate change risk mitigation within FFSCs (Huynh, 2022; Rafi-Ul-Shan et al., 2024).

6.1 Theoretical contributions

This research makes four significant contributions to knowledge. First, this research enhances our understanding of key climate risks and mitigation strategies adapted by fashion companies in both developing and developed countries. The extant empirical research has mainly focused on downstream levels of fashion supply to investigate sustainability issues (Alhola et al., 2019; Hartley et al., 2022; Abbate et al., 2023) and the role of emerging technologies (Feng et al., 2022; Rafi-ul-Shan et a;., 2024). By conducting a comparative contextual analysis, this research makes original contributions by exploring key climate risks and mitigation strategies adapted by different firms in the FF industry of UK and Pakistan. This comprehensive approach allows for a more nuanced appreciation of how firms face diverse climate risks despite operating in the same industry. Consequently, this research enhancing our understanding of how the response strategies varies across different contexts including the nature of challenges which firms face to managing their climate risks. Such understandings enables better decision-making and efficient resource allocation to design climate risk related robust mitigation strategies, consequently, enhanced effectiveness in the given context (Huynh, 2022).

Second, this research make original contribution by enhancing our understanding of the role of emerging technologies in mitigating climate risks from a comparative analysis perspective. contribution from emerging technologies perspective. This research highlighted that FF firms in both contexts use emerging technologies such as IoTs, AI predictive maintenance, blockchains, 3D printing, advanced barcodes for climate risk mitigation but Pakistani firms face more integration, cots and digital skills literacy problems. By exploring the role of technology in addressing climate risks, the research highlights the potential of innovative solutions to transform the fashion industry. This examination of technological advancements and their practical applications provides a valuable framework for companies looking to adopt cutting-edge strategies to manage climate risks effectively. However, drivers for ET adoption and institutional pressures various across both contexts. Third, this research made a novel contribution by exploring the role of institutional forces in shaping decision-making criteria for the adoption of emerging technologies to mitigate climate risks. contribution from Institutional theory perspective.

Finally, this study made original contribution from the research rigor perspective by conducting a structured systematic literature review to synthesise fragmented extant empirical research in the knowledge domain. The structured SLR provided insights regarding key climate risks, mitigation strategies, challenges and emerging technologies in fashion industry. Thus, enabled us to design robust research objectives and conduct expert interviews to fill the knowledge gaps and, thus, make novel and original contributions from a contextual comparative analysis perspectives. The research provides valuable insights into the strategies employed to manage climate risks in both developing and developed country contexts. By comparing and contrasting these strategies, this paper highlights the unique approaches taken by companies in different regions to mitigate climate-related challenges.

6.2 Practical contributions

The practical contribution of this research are threefold. First, explored key climate risks in the FF supply chain from upstream and downstream perspective and contextual perspectives. Thus, enabling managers to understand the nature and criticality of key climate risks in their supply chain from end-to-end perspective. Consequently, designing relevant mitigation strategies. Second, this research explored various response strategies for climate risk mitigation which can be used by managers to benchmark best practices. By presenting these strategies, this paper provides actionable insights that can be implemented by fashion companies to effectively manage and reduce the impact of climate risks. Third, this research explored key types of emerging technologies for mitigating climate risks including adoption and implementation challenges. Managers can benefit from this research to adopt and implement most effective emerging technologies with increased understanding of the inherent challenges.

Finally, this research used Institutional Theory lens which can help managers to understand their institutional environment and forces in the given environment which shape their strategic decision-making. Consequently, managers can proactively design climate risk response strategies to maintain and enhance their legitimacy in the given environment and beyond their firm boundaries, from supply chain perspective. Overall, this research offers a comprehensive and practical framework for industry stakeholders to enable them to understand, manage, and mitigate climate risks in the FFSC. By providing clear challenges, best practices, and guidelines for adopting emerging technologies, the paper equips fashion companies with the tools and knowledge needed to navigate the complexities of climate risk management in both developing and developed country contexts.

6.3 Limitations and future research directions

This research acknowledges some limitations and, thus, suggest avenues for the future research. First, due to exploratory qualitative nature, findings of this research cannot be generalised. The insights derived from this study are context-specific and may not be universally applicable across different settings. This limitation is typical of qualitative research, where the focus is on the depth and richness of data rather than broad generalisation. Second, the research is limited by its sampling approach, as the data was collected from managers in only one developing and one developed country. This narrow sampling frame restricts the ability to generalise the findings to other regions or contexts. Future research should consider expanding the sample to include managers from multiple countries to enhance the generalisability of the results. Third, there is a potential for bias in the perceptions of the managers interviewed. Personal biases and subjective interpretations can influence the responses, which may affect the reliability of the data. To mitigate this, future studies could incorporate additional data sources or triangulate the findings with other methods to validate the results.

Fourth, the online nature of the interviews limits the use of observations in the data collection process. The inability to conduct in-person observations may result in a loss of contextual and non-verbal cues that could enrich the data. Future research could benefit from incorporating face-to-face interviews or on-site observations to capture a more comprehensive understanding of the phenomena under study. Additionally, employing methodological variations such as mixed-methods or quantitative research can provide a more robust and comprehensive perspective. These approaches can help validate the findings and offer a more nuanced understanding of the complex dynamics at play. Finally, theoretical lens of Institutional Theory was instrumental in exploring implications of various institutional pressures for climate risk mitigation and the adoption of emerging technologies. However, the application of other theories such as dynamic capabilities or natural resource-based view can further enhance our understanding of dynamic of industry, resource requirements and implications for climate change.

References

Abbate, S., Centobelli, P., Cerchione, R., 2023. From Fast to Slow: An Exploratory Analysis of Circular Business Models in the Italian Apparel Industry. Int. J. Prod. Econ. 260, 108824.

AccuWeather, 2025. AccuWeather estimates more than $250 billion in damages and economic loss from LA wildfires [WWW Document]. AccuWeather, Inc.

Agrawal, T.K., Kumar, V., Pal, R., Wang, L., Chen, Y., 2021. Blockchain-based framework for supply chain traceability: A case example of textile and clothing industry. Comput. Ind. Eng. 154, 107130.

Ahmad, H., Yaqub, M., Lee, S.H., 2024. Environmental-, social-, and governance-related factors for business investment and sustainability: a scientometric review of global trends. Environ. Dev. Sustain. A Multidiscip. Approach to Theory Pract. Sustain. Dev. Springer, 26, 2965–2987.

Ahmad, S., Miskon, S., Alabdan, R., Tlili, I., 2020. Towards sustainable textile and apparel industry: Exploring the role of business intelligence systems in the era of industry 4.0. Sustain. 12.

Akbar, S., Deegan, C., 2021. Analysis of corporate social disclosures of the apparel industry following crisis: an institutional approach. Account. Financ. 61, 3565–3600.

Akter, S., Babu, M.M., Hani, U., Sultana, S., Bandara, R., Grant, D., 2024. Unleashing the power of artificial intelligence for climate action in industrial markets. Ind. Mark. Manag. 117, 92–113.

Alam, M.F. Bin, Hosen, M.I., Mridha, J.H., Chowdhury, S.E., Rahman, M.A., 2023. Assessing the barriers of integrating technological innovations in textiles sector: Implications towards sustainable production. Green Technol. Sustain. 1, 100039.

Alexander, E.A., 2012. The effects of legal, normative, and cultural-cognitive institutions on innovation in technology alliances. Manag. Int. Rev. 52, 791–815.

Alhola, K., Ryding, S.O., Salmenperä, H., Busch, N.J., 2019. Exploiting the Potential of Public Procurement: Opportunities for Circular Economy. J. Ind. Ecol. 23, 96–109.

APTMA, 2022. Sustainable Business Practices in Textile Sector of Pakistan [WWW Document]. APTMA. URL https://aptma.org.pk/sustainable-business-practices-in-textile-sector-of-pakistan/

Bennett, P., 2023. Climate change is costing the world $16 million per hour: study [WWW Document]. World Econ. Forum.

Bin Makhashen, Y., Rafi-ul-Shan, P.M., Bashiri, M., Hasan, R., Amar, H., Khan, M.N., 2020. Exploring the role of ambidexterity and coopetition in designing resilient fashion supply chains: a multi-evidence-based approach. J. Enterp. Inf. Manag. 33, 1599–1625.

Birtwistle, G., Fiorito, S.S., Moore, C.M., 2006. Supplier perceptions of quick response systems. J. Enterp. Inf. Manag. 19, 334–345.

Bogner, A., Littig, B., Menz, W., 2018. Generating Qualitative Data with Experts and Elites, The SAGE Handbook of Qualitative Data Collection.

Bressanelli, G., Visintin, F., Saccani, N., 2022. Circular Economy and the evolution of industrial districts: a supply chain perspective. Int. J. Prod. Econ. 243, 108348.

Brydges, T., Henninger, C.E., Barbu, L., Lupu, R., 2023. Designing for Longevity and Neutrality: Investigating How the Swedish Children’s Clothing Industry Implements

Circular Economy Principles. Fash. Pract. 15, 424–446.

Caldarelli, G., Zardini, A., Rossignoli, C., 2021. Blockchain adoption in the fashion sustainable supply chain: Pragmatically addressing barriers. J. Organ. Chang. Manag. 34, 507–524.

Chandy, R., Dowell, G., Mayer, C., Plambeck, E., Serafeim, G., Toffel, M.W., Toktey, L.B., Weber, E., 2023. Introduction to the special section on business and climate change. Manage. Sci. 69, 7347–7351.

Colucci, M., Vecchi, A., 2024. Tackling Climate Change with End-of-Life Circular Fashion Practices—Remade in Italy with Amore. Br. J. Manag. 35, 1157–1179.

De Brito, M.P., Carbone, V., Blanquart, C.M., 2008. Towards a sustainable fashion retail supply chain in Europe: organisation and performance. Int. J. Prod. Econ. 114, 534–553.

Denyer, D., Tranfield, D., 2009. Producing-a-Systematic-Review.pdf. In: Buchanan, D., Bryman, A. (Eds.), The Sage Handbook of Organizational Research Methods. Sage publications, London, pp. 671–689.

Dhillon, M.K., Rafi-Ul-Shan, P.M., Amar, H., Sher, F., Ahmed, S., 2022. Flexible Green Supply Chain Management in Emerging Economies: A Systematic Literature Review. Glob. J. Flex. Syst. Manag. 24, 1–28.

Diddi, S., Yan, R.N., Bloodhart, B., Bajtelsmit, V., McShane, K., 2019. Exploring young adult consumers' sustainable clothing consumption intention-behavior gap: A Behavioral Reasoning Theory perspective. Sustain. Prod. Consum. 18, 200–209.

DiMaggio, P.J., Powell, W.W., 1983. The iron cage revisited: Insti- tutional isomorphism and collective rationality in organizational fields. Am. Sociol. Rev. 48, 147–160.

Duong, A.T.B., Pham, T., Truong Quang, H., Hoang, T. G., McDonald, S., Hoang, T.-H., Pham, H.T., 2023. Ripple effect of disruptions on performance in supply chains: An empirical study. Eng. Constr. Archit. Manag.

Er Kara, M., Ghadge, A., Bititci, U.S., 2021. Modelling the impact of climate change risk on supply chain performance. Int. J. Prod. Res. 59, 7317–7335.

Feng, T., Liu, ; Shasha, Zhang, ; Qiansong, 2022. Linking perceived institutional force and environmental strategy: the moderating role of institutional. Balt. J. Manag. 17, 392–412.

Fernie, J., Sparks, L., McKinnon, A.C., 2010. Retail logistics in the UK: Past, present and future. Int. J. Retail Distrib. Manag. 38, 894–914.

Ghadge, A., Wurtmann, H., Seuring, S., 2020. A conceptual framework for barriers of circular supply chains for sustainability in the textile industry. Int. J. Prod. Res. 58, 44–64.

Giannakis, M. Papadopoulos, T., 2016. Supply chain sustainability: A risk management approach. Int. J. Prod. Econ. 171, 455-470.

Gligor, D.M., Holcomb, M., 2014. The road to supply chain agility: an RBV perspective on the role of logistics capabilities. Int. J. Logist. Manag. 25, 160–179.

Govindan, K., Shaw, M., Majumdar, A., 2021. Social sustainability tensions in multi-tier supply chain: A systematic literature review towards conceptual framework development. J. Clean. Prod. 279, 123075.

Hartley, K., Roosendaal, J., Kirchherr, J., 2022. Barriers to the circular economy: The case of the Dutch technical and interior textiles industries. J. Ind. Ecol. 26, 477–490.

Holtström, J., Bjellerup, C., Eriksson, J., 2019. Business model development for sustainable apparel consumption: The case of Houdini Sportswear. J. Strateg. Manag. 12, 481–504.

Howard-Grenville, J., Buckle, S.J., Hoskins, B.J., George, G., 2014. Climate change and management. Acad. Manag. J. 57, 615–623.

Huang, T.L., Mathews, S., Chou, C.Y., 2019. Enhancing online rapport experience via augmented reality. J. Serv. Mark. 31, 851–865.

Huq, F.A., Stevenson, M., 2020. Implementing Socially Sustainable Practices in Challenging Institutional Contexts: Building Theory from Seven Developing Country Supplier Cases. J. Bus. Ethics 161, 415–442.

Huq, F.A., Stevenson, M., Zorzini, M., 2014. Social sustainability in developing country suppliers: an exploratory study in the readymade garments industry of Bangladesh . Int. J. Oper. Prod. Manag. 34, 610–638.

Husain, M.D., Farooq, S., Siddiqui, M.O.R., Khan, D.R., 2024. Textile Dynamics in Pakistan: Unraveling the Threads of Production, Consumption, and Global Competitiveness. In: Sadhna, Kumar, R., Memon, H., Greeshma, S. (Eds.), Consumption and Production in the Textile and Garment Industry. SDGs and Textiles. Springer.

Huynh, P.H., 2022. Enabling circular business models in the fashion industry: the role of digital innovation. Int. J. Product. Perform. Manag. 71, 870–895.

Jain, G., Kamble, S.S., Ndubisi, N.O., Shrivastava, A., Belhadi, A., Venkatesh, M., 2022. Antecedents of Blockchain-Enabled E-commerce Platforms (BEEP) adoption by customers – A study of second-hand small and medium apparel retailers. J. Bus. Res. 149, 576–588.

Jia, F., Yin, S., Chen, L., Chen, X., 2020. The circular economy in the textile and apparel industry: A systematic literature review. J. Clean. Prod. 259, 120728.

Kaiser, R., 2014. Qualitative Experteninterviews, Konzeptionelle Grundlagen und praktische Durchführung. Springer.

Kazancoglu, I., Kazancoglu, Y., Kahraman, A., Yarimoglu, E., Soni, G., 2022. Investigating barriers to circular supply chain in the textile industry from Stakeholders' perspective. Int. J. Logist. Res. Appl. 25, 521–548.

Kazancoglu, I., Kazancoglu, Y., Yarimoglu, E., Kahraman, A., 2020. A conceptual framework for barriers of circular supply chains for sustainability in the textile industry. Sustain. Dev. 28, 1477–1492.

Khan, H., Amankwah-Amoah, J., Lee, R., Knight, G., Hussain, N., 2024. Breaking Barriers: How Do the Marketing Capabilities of Emerging-Market Micro-Multinationals Drive Social Innovation? Manag. Int. Rev. 64, 701–726.

Khan, M.N., Akhtar, P., Merail, Y., 2018. Strategies and effective decision-making against terrorism affecting supply chain risk management and security: A novel combination of triangulated methods. Ind. Manag. Data Syst. 118, 1528–1546.

Khan, S.A.R., Tabish, M., Zhang, Y., 2023. Embracement of industry 4.0 and sustainable supply chain practices under the shadow of practice-based view theory: Ensuring environmental sustainability in corporate sector. J. Clean. Prod. 398, 136609.

Kim, T., Kim, D., Park, Y., 2022. Recent progress in regenerated fibers for “green” textile products. J. Clean. Prod. 376, 134226.

Lee, A., Fiore, A.M., 2024. Factors affecting social media usage by market mavens for fashion-related information provision. J. Fash. Mark. Manag. 28, 254–272.

Liedong, T.A., Frynas, J.G., 2018. Investment Climate Constraints as Determinants of Political Tie Intensity in Emerging Countries: Evidence from Foreign Firms in Ghana. Manag. Int. Rev. 58, 675–703.

Luoma, P., Penttinen, E., Tapio, P., Toppinen, A., 2022. Future images of data in circular economy for textiles. Technol. Forecast. Soc. Change 182.

Lyu, J., Hahn, K., Lee, H.J., 2023. Potential determinants of consumers’ intention to purchase 3D printed fashion products. Int. J. Retail Distrib. Manag. 51, 1027–1044.

Mammadov, A., Wald, A., 2025. The Role of Cultural Intelligence and Emotional Intelligence in the Internationalization of SMEs : Does Global Mindset. Manag. Int. Rev.

Matuszak-Flejszman, A., Preisner, A., Banach, J.K., 2024. Transport-Related Emissions and Transition Strategies for Sustainability—A Case Study of the Fast Fashion Industry. Sustain. 16.

Maware, C., Parsley, D.M., 2022. The Challenges of Lean Transformation and Implementation in the Manufacturing Sector. Sustain. 14, 1–24.

McMaster, M., Nettleton, C., Tom, C., Xu, B., Cao, C., Qiao, P., 2020. Risk management: Rethinking fashion supply chain management for multinational corporations in light of the COVID-19 outbreak. J. Risk Financ. Manag. 13, p.173.

Meuser, M., Nagel, U., 2009. The expert interview and changes in knowledge productionin Alexander Bogner, Beate Littig and Wolfgang Menz (eds.), Interviewing Experts. Palgrave Macmillan, Basingstoke.

Miles, M.B., Huberman, A.M., Saldana, J., 2014. Qualitative data analysis: a methods sourcebook. Sage Publications, Thousand Oaks, CA.

Miles, M.B., Huberman, A.M., Saldana, J., 2019. Qualitative data analysis: A methods sourcebook, 4th ed. ed. Thousand Oaks, CA: Sage.

Millward-Hopkins, J., Purnell, P., Baurley, S., 2023a. Scenarios for reducing the environmental impacts of the UK clothing economy. J. Clean. Prod. 420, 138352.

Millward-Hopkins, J., Purnell, P., Baurley, S., 2023b. A material flow analysis of the UK clothing economy. J. Clean. Prod. 407, 137158.

Mohr, I., Fuxman, L., Mahmoud, A.B., 2022. A triple-trickle theory for sustainable fashion adoption: the rise of a luxury trend. J. Fash. Mark. Manag. 26, 640–660.

Nath, S.D., Eweje, G., Bathurst, R., 2021. The Invisible Side of Managing Sustainability in Global Supply Chains: Evidence from Multitier Apparel Suppliers. J. Bus. Logist. 42, 207–232.

National Grid, 2024. What are scope 1, 2 and 3 carbon emissions? [WWW Document]. Natl. Grid.

Newbert, S.L., 2007. The Effect of Firm Compensation Structures on the Mobility and Entrepreneurship of Extreme Performers. Strateg. Manag. J. 28, 212–146.

Oguntegbe, K.F., Di Paola, N., Vona, R., 2023. Communicating responsible management and the role of blockchain technology: social media analytics for the luxury fashion supply chain. TQM J. 35, 446–469.

Ostermann, C.M., Nascimento, L. da S., Steinbruch, F.K., Callegaro-de-Menezes, D., 2021. Drivers to implement the circular economy in born-sustainable business models: a case study in the fashion industry. Rev. Gest. 28, 223–240.

Oxborrow, L., Brindley, C., 2014. Disintermediation in the apparel supply chain. J. Fash. Mark. Manag. 18, 252–268.

Papamichael, I., Chatziparaskeva, G., Voukkali, I., Navarro Pedreno, J., Jeguirim, M., Zorpas, A.A., 2023. The perception of circular economy in the framework of fashion industry. Waste Manag. Res. 41, 251–263.

Pedersen, E.R.G., Gwozdz, W., 2014. From Resistance to Opportunity-Seeking: Strategic Responses to Institutional Pressures for Corporate Social Responsibility in the Nordic Fashion Industry. J. Bus. Ethics 119, 245–264.

Perez-Batres, L.A., Miller, V. V., Pisani, M.J., Henriques, I., Renau-Sepulveda, J.A., 2014. Why Do Firms Engage in National Sustainability Programs and Transparent Sustainability Reporting? Evidence from Mexico’s Clean Industry Program. Manag. Int. Rev. 52, 107–136.

Pham, H.T., Pham, T., Quang, T.., Dang, C.N., 2022. Supply chain risk management research in construction: A systematic review. Int. J. Constr. Manag. 23, 1–11.

Posadas, S.C., Ruiz-Blanco, S., Fernandez-Feijoo, B. Tarquinio, L., 2023. Institutional isomorphism under the test of Non-financial Reporting Directive. Evidence from Italy and Spain. Meditari Account. Res. 31, 26-48.

Purkayastha, A., Filatotchev, I., 2023. Foreign Equity Valuations of Emerging Market Firms: The Effects of Institutional Distance and Information Spillovers, Management International Review. Springer Berlin Heidelberg.

Radanliev, P., De Roure, D., 2023. New and emerging forms of data and technologies: literature and bibliometric review. Multimed. Tools Appl. 82, 2887–2911.

Rafi-Ul-Shan, P.M., Bashiri, M., Kamal, M.M., Mangla, S.K., Tjahjono, B., 2024. An Analysis of Fuzzy Group Decision Making to Adopt Emerging Technologies for Fashion Supply Chain Risk Management. IEEE Trans. Eng. Manag. 71, 8469–8487.

Rafi-Ul-Shan, P.M., Grant, D.B., Perry, P., 2020. Are fashion supply chains capable of coopetition? An exploratory study in the UK. Int. J. Logist. Res. Appl. 25, 278–295.

Rafi-Ul-Shan, P.M., Grant, D.B., Perry, P., Ahmed, S., 2018. Relationship between sustainability and risk management in fashion supply chains: A systematic literature review. Int. J. Retail Distrib. Manag. 46, 466–486.

Reid, E.M., Toffel, M.W., 2009. Responding to public and private politics: Corporate disclosure of climate change strategies. Strateg. Manag. J. 30, 1157-1178.

Sadowski, M., Perkins, L., McGarvey, E., 2021. Roadmap to Net Zero: Delivering Science-Based Targets in the Apparel Sector, World Resources Institute.

Saha, K., Dey, P.K., Kumar, V., 2024. A comprehensive review of circular economy research in the textile and clothing industry. J. Clean. Prod. 444, 141252.

Saha, K., Dey, P.K., Papagiannaki, E., 2021. Implementing circular economy in the textile and clothing industry. Bus. Strateg. Environ. 30, 1497–1530.

Salmi, A., Kaipia, R., 2022. Implementing circular business models in the textile and clothing industry. J. Clean. Prod. 378, 134492.

Salo, H.H., Suikkanen, J., Nissinen, A., 2020. Eco-innovation motivations and ecodesign tool implementation in companies in the Nordic textile and information technology sectors. Bus. Strateg. Environ. 29, 2654–2667.

Sandvik, I.M., Stubbs, W., 2019. Circular fashion supply chain through textile-to-textile recycling. J. Fash. Mark. Manag. 23, 366–381.

SAP, 2024. What are scope 1, 2, and 3 emissions? Guide to GHG emissions [WWW Document]. SAP.

Scheiber, F., 2015. Dressing up for Diffusion: Codes of Conduct in the German Textile and Apparel Industry, 1997–2010. J. Bus. Ethics 126, 559–580.

Schmutz, M., Som, C., 2022. Identifying the potential for circularity of industrial textile waste generated within Swiss companies. Resour. Conserv. Recycl. 182.

Schütze, F., Stede, J., 2024. The EU sustainable finance taxonomy and its contribution to climate neutrality. J. Sustain. Financ. Invest. 14, 128–160.

Scott, W.R., 2008. Approaching adulthood: the maturing of institutional theory. Theory Soc. 37, 427–442.

Serrano, R., Fortunati, L., Lacerda, D.P., 2022. Wearable technologies in the fashion value ecosystem: a conceptual model. Innov. Manag. Rev. 19, 90–105.

Sharma, M., Joshi, S., Luthra, S., Kumar, A., 2022. Managing disruptions and risks amidst COVID-19 outbreaks: role of blockchain technology in developing resilient food supply chains. Oper. Manag. Res. 15, 268–281.

Shou, M., Domenech, T., 2022. Integrating LCA and blockchain technology to promote circular fashion – A case study of leather handbags. J. Clean. Prod. 373, 133557.

Statista, 2025. Annual expenditure on clothing in the United Kingdom (UK) from 2005 to 2023, based on volume [WWW Document]. Statista. URL https://www.statista.com/statistics/300842/annual-expenditure-on-clothing-in-the-united-kingdom-uk/

Strauss, A., Corbin, J., 1998. Basics of Qualitative Research: Techniques and Procedures for Developing Grounded Theory. Sage, Thousand Oaks, CA.

Szozda, N., 2023. Omnichannel as a driver of digitalization: evidence from the emerging market in the fashion industry. J. Fash. Mark. Manag. 27, 905–923.

Talyka, M., Johnson, A., Dvouletý, O., Zíka, V., 2024. Towards Understanding Sustainability Practices in the Fast Fashion Industry: A Multi-Case Study. New Perspect. Polit. Econ. 20, 59–89.

Tam, F.Y., Lung, J.W.Y., 2023. Impact of COVID-19 and innovative ideas for a sustainable fashion supply chain in the future. Foresight 25, 225–248.

Textile Exchange, 2023. 2023 Textile Exchange Conference [WWW Document]. Text. Exch. URL https://textileexchange.org/event/2023-textile-exchange-conference/

The Ellen MacArthur Foundation, 2025. Fashion and the circular economy – deep dive [WWW Document]. Ellen MacArthur Found.

The Gazette of Pakistan, 1997. Pakistan Environmental-Protection-Act-1997.

Todeschini, B.V., Cortimiglia, M.N., de Medeiros, J.F., 2020. Collaboration practices in the fashion industry: Environmentally sustainable innovations in the value chain. Environ. Sci. Policy 106, 1–11.

Trevino, L.J., Thomas, D.E., Cullen, J., 2008. The three pillars of institutional theory and FDI in Latin America: an institutionalization process. Int. Bus. Rev. 17, 118–133.

Tupikovskaja-Omovie, Z., Tyler, D., 2020. Clustering consumers' shopping journeys: eye tracking fashion m-retail. J. Fash. Mark. Manag. 24, 381–398.

UNDRR, 2020. Human Cost of Disasters, United Nations Office for Disaster Risk Reduction.

UNECE, 2018. Fashion and the SDGs: What role for the UN ? In: Internation Conference Center Geneva. p. 2.

United Nations Environment Management Group, 2023. An overview of UN Activities and Initiatives related to Pollution.

World Resources Institute, 2025. Greenhouse Gas Protocol [WWW Document]. World Resour. Inst. URL https://www.wri.org/initiatives/greenhouse-gas-protocol

Wren, B., 2022. Cleaner Logistics and Supply Chain Sustainable supply chain management in the fast fashion Industry : A comparative study of current efforts and best practices to address the climate crisis. Clean. Logist. Supply Chain 4, 100032.

Wünsche, J.F., Fernqvist, F., 2022. The Potential of Blockchain Technology in the Transition Towards Sustainable Food Systems. Sustain. 14.

Yin, R.K., 2018. Case Study Research and Applications Design and Methods, 6th edn. ed. SAGE Publications, Inc.

Zhang, X., Dong, F., 2021. How virtual social capital affects behavioral intention of sustainable clothing consumption pattern in developing economies? A case study of China. Resour. Conserv. Recycl. 170, 105616.

Zhu, Z., Wang, J., Wang, X., Wan, X., 2016. Exploring factors of user's peer-influence behavior in social media on purchase intention: Evidence from QQ. Comput. Human Behav. 63, 980–987.

Appendixes

Appendix 1: Key search string

1) Climate change AND/OR Fashion/ Apparel/ Textile
2) Climate change risk AND/OR Fashion/ Apparel/ Textile
3) Emerging technologies AND/OR Fashion/ Apparel/ Textile
4) Technology AND/OR Fashion/ Apparel/ Textile
5) Climate change risk AND/OR Mitigation/Strategies
6) Emerging technologies AND/OR Mitigation/Strategies
7) Climate change AND/OR Challenges.
8) Emerging technologies AND/OR Challenges.
9) Climate change AND/OR Fashion AND/OR Supply chain
10) Climate change AND/0R Emerging technologies AND/OR Challenges
11) Climate change AND/0R Emerging technologies AND/OR Fashion AND/OR
12) Mitigation/Strategies

Appendix 2: Details of the Expert Interviews

No.	Code	Role	Area of Expertise	Years of Experience
	Pakistan			
1	OL & Sus-Mgr-1	Head of Organisational Learning and Sustainability	Organisational learning, sustainability	18
2	SC-Mgr-2	Head of Supply Chain	Supply chain	15
3	Ops-Mgr-3	Head of Operations	Operations	20
4	Sus-Mgr-4	Director Environmental Sustainability	Environmental sustainability	17
5	Ops-Mgr-5	Vice President Operations	Operations management	15
6	Sus-Mgr-6	Manager Sustainability	Environmental sustainability	15
7	SC-Mgr-7	General Manager Supply Chain	Supply chain	18
8	Ops-Mgr-8	General Manager Operations	Operations	15
9	Prod-Mgr-9	Head of Production	Production	20
10	SC-Mgr-10	Manager Supply Chain	Supply chain	12
	UK			
11	SC-Mgr-11	Supply Chain Manager	Supply chain	17
12	SC-Dir-12	Supply Chain Director	Production	10
13	SO-Mgr-13	Sourcing Manager	Sourcing	16
14	G&S-14	Generalist/ Supervisor	Supply chain	12
15	LO-Mgr-15	Logistics Manager	Logistics	13
16	De-Mgr-16	Design Manager	Design	16
17	Pu-Mgr-17	Purchasing Manager	Sourcing	19

18	QC-Mgr-18	Quality Control Manager	Production	10
19	SC-Mgr-19	Supply Chain Manager	Supply chain	18
20	Ops-Mgr-20	General Manager Operations	Operations	16
21	Sus-Mgr-21	Manager Sustainability	Ethical Sourcing	17
22	QC-Mgr-22	Quality Control Manager	Production	19
23	SC-Mgr-23	Supply Chain Manager	Supply chain	11
24	SC-Mgr-24	Supply Chain Manager	Supply chain	18
25	G&S-25	Generalist/ Supervisor	Supply chain	10