

SDGs and Textiles


José Moleiro Martins *Editor*

Industry and Innovation: Textile Industry

 Springer

SDGs and Textiles

Editor-in-Chief

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The book series “SDGs and Textiles” addresses the strategies to achieve sustainable development goals (SDGs) in the present, past, and future. It presents books about the present and future policies of textile ministries of different countries, and books related to sustainability education around different parts of the world in the textile sector. Moreover, it would welcome the conference proceeding related to SDGs and Textiles. The series would cover books comparing the sustainability and SDGs of different institutions and countries. The individual book volumes in the series are thematic. The goal of each book is to give readers a comprehensive overview of a different area of sustainability in the textile sector. As a collection, the series provides valuable resources to a broad audience in academia, the research community, industry, and anyone looking to expand their knowledge of SDGs and Textiles.

Textiles and life are together – life cannot be separated from textiles as it is the most important need for human beings after food. In 2015, the United Nations General Assembly proposed 17 interlinked global goals to be achieved by 2030. Since then, academia and industry have paid much attention to achieving these goals. Textile found its close relation with almost all of these 17 goals.

SDG 1 - No Poverty: Poverty would never be overcome by a charity only; it is essential to develop people’s skills to have a better and wealthy life. Thus, the textile can be considered an excellent discipline to achieve this goal by creating jobs and small and medium businesses.

SDG 2 - Zero Hunger: Through the effective utilization of advanced application of Agrotech Textiles, it is possible to have higher crop yields and save crops from rough weather, unexpected rains, floods, insects, etc.; thus, geotextiles play an essential in achieving this goal of sustainable development.

SDG 3 - Good Health & well-being: There has been much health consciousness after Covid19, and medical textiles assist in getting good health and well-being.

SDG 4 - Learning & Education: Textile or fashion has remained a significant discipline for societies for ages, and there has always remained much to explore in this field. Textile-related universities may play a vital role by offering free access to their education resources, training and spreading information among the locals.

SDG 5 - Gender Equality: The textile sector is one of the industrial sectors that accepted gender equality long ago; in particular, the garment sector has more females than males. Thus, the textile sector has been doing gender equality. Moreover, there has been a recent trend for Gender Neutral Clothing, which need worth studying and may further assist gender equality.

SDG 6 - Clean Water & Sanitation: Textiles could be achieved through filtration, and of course, textile is one of the critical materials for filtration.

SDG 7 - Affordable & Clean Energy: With the recent advancement in material science and engineering, the textile sector has come on the front for, not only by using this clean energy during textile production but also by assisting the production of this clean energy, either in the form of wind turbines blades made of textile composites or by energy harvesting from T-Shirts, etc.

SDG 8 - Decent Work: Recently, there has been much attention that the textile workers are not paid well, labor rights are not cared about, etc.

SDG 9 - Industry and innovation: Textile Industry always follows innovation; the textile companies that do not chase innovation cannot survive in the market.

SDG 10 - Reduced Inequalities: Getting better life and well-being would help reduce inequalities in the textile industry.

SDG 11 - Sustainable Cities: Sustainable Textile Cities through Buildtech and transport textiles.

SDG 12 - Consumption and Production: Textile and garment consumption and production all come under.

SDG 13 - Climate Action: Oekotech or Ecotech Textile, waste management of textiles are upfront to achieve this goal of sustainable development.

SDG 14 - Life Below Water: Mitigating microfiber waste in rivers and oceans may come under the context of it. There has been much attention on this subject after passing the bill at the parliament level of the UK.

SDG 15 - Life on Land: Geotech or Geotextiles studies life on land.

SDG 16 - Peace, Justice, and Strong Institutions: Protective textiles are doing their best to achieve peace, justice, and strong institutions.

SDG 17 - Partnerships for the Goals: The application of textiles to achieve sustainable development goals is only an example. In all textiles sectors, combined efforts of all the goals are essential to achieve true sustainability.

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ISSN 2948-1236

ISSN 2948-1244 (electronic)

SDGs and Textiles

ISBN 978-3-031-57803-8

ISBN 978-3-031-57804-5 (eBook)

<https://doi.org/10.1007/978-3-031-57804-5>

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Preface

Globalization provides access to practically all textiles traded worldwide. While beneficial for consumers, it poses challenges for the textile manufacturing industry. The textile industry is one of the most polluting sectors. Therefore, in addition to the impact of global competition demanding continuous innovation, the adoption of a sustainability strategy is necessary to reduce its negative impact on the environment. Competitiveness in the textile industry hinges on sustainable innovation.

In 2010, the implementation of Industry 4.0 began, a term introduced at the Hanover Fair in 2011. It represents an intelligent industry with a new way of organizing production methods and utilizing resources more efficiently. Its flexibility and adaptability to production needs aligned with consumer demands are based on new technologies such as blockchain and the Internet of Things (IoT).

In this new scenario, traditional manufacturing sectors, such as the textile industry, are facing times of change. It is imperative for textile companies to transition from machine-dominated manufacturing to digital manufacturing. This sector relies on product customization and short manufacturing cycles. However, the textile industry is mainly composed of small and medium-sized enterprises (SMEs) with limited capacity to invest and adopt new production technologies.

Interoperability can occur in the textile industrial ecosystem through the integration of companies via value networks. Interoperability involves the ability to communicate between cyber-physical systems, IoT devices, production units, and collaborators. In this context, computational intelligence techniques can also be applied in cutting, sewing, finishing, and packaging clothing. The new paradigm includes productive modular structures composed of devices in the Internet of Things environment. Robotic tasks can be used in the autonomous or collaborative assembly of clothing sets, as well as in the unfolding of garment pieces.

SMEs in the textile sector can benefit from technological innovations in cloud computing for smart clothing, fabric customization, production line control, mass customization, store programming, efficiency improvement, and pollution reduction in the environment. This new production approach requires new business models, increased management capabilities, and the updating of physical infrastructure and

information technologies in companies, enabling the management of distributed resources (employees and equipment) in remote interaction with each other.

In this panorama, this book includes various subjects that help understand and deepen knowledge in the field of textile industry and innovation, in a cross-cutting thematic approach, as follows.

Chapter “[Risk and Innovation Management of Small Businesses in the Textile Industry](#)”. This study offers a strategic compass for businesses, researchers, and policymakers, underscoring the multidimensional and global endeavors to bolster the textile industry’s innovative and risk management capacities.

Chapter “[Impact of Effective Leadership Styles to Achieve the Sustainable Growth of Manufacturing Firms](#)”. This research examines the crucial role of leadership in driving sustainable growth within the manufacturing sector, with a specific focus on the textile industry. It contributes to the understanding of the dynamic interplay between leadership styles and sustainable manufacturing practices.

Chapter “[The Role of the Supply Chain in Developing Innovation Processes in the Textile Industry](#)”. This chapter explores the vital interconnection between supply chain management and innovation in the textile manufacturing industry. The emergence of smart textiles and eco-friendly materials has further underscored the need for a supply chain capable of sourcing novel materials while maintaining quality and cost-efficiency.

Chapter “[Communication and Market Orientation as Part of an Innovation Strategy in Smart Textile Companies](#)”. This study addresses the reasons why people are becoming increasingly entrepreneurial in the European textile and clothing industries, and how innovation and communication have become so important in the strategies for entrepreneurship in these industries.

Chapter “[The Influence of the Marketing Orientation of Textile Companies in Increasing Their Competitiveness](#)”. The study’s main aim is to examine the influence of the marketing orientation on the competitive advantage of textile firms in terms of market innovation and global strategy. The study found that market turbulence moderates the association between marketing orientation, strategy, and competitive advantage.

Chapter “[Knowledge and Innovation Management as a Driver of Competitiveness in Textile Firms](#)”. This study aims to comprehensively investigate the role of knowledge and innovation management as crucial drivers of competitiveness in textile firms. The analysis highlights a pivotal interplay between knowledge and innovation management in shaping competitiveness, with a growing scholarly focus on the subject.

Chapter “[How Knowledge Management Capabilities Enhance Textile Firms’ Innovative Performance](#)”. According to this study, innovation is an indispensable factor in bolstering the operational effectiveness of textile companies. It enhances the organization’s capacity to operate effectively. Therefore, innovation possesses the capacity to enhance the efficiency of businesses. It is of utmost importance to assist businesses with employee training and research and development expenditures, as doing so has a direct positive impact on output.

Chapter “[Innovation, the Clothing Industry, and Textile Manufacturing in Portugal: An Exploratory Analysis of the Sector Between 2003 and 2022](#)”. The study points to the need to define strategies aimed at increasing the efficiency of economic activities and promoting a strategy based on competitiveness, adaptability, and greater efficiency in the textile and clothing industry in Portugal.

Chapter “[Innovation and Green Finance Management in the Textile Industry: Emerging Trends and Challenges](#)”. This research aims to conduct a comprehensive bibliometric analysis to examine the evolving landscape of innovation and green finance in the textile industry. It informs researchers, industry stakeholders, and policymakers about emerging trends and opportunities to advance sustainable practices within the sector.

Chapter “[The Innovative Influence of Industry 4.0 on the Textile Industry](#)”. This study aims to perform a bibliometric analysis of the burgeoning field of research at the intersection of Industry 4.0 and the textile industry. The article concludes with a call for future research to broaden the scope to encompass sustainability, economic, and policy perspectives, thereby enriching the current understanding of this industrial transformation.

Chapter “[Textile Innovation, Sustainability, Survival, and the Future](#)”. This research describes the future of textiles in the world, especially in Portugal, is undoubtedly challenging. It seems that the market of the future will face significant concerns related to the environmental and social impact of fashion. For humans and the textile industry to survive, the mission must demonstrate economic viability and combine truly environmentally sustainable innovation with a better life.

Chapter “[The Role of Financing in the Development of Innovation Processes in Textile Companies](#)”. This research delves into the intricate relationship between financing and innovation in the textile industry, exploring its historical evolution, current practices, and future trends. The shift toward diverse and sophisticated financing strategies reflects the industry’s need to adapt to changing market demands and foster innovation, ensuring sustainability and technological progression in the highly competitive global textile market.

Chapter “[Management Control Systems and Innovation in Textile Industry](#)”. The study reveals the essential role of MCS in shaping organizational culture and driving innovation, emphasizing the need for integrating sustainability and technological advancements. It identifies gaps and potential areas for future research, stressing the importance of international collaboration and exploring under-represented topics to enrich the textile industry’s innovation and adaptability.

Chapter “[Enhancing Textile Enterprises’ Integrated Development: Innovative Management Optimization and Monitoring System](#)”. This study introduces an innovative monitoring system for the integrated development of textile enterprises, addressing a significant gap in the current literature. The research focuses on the integration of management practices with technological advancements, essential for the textile industry’s dynamic and evolving market.

Chapter “[Export Performance of the Textile Industry: Influence of Financial Resources and Productivity](#)”. This study aims to examine the effect of certain factors on the export performance of the Portuguese textile industry. The study provides several findings for export-oriented firms, revealing that financial resources, productivity, and size are significant determinants of export performance.

Chapter “[Sustainability Innovation in the Textile Industry](#)”. The aim of this chapter is to identify key themes of sustainability innovation in the textile industry and to map research in this area. These include basic themes consisting of sustainability, innovation, circular economy, and nanotechnology; niche themes consisting of green innovation, smart textiles, and electrospinning; as well as emerging themes, namely competitiveness and technological innovation.

Finally, I would like to express gratitude to all the authors who contributed to the completion of the book.

Estoril, Portugal
February 2024

José Moleiro Martins

Contents

Risk and Innovation Management of Small Businesses in the Textile Industry	1
António Abreu	
Impact of Effective Leadership Styles to Achieve the Sustainable Growth of Manufacturing Firms	25
João Lucas	
The Role of the Supply Chain in Developing Innovation Processes in the Textile Industry	53
João Rita	
Communication and Market Orientation as Part of an Innovation Strategy in Smart Textile Companies	65
Jose Agostinho	
The Influence of the Marketing Orientation of Textile Companies in Increasing Their Competitiveness	95
Muhammad Farrukh Shahzad, Iqra Javed, and Imran Zahid	
Knowledge and Innovation Management as a Driver of Competitiveness in Textile Firms	119
José Moleiro Martins	
How Knowledge Management Capabilities Enhance Textile Firms' Innovative Performance	147
Syed Arslan Haider and Sonia Tabassum Anees	
Innovation, the Clothing Industry, and Textile Manufacturing in Portugal: An Exploratory Analysis of the Sector Between 2003 and 2022	165
Ricardo de Moraes e Soares	

Innovation and Green Finance Management in the Textile Industry: Emerging Trends and Challenges 185
Mário Nuno Mata

The Innovative Influence of Industry 4.0 on the Textile Industry 213
Rui Dantas

Textile Innovation, Sustainability, Survival, and the Future 239
Tânia Alves de Jesus

The Role of Financing in the Development of Innovation Processes in Textile Companies 251
Tânia Saraiva

Management Control Systems and Innovation in Textile Industry 265
Jéssica Nunes Martins

Enhancing Textile Enterprises’ Integrated Development: Innovative Management Optimization and Monitoring System 291
Kateryna Boichenko

Export Performance of the Textile Industry: Influence of Financial Resources and Productivity 317
Isabel Soares de Moura

Sustainability Innovation in the Textile Industry 339
Budi Harsanto, Joval Ifghaniyafi Farras, and Dimas Indradi

Risk and Innovation Management of Small Businesses in the Textile Industry



António Abreu

Abstract This study aims to conduct a bibliometric analysis of the literature at the nexus of risk management, innovation, and small businesses in the textile industry. The study conducted a bibliometric analysis of publications in the Web of Science and Scopus scientific databases for 1985–2022 using RStudio and Biblioshiny software. Drawing from the Web of Science and Scopus databases, the study maps the evolution of academic discourse, highlighting thematic trends, seminal works, and existing research gaps. The temporal analysis indicates heightened interest during global disruptions, notably the 2008 financial crisis and the COVID-19 pandemic. Despite an upward trajectory in publications, citation metrics stress the primacy of quality over sheer volume. A geographic examination reveals a diversified global input, with emerging economies like Brazil and India accentuating their academic footprint. Institutional trends spotlight the sustained commitment from universities such as Zhejiang University and Lodz University of Technology. Lotka’s Law underpins a significant author productivity skewness, indicating a broad spectrum of perspectives, yet spotlighting a select group with higher output potential. The findings urge closer academia-industry collaboration, an emphasis on research quality, and a watchful eye on new academic entrants. This study offers a strategic compass for businesses, researchers, and policymakers, underscoring the multi-dimensional and global endeavors to bolster the textile industry’s innovative and risk management capacities.

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1 Introduction

The textile industry, one of the oldest sectors of human civilization, remains a key pillar of global commerce and economic progress. With roots reaching back to prehistoric eras, textiles have played an indispensable role in socio-cultural evolution, technological advancement, and economic development (Araújo et al., 2019). Over the centuries, it has evolved from hand-woven materials produced for local consumption to a highly mechanized, globalized industry characterized by vast production scales and intricate supply chains. Today, it stands as a representation of a complex web of activities encompassing the design, production, distribution, and consumption of textile products (Shafi et al., 2021).

The dynamic interplay of rapidly evolving global markets, changing consumer preferences, sustainability concerns, and technological innovations presents both opportunities and threats to businesses within the textile industry (Ikram, 2022). These drivers of change are especially salient for small businesses, which often operate with limited resources, making them particularly susceptible to external shocks and the risk of market turbulence.

Risk management, in this context, has emerged as a critical imperative for ensuring the sustained competitiveness and longevity of these businesses. Without appropriate risk mitigation strategies, small textile enterprises may find it challenging to navigate the turbulent waters of the global market. From supply chain disruptions and volatile raw material prices to stringent environmental regulations and competitive pressures, the litany of potential risks is extensive (Luque and Herrero-García, 2019). However, it is not enough for these businesses to merely manage risks; to thrive, they must also embrace innovation.

Innovation, typically perceived as the lifeblood of business survival and growth, plays a quintessential role in shaping the textile industry's future trajectory. For small businesses, innovation can be the distinguishing factor that propels them ahead of competitors, allows them to tap into new market segments, or even reinvents their business models for unprecedented success. Yet, innovation is not without its risks. The paradox lies in the fact that while innovation is necessary for competitive advantage, it simultaneously exposes businesses to new uncertainties.

The dynamics between risk and innovation, especially within the context of small businesses in the textile industry, is an intriguing area of study. Despite its significance, there exists a noticeable gap in the literature pertaining to how these two domains intersect and influence one another. Bibliometric analysis offers a robust methodological tool to delve into this lacuna. By mapping the existing literature landscape, it enables researchers to identify prevailing trends, seminal works, key contributors, and potential avenues for future research. Such analyses not only bring clarity to the current state of knowledge but also catalyze further exploration by highlighting understudied areas.

This study aims to conduct a bibliometric analysis of the literature at the nexus of risk management, innovation, and small businesses in the textile industry. By offering a holistic view of the current research landscape, it seeks to (1) elucidate the

major themes and trends that have emerged over the years, (2) pinpoint the seminal works that have shaped the discourse, (3) identify gaps and areas that warrant deeper investigation, and (4) provide a foundation upon which future researchers can build. The study conducted a bibliometric analysis of publications in the Web of Science and Scopus scientific databases for 1985–2022 using RStudio and Biblioshiny software.

As global economies become increasingly interconnected and industries more complex, understanding the multifaceted relationship between risk and innovation is crucial. For the textile industry, which holds cultural, economic, and historical significance, the stakes are even higher. Small businesses, often hailed as the backbone of economies worldwide, stand at the crossroads of these challenges. Ensuring their survival and prosperity entails a thorough comprehension of how they navigate the intertwined pathways of risk and innovation. This study is a step in that direction, offering insights that hold implications not just for academia but also for practitioners, policymakers, and stakeholders within the textile industry.

2 Systematic Literature Review

The span of nearly four decades from 1985 to 2022 provides a rich tapestry of academic contributions, marking distinct shifts in thought processes, methodologies, and paradigms in diverse research areas. An analysis of the publications indexed in two of the most esteemed scientific databases, Scopus and Web of Science, yields a compelling narrative of academic endeavors during this period.

According to the data presented in Table 1, the studied timespan encompasses 132 documents sourced from an array of 112 different journals, books, and other platforms. This corpus of academic material showcases steady growth, with an annual growth rate pegged at 3.72%. The average age of these documents is 10.3 years, suggesting a mix of both seminal, foundational papers and newer, emergent ideas.

Interestingly, the average number of citations per document stands at 11.87, highlighting the significance and impact of these works within the academic community. Such a number underscores the importance of these documents in furthering understanding, sparking debate, and laying the groundwork for subsequent research.

Diving deeper into authorship metrics, a total of 313 authors have contributed to this collection of documents. While collaborative efforts dominate, 42 authors have singularly penned documents, accounting for 56 single-authored pieces. This reflects a healthy balance between individual scholarship and collaborative explorations. Collaboration is further exemplified by the fact that each document averages about 2.58 co-authors. Significantly, international collaborations constitute 12.88% of the total, indicating the global nature of discussions and the cross-border exchanges enriching academic discourse.

Breaking down the 132 documents by type provides insights into the modes of scholarly communication favored over the period. Articles lead the way with 79 entries, followed by conference papers (24), book chapters (10), reviews (9), and conference reviews (6). Books (3) and notes (1) round off the list. The predominance

Table 1 Main information about data

Description	Results
Timespan	1985:2022
Sources (Journals, Books, etc.)	112
Documents	132
Annual growth rate %	3.72
Document average age	10.3
Average citations per doc	11.87
Authors	–
Authors	313
Authors of single-authored docs	42
Authors collaboration	–
Single-authored docs	56
Co-authors per doc	2.58
International co-authorships %	12.88
Document types	–
Articles	79
Books	3
Book chapters	10
Conference papers	24
Conference reviews	6
Notes	1
Reviews	9

of articles and conference papers underscores the importance of peer-reviewed journals and conferences as primary platforms for disseminating research findings and engaging with the academic community.

The bibliometric data spanning 1985–2022, as sourced from Scopus and Web of Science, offers a panoramic view of academic contributions during this period. From the steady growth of publications to the balance between individual and collaborative efforts, and from the global nature of discussions to the variety of document types, the narrative is one of dynamic scholarship and continuous evolution. In order to conduct the research and identify the key features of the conducted research, scientists performed a cluster analysis of publications by the keywords “risk”, “innovation management”, “small business”, and “textile industry” using the VOSviewer program. The results of this analysis are visualized in Fig. 1.

The two most frequent terms, “textile industry” and “textiles”, highlight the core theme and focus of the analyzed documents. Their predominance underlines the sector-specific nature of the content. “Risk assessment”, “health risks”, and “occupational health” are clearly prevalent. This underscores the strong emphasis on risk management in the textile industry, encompassing both generalized and specific

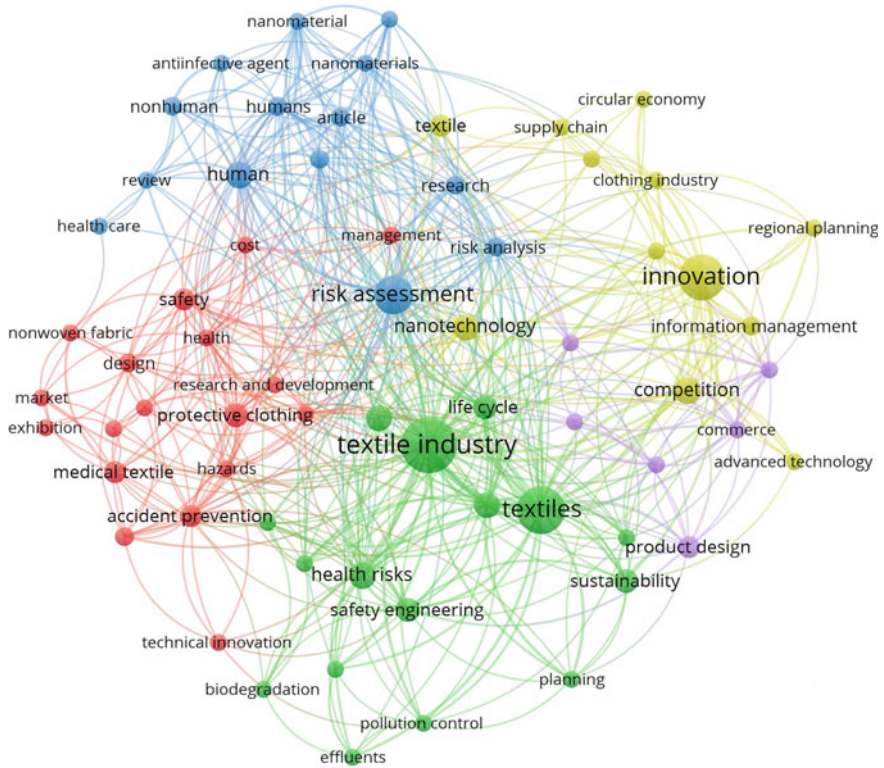


Fig. 1 Cluster analysis of publications in the context of risk and innovation management of small businesses in the textile industry in the scopus and web of science databases from 1985 to 2022

threats. The mention of “innovation” indicates a focus on forward-thinking strategies, improvements, and technological advancements that businesses in the textile industry are either adopting or considering. “Nanotechnology” appearing in the list suggests a growing interest in integrating advanced technologies into textiles. Nanotechnology offers potential benefits like improved fabric properties, but it may also introduce new risks, emphasizing the need for risk assessment. The mention of “competition” emphasizes the challenges faced by small businesses in the textile sector. This may pertain to both local market competition and global competitive pressures, underscoring the need for innovative solutions to maintain or enhance market position. Words like “human” and “occupational health” bring attention to the human factor in the textile industry. This suggests an awareness of the direct impacts on workers, stressing the importance of safe practices, well-being, and perhaps even ethical considerations. “Protective clothing” is a term that integrates both risk (protection from harm) and innovation (developing advanced protective textiles). This could refer to clothing designed for workers within the textile industry or for end consumers in specific environments.

Figure 2 provides a breakdown of the most frequent words that appear in the literature or articles discussing risk and innovation management in small businesses within the textile industry.

Over the past few decades, the textile industry has experienced unprecedented changes influenced by socio-economic dynamics, technological advancements, and global trends. One of the key areas of interest within this realm has been risk and innovation management (Fig. 3).

Recent literature underscores the importance of sustainability in the textile sector, addressing environmental implications and advocating for eco-friendly innovations (Behera et al., 2021; Gu et al., 2021; Levanen et al., 2021; Phan et al., 2020). Such contributions shed light on the transition from traditional processes to more sustainable models, emphasizing the need for businesses to integrate sustainable practices not just for environmental benefits but also to mitigate associated risks (Fu et al.,

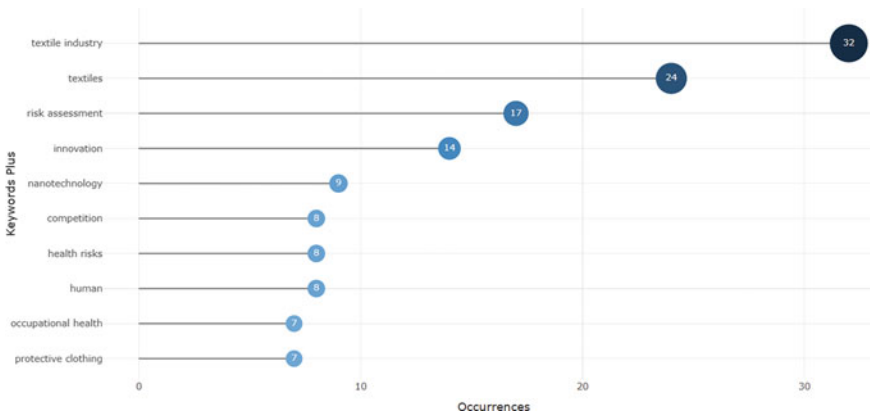


Fig. 2 Most frequently occurring words in the researched publications

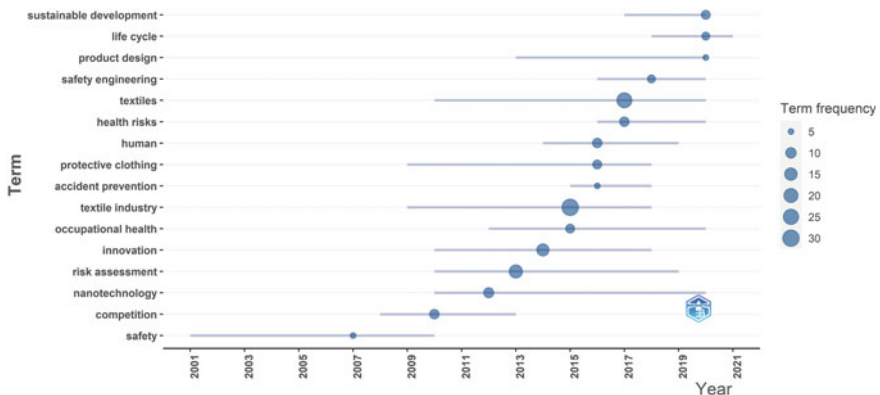


Fig. 3 Trend topics in the researched publications

2023; Seidu et al., 2023). Indeed, in examining the broader ecosystem, sustainability is viewed as both a challenge and an opportunity for small businesses in the textile sector (Denuwara et al., 2019).

The advancement of digital technology has also profoundly impacted the industry. A significant number of studies have been dedicated to the exploration of technological innovations and their implications on risk management. The integration of intelligent systems, for instance, offers new avenues for improving efficiency, customization, and supply chain management (Ding et al., 2020; Ledda & Palomba, 2020; Romao & Simoes, 2020). While these advancements open up unprecedented opportunities for businesses, they also introduce unique risks, emphasizing the need for an effective risk management framework tailored to the digital age (Ho & Watanabe, 2020).

Historical analyses provide a broader perspective on the textile industry's evolution, shedding light on past challenges and strategies, thereby offering valuable insights into managing contemporary risks and embracing new innovations (Donges & Selgert, 2019). Furthermore, as businesses within the textile industry are becoming increasingly global, international collaborations and interactions have gained prominence. This international dimension adds layers of complexity in managing risks and fostering innovation, as highlighted by the percentage of international co-authorships observed in the bibliometric data.

The importance of collaboration, both at the individual and institutional levels, is further echoed in the literature. Collaborative endeavors are often seen as a conduit for fostering innovation, pooling resources, sharing risks, and navigating complex challenges that single entities might find overwhelming (Kafuku, 2019; Pfoser et al., 2021).

Literature delving into the nuances of the textile industry's unique risks also explores the cultural, socio-economic, and market-specific dimensions. There are studies dedicated to understanding the cultural implications of textiles, suggesting that understanding cultural shifts and preferences can be pivotal for risk management and innovative product development (del Solar, 2019). Studies have also emphasized the importance of understanding consumer behavior, market dynamics, and the broader societal implications of textiles. An understanding of these dimensions is crucial for businesses to identify potential risks and innovate in ways that resonate with their target audiences (Sugg, 2022; Tsai & Su, 2022).

Some research highlights the intricate relationship between the environment, materials, and textile production. The interactions between various materials, especially in the context of microbial processes, have profound implications for product quality, sustainability, and associated business risks (Bockmühl et al., 2019; Lugani et al., 2021). In addition to the aforementioned themes, a set of studies has also provided valuable insights into niche areas of the textile industry. These range from specific types of materials such as silk and its properties (Shah et al., 2022; Wang et al., 2019) to more overarching discussions on the economic, historical, and social aspects of textiles and their significance in global trade and culture (Vanegas-López et al., 2021; Wescoat & Rawoot, 2021).

The literature spanning offers a comprehensive view of the multifaceted domain of risk and innovation management within the textile industry. The intersection of sustainability, technology, collaboration, and socio-cultural dimensions presents both challenges and opportunities for small businesses in this sector. As the industry continues to evolve, understanding these dynamics, as evidenced by the rich tapestry of academic contributions, will be pivotal for businesses to navigate future uncertainties and harness the power of innovation.

The main themes emerging from the bibliometric analysis related to risk and innovation management of small businesses in the textile industry are discerned by identifying clusters and examining the number of occurrences, centrality measures, and PageRank values for the most frequent words (Fig. 4).

Safety cluster. The words most frequently associated with safety are “safety”, “medical textile”, “testing”, “waste disposal”, and “conference”, among others.”Safety” has the highest betweenness centrality, highlighting its role as a bridge in the network, while also commanding a considerable PageRank centrality value. Other terms in this cluster like “fabric” and “silk” have very high betweenness centrality values, suggesting they too might play significant intermediary roles within the theme of safety.

Textile industry cluster. The dominant terms in this cluster include “textile industry”, “textiles”, “innovation”, “nanotechnology”, and “competition”. These terms appear most frequently and thus form the core of the discussions. “Textile industry” and “textiles” have remarkably high betweenness centrality values, emphasizing their essential position within this thematic discussion. Their PageRank centrality

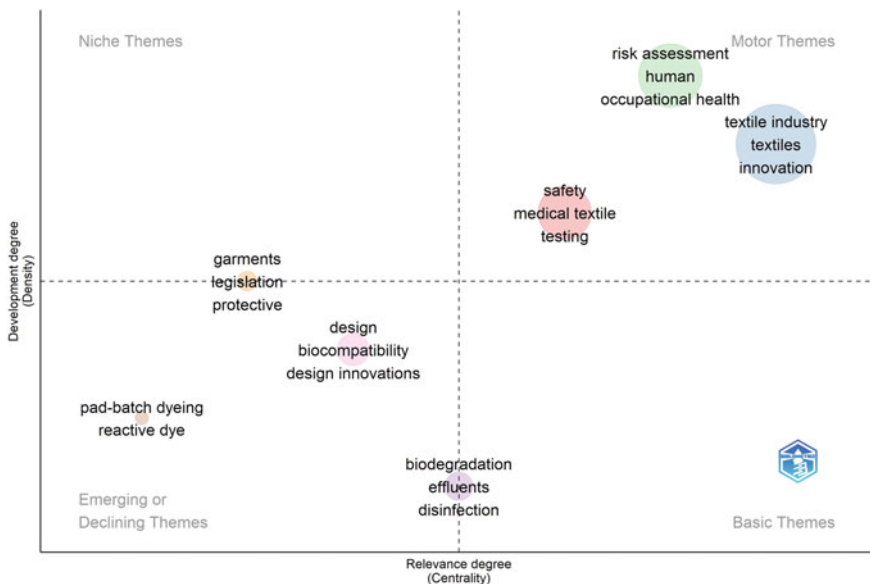


Fig. 4 Thematic map for the researched publications

Table 2 Cluster analysis according to the thematic map

Cluster	Callon centrality	Callon density	Rank centrality	Rank density	Cluster frequency
Safety	6.5417	84.5029	5	5	49
Textile industry	15.9478	115.1425	7	6	258
Risk assessment	9.1724	163.1192	6	7	93
Biodegradation	1.8611	61.1111	4	1	10
Garments	0.25	83.3333	2	4	6
Pad-batch dyeing	0	75	1	2	4

values are significantly higher than others, indicating their dominant influence in the network. Words like “innovation”, “nanotechnology”, and “health risks” underline the areas of focus within the textile industry, highlighting the areas of innovation and concerns related to the industry.

High betweenness centrality suggests that a term acts as a bridge or connection between different parts of the network (Table 2). In our data, words like “textile industry” and “safety” have high betweenness centrality, making them crucial in connecting different discussions. High closeness centrality means a term is closer to all other terms in the network. However, given our data, most terms have relatively similar closeness centrality values. PageRank centrality gives an indication of the most influential terms in the network. Here, “textile industry”, “textiles”, and “innovation” stand out, suggesting they are central to the discourse.

The vast range of terms indicates the diverse areas of interest when discussing risk and innovation management in the textile industry. From focusing on technological aspects (e.g., “nanotechnology”, “Internet of Things”, “Industry 4.0”) to environmental and health concerns (e.g., “sustainable development”, “pollution control”, “health risks”), the discourse appears comprehensive. There’s also a considerable focus on business and management strategies, as evidenced by terms like “risk management”, “information management”, “human resource management”, and “production management”.

The textile industry, from this bibliometric analysis, is observed to be a complex field with multiple facets. Safety remains a prominent theme, with emphasis also on the industry’s innovations, risks, and the interplay between different aspects of the business, technology, and environmental factors. For small businesses in the textile sector, understanding these key themes is essential for both risk mitigation and harnessing innovation opportunities.

2.1 The Common Research Trends and Meta-Analysis

Figure 5 provided sheds light on the annual scientific production concerning risk and innovation management in the textile industry over the span of approximately four

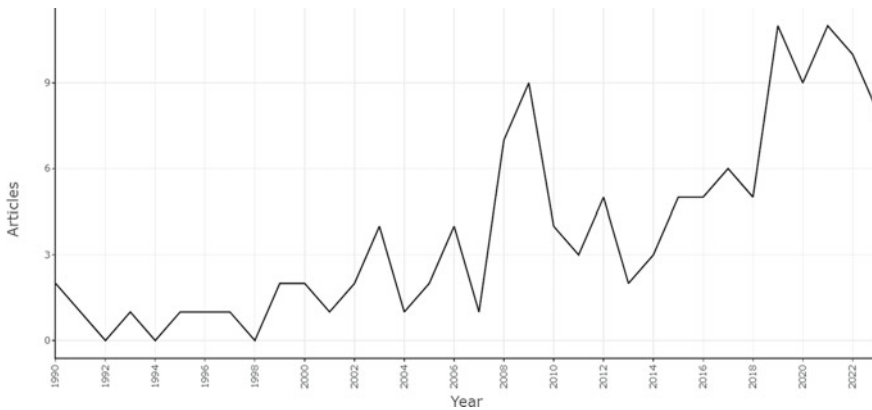


Fig. 5 Annual scientific production for the direction of risk and innovation management in the textile industry

decades, from 1985 to 2022. Over the 38-year period, there are noticeable fluctuations in the number of articles produced annually. The overall trend, however, shows an upward trajectory especially when comparing the early years to the more recent ones. The decade 1985–1994 began with a minimal interest in the topic, with only 2 articles in 1985. The number of articles remained low, with several years seeing no publications at all. 1995–2004—the production remained fairly consistent, with an average of about 1.4 articles per year. A significant spike was observed in 2003 with 4 articles. The decade 2005–2014 saw an overall increase in the annual scientific production, reaching up to 9 articles in 2009. The decade averaged around 4 articles per year.

The period 2015–2022 has the highest consistent production, peaking at 11 articles in both 2019 and 2021. The least number of articles in this period is still a notable 5, suggesting heightened interest and research in the field. The years 2008, 2009, 2019, 2021, and 2022 stand out with a significant number of articles, suggesting periods of heightened research interest or perhaps responses to global events or industry shifts that required more attention to risk and innovation management in textiles.

The global financial crisis around 2008–2009 might have prompted businesses to delve deeper into risk management strategies, explaining the surge in publications during this period. The latter peaks around 2019–2022 might be influenced by the disruptions caused by the COVID-19 pandemic, which affected global supply chains and demanded innovative solutions, especially for industries like textiles. From the bibliometric data presented, it is evident that the importance of understanding risk and fostering innovation in the textile industry has grown over time. While the initial years showed sporadic interest, the past two decades, especially the 2015–2022 period, highlight an increased awareness and emphasis on the subjects of risk and innovation in the textile business sector.

Table 3 provides insights into the average citations per year in the context of research articles related to risk and innovation management for small businesses in the textile industry.

The year 2013 stands out with an average of 87 citations per article, and a Mean Total Citation (MeanTCperYear) of 7.91. This suggests that the literature published in this year may have had a significant impact or presented groundbreaking insights. The number of publications (N) has generally seen an increasing trend in the 2010s,

Table 3 Average citations per year for the researched publications

Year	MeanTCperArt	N	MeanTCperYear	Citable years
1990	40.5	2.00	1.19	34
1991	13	1.00	0.39	33
1993	0	1.00	0.00	31
1995	0	1.00	0.00	29
1996	0	1.00	0.00	28
1997	0	1.00	0.00	27
1999	1	2.00	0.04	25
2000	58	2.00	2.42	24
2001	1	1.00	0.04	23
2002	0	2.00	0.00	22
2003	0	4.00	0.00	21
2004	0	1.00	0.00	20
2005	33.5	2.00	1.76	19
2006	2.25	4.00	0.12	18
2007	1	1.00	0.06	17
2008	0	7.00	0.00	16
2009	10.33	9.00	0.69	15
2010	15.75	4.00	1.12	14
2011	2	3.00	0.15	13
2012	1.6	5.00	0.13	12
2013	87	2.00	7.91	11
2014	19.67	3.00	1.97	10
2015	6.4	5.00	0.71	9
2016	22.8	5.00	2.85	8
2017	11	6.00	1.57	7
2018	2.2	5.00	0.37	6
2019	25.73	11.00	5.15	5
2020	10.89	9.00	2.72	4
2021	18.18	11.00	6.06	3
2022	6.6	10.00	3.30	2

with 2019 and 2021 both having 11 publications, the highest in the dataset. A peak in citations is observed in the early 1990s and early 2000s, followed by a few years of minimal citations. Another peak appears around 2013, followed by relatively consistent citations until 2022. The data suggests periods of increased research interest and impact, notably in the early 1990s, early 2000s, and around 2013. The reasons behind these spikes could be multifaceted, possibly involving industry changes, global events, or advances in technology and methodology.

The increasing number of publications in recent years may indicate growing interest or evolving challenges and opportunities in the field of risk and innovation management for small textile businesses. Citations do not always correlate with the number of publications. Some years with fewer publications had a higher average citation rate, suggesting the quality or significance of research can be more impactful than the quantity. Figure 6 tracks the publication count of various journals over the years, specifically in relation to risk and innovation management in small businesses in the textile industry.

Based on the total number of publications over the years, “Technical Textiles International” and “Technovation” are the dominant sources with the highest consistent contributions. While “Technical Textiles International” and others have been consistent, journals like “Advances in Intelligent Systems and Computing” show a rapid increase in recent years, indicating its emerging role in the field. The latter part of the figure, especially post-2019, shows more diversity in journals contributing to the topic, indicating a broader academic interest and more comprehensive coverage of the subject. The trends suggest a growing and diversifying interest in the topic, with both traditional and emerging journals contributing to the discourse.

Figure 7 provides an overview of authorship production over time within the context of the analyzed research.

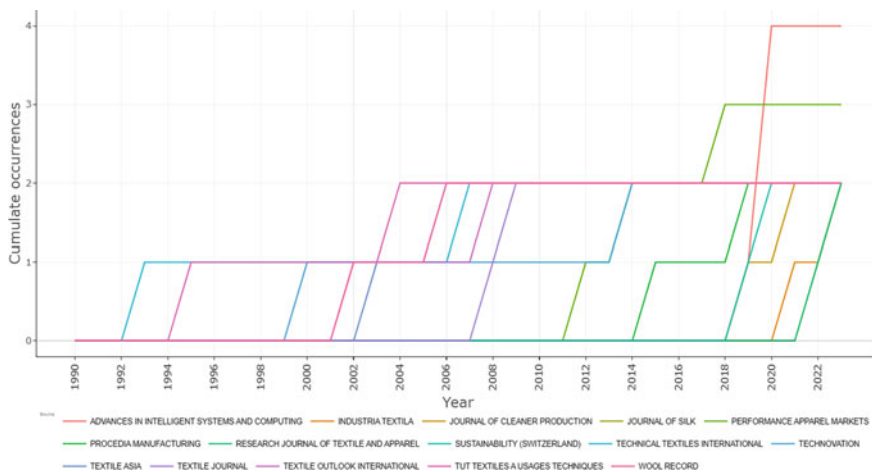


Fig. 6 Sources' production over time

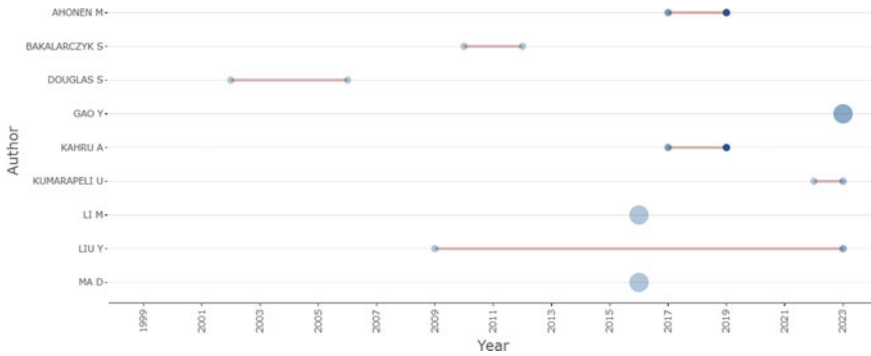


Fig. 7 Authors’ production over time

The papers of Ahonen and Kahru (Dunne et al., 2020; Rosenberg et al., 2019) from 2019 have the highest citation count at 39. Average yearly citations provide insights into the relevance and importance of the work over time. Papers with high TCpY suggest they continue to be influential and are frequently referenced in ongoing research. All other authors have relatively low citation counts, ranging from 0 to 2 for their respective papers. Li and Ma (2016), despite publishing twice in 2016, have relatively low average yearly citations of 0.250. Authors like Liu Y. (from 2009) and Li M. (from 2016) have publications with the lowest TCpY, with 0.133 and 0.250 respectively. The bibliometric data provides a comprehensive overview of the authors’ contributions and the impact of their research in the textile industry. It can serve as a foundation for further analysis to identify influential authors, emerging trends, and the trajectory of research in this sector.

In the evolving field of risk and innovation management within the textile industry, several significant works have emerged that have shaped the discourse. The examination of these pivotal contributions illuminates the direction and scope of current research trends (Fig. 8).

One of the most influential works was presented by Dangelico et al. (2013), which has received consistent attention, amassing 167 citations over the past decade, highlighting its lasting impact. This paper’s normalized citation rate is 1.92, indicating its broad influence in the discipline relative to its publication year. Similarly, a study from Ayres (1990) has maintained relevance with a normalized citation rate. Both studies offer valuable insights into the nuanced complexities of innovation in the textile realm.

Recent literature has exhibited a heightened emphasis on sustainable and environmental aspects. de Oliveira Neto’s et al. (2019) work has been highly cited, emphasizing the growing attention to cleaner production methods. This document, along with Behera et al. (2021) contribution, both possess an impressive, normalized citation rate of 5.67, which underscores the urgency and significance of environmental concerns in modern textile innovation.

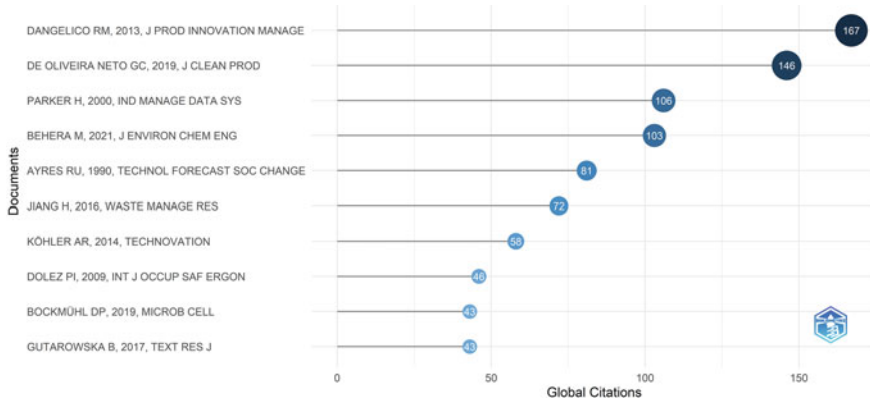


Fig. 8 Most global cited documents

The industry’s adaptation to technological shifts can be traced back to Parker’s (2000) publication, which has maintained relevance over the years, given its normalized citation rate of 1.83. On the other hand, Köhler and Som (2014) study focuses on the challenges and opportunities brought about by technological innovations in the textile domain, as indicated by its normalized citation rate of 2.95.

Waste management, another crucial aspect of the textile industry, was detailed in Jiang et al. (2016) research, which offers a perspective on the industry’s approach to minimizing waste, supported by its 3.16 normalized citation rate. Meanwhile, safety remains a pivotal concern, as evidenced by Dolez and Vu-Khanh (2009) investigation, which garnered a high normalized citation rate of 4.45.

Recent studies by Bockmühl et al. (2019) and Gutarowska et al. (2017) have delved into the microbial and chemical aspects of textiles. Their respective normalized citation rates, 1.67 and 3.91, demonstrate the multifaceted nature of textile research, which encompasses both innovative and risk management domains. The cited works collectively paint a comprehensive picture of the textile industry’s trajectory, with a keen emphasis on sustainability, technological adaptation, waste management, and safety.

The data underscores the principle of Lotka’s law (Fig. 9).

The vast majority of authors (94.9%) have produced only a single document. This can be attributed to the challenges faced in producing multiple research works, lack of resources or interest, or simply the nature of academic publishing where many contribute once or twice but do not continue in the long term. On the other hand, a minuscule percentage of authors (those who’ve written 2 or more documents, adding up to 5.1%) have shown a higher productivity rate. The single author who has written 13 documents stands out, representing the pinnacle of productivity within this dataset.

Figure 10 provides the frequency (number of publications or occurrences) of different universities in the textile industry’s risk and innovation management. The general trend across all universities shows a rising interest in risk and innovation

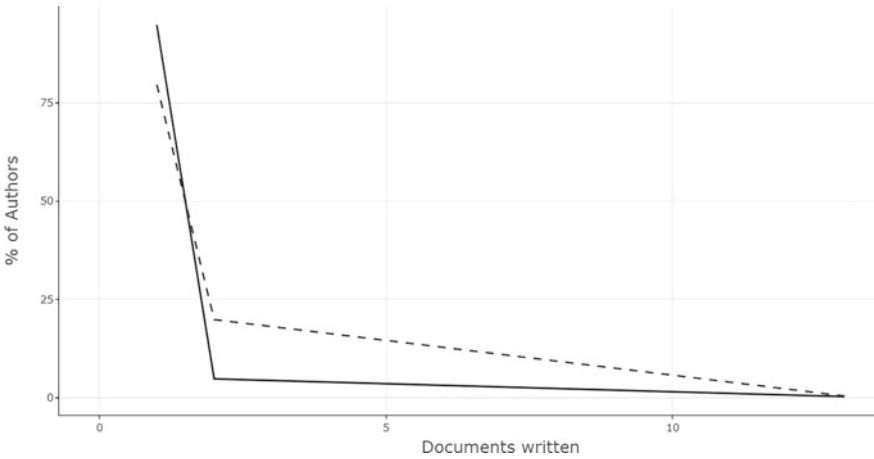


Fig. 9 Author productivity through Lotka's law

management in the textile industry over the years. This might reflect the growing importance of the topic in the textile sector or increased academic attention to the domain. Institutions like RMIT University and the University of Moratuwa have seemingly begun contributing later compared to others but have shown a rapid increase in their contributions once they started. Zhejiang University and Lodz University of Technology have consistently contributed over a longer period. Their steady numbers suggest a long-term commitment to research in this domain.

The affiliation of Zhejiang University started having relevant publications or mentions from the year 2008, with a steady rise to 3 by the year 2022. This indicates a growing interest or contribution from this institution in the specific domain over

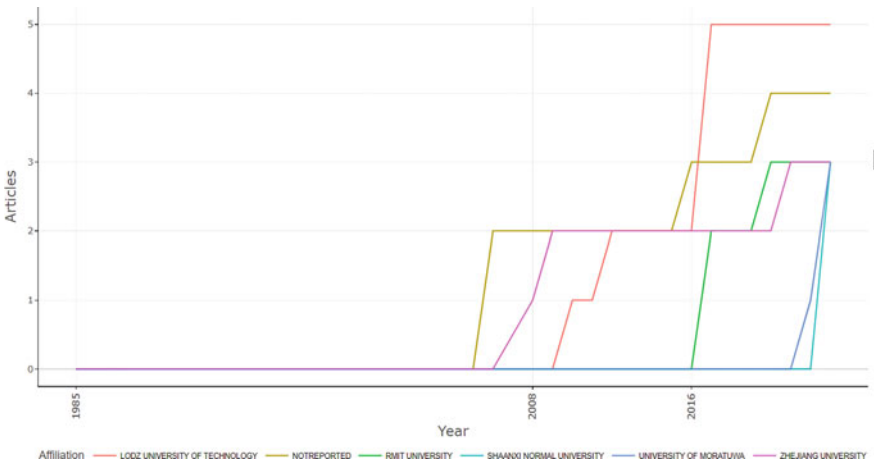


Fig. 10 Affiliations' production over time

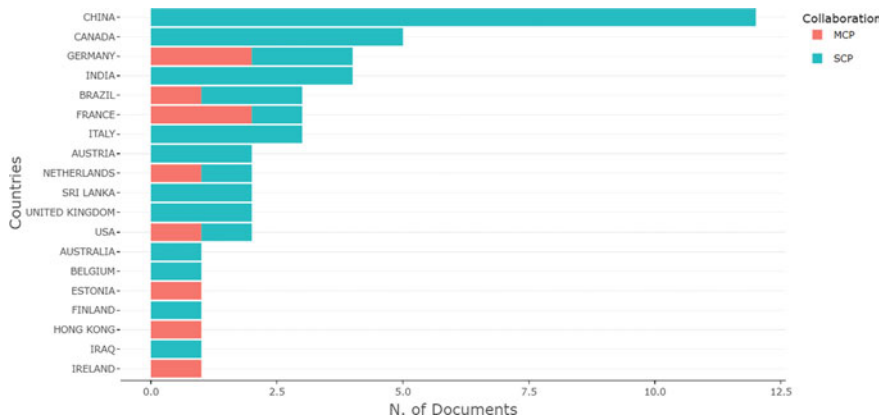


Fig. 11 Corresponding author's countries

the years. For Lodz University of Technology the activity started a bit later, with the first mention in 2010. However, from 2017 onwards, there's a sharp increase to 5 publications or mentions annually, suggesting a consistently high level of contribution or interest in this field. RMIT University shows no activity in the domain until 2017. From 2017 to 2020, there's a steady increase in the number of publications or mentions, reaching 3 by 2020 and maintaining this through 2022. University of Moratuwa showed no activity in the domain for a significant duration, only recording its first mention in 2022. However, there's a notable jump from 1 in 2022 to 3 in 2022, indicating a possible growing interest or burgeoning research area for the institution.

Figure 11 presents a bibliometric analysis regarding the distribution of articles in the domain of risk and innovation management of small businesses in the textile industry. This distribution is based on the country of the corresponding author.

China is the leading country with 12 articles, accounting for a frequency (Freq) of 9.1% among the countries listed. Canada and Germany follow with 5 and 4 articles respectively. India, Brazil, France, and Italy each have contributed 3 articles. Every article with a corresponding author from China, Canada, India, Italy, and Austria is a Single Country Publication (SCP). This implies these articles had authors only from the specified country and not from international collaborations. Germany, Brazil, France, and the Netherlands have a mix of SCP and Multi-Country Publications (MCP), indicating some level of international collaboration in their research articles. France has the highest MCP ratio at 0.667. Out of the 3 articles, 2 of them involved international collaboration. Germany and the Netherlands follow closely with an MCP ratio of 0.5. China, which has the highest number of articles, shows no signs of international collaboration as the MCP ratio stands at 0. This might indicate a more insular or self-sufficient research environment in this specific domain for China. Similarly, Canada, India, Italy, and Austria also have an MCP ratio of 0.

A higher MCP ratio suggests a broader collaboration across borders in the research domain. Countries with higher MCP ratios may benefit from diverse perspectives

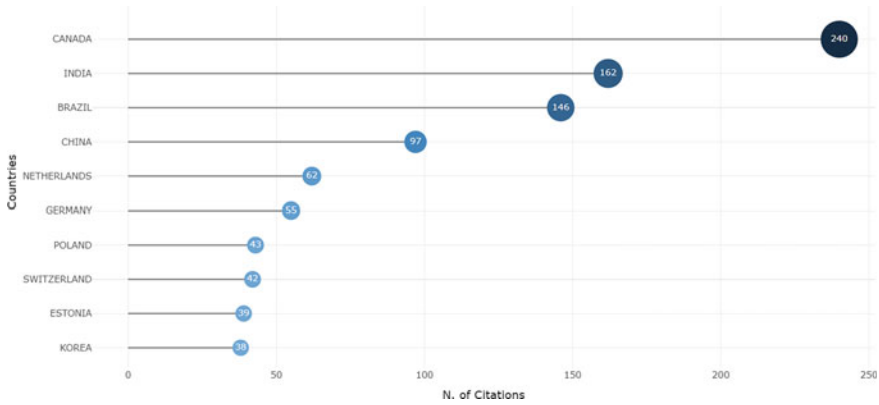


Fig. 12 Most cited countries

and expertise, which can enhance the depth and quality of research. On the other hand, countries with lower MCP ratios might be relying on local expertise or may have strong domestic institutions and research environments that facilitate more localized research. While China leads in terms of sheer numbers, countries like France, Germany, and the Netherlands demonstrate a more collaborative approach in the domain of risk and innovation management for small businesses in the textile industry. The figure provides valuable insights into the global research landscape and highlights the balance between domestic and collaborative research across countries.

Figure 12 presents the most cited countries in the context of risk and innovation management of small businesses in the textile industry based on two main metrics—Total Citations (TC) and Average Article Citations.

At first glance, Canada leads in the total number of citations (TC) with 240 citations. However, when we dive into the average article citations, Brazil outpaces Canada with an average of 48.70 citations per article, even though Brazil has fewer total citations. This indicates that while Canada produces a significant volume of research, the average quality or impact of individual articles from Brazil is slightly higher.

Countries such as India and Brazil, which are often seen as emerging markets, have made substantial contributions in terms of citations, rivaling established Western countries. This underscores the increasing importance and influence of research from non-traditional hubs in the global academic landscape.

China, a global powerhouse in many research domains, has a relatively low average of 8.10 citations per article in this particular field. This number is quite low when compared to other countries in the list, suggesting that while China may be producing a significant number of papers, they might not be as influential or widely recognized in the global textile industry’s risk and innovation management domain.

The presence of countries like the Netherlands, Germany, Poland, Switzerland, and Estonia highlights the diverse research output from Europe. Each of these nations, despite their varying sizes and economic scales, has made noteworthy contributions

to the field. Their average article citations, hovering around the 30–40 mark (except for Germany), indicate a good balance between quantity and quality.

Countries such as Poland, Switzerland, Estonia, and Korea have average article citations that closely match their total citation numbers, suggesting that these countries have produced a relatively consistent number of articles, each of which has garnered similar attention. While traditional research giants continue to make their mark, emerging markets are making significant inroads, suggesting a shift in the balance of academic power and influence. It also emphasizes the importance of looking beyond sheer volume to understand the true impact and quality of research output.

Figure 13 provides a quantitative breakdown of the research output across various countries. China and India are leading contributors, with China accounting for the highest number of publications at 29. This highlights Asia's significant role in the textile industry and its investment in research related to innovation and risk management. The prominence of China and India could be attributed to their established textile manufacturing hubs, vast raw material bases, and increasing emphasis on innovation and technology.

European countries, namely Germany, Switzerland, the UK, France, and the Netherlands, collectively contribute 53 publications. Their combined contribution surpasses even that of China, underscoring Europe's continued importance in the global textile industry and its focus on ensuring that small businesses are equipped to handle risks and foster innovation.

The USA and Canada collectively account for 20 publications. While the USA has traditionally been a significant player in various research areas, its modest contribution (relative to China and India) suggests a possible shift in the textile industry's epicenter. Canada's equal contribution with countries like Australia and France suggests an active engagement in research despite its smaller population. The USA, often a global leader in scientific research, trails behind Germany and India in

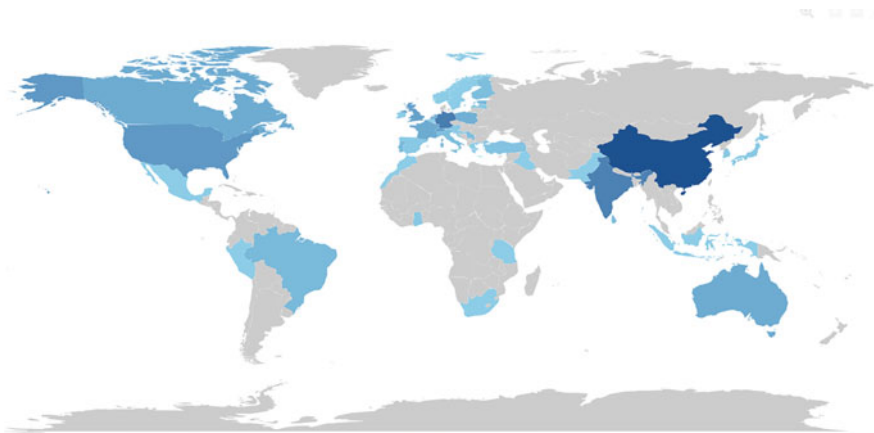


Fig. 13 Countries' scientific production

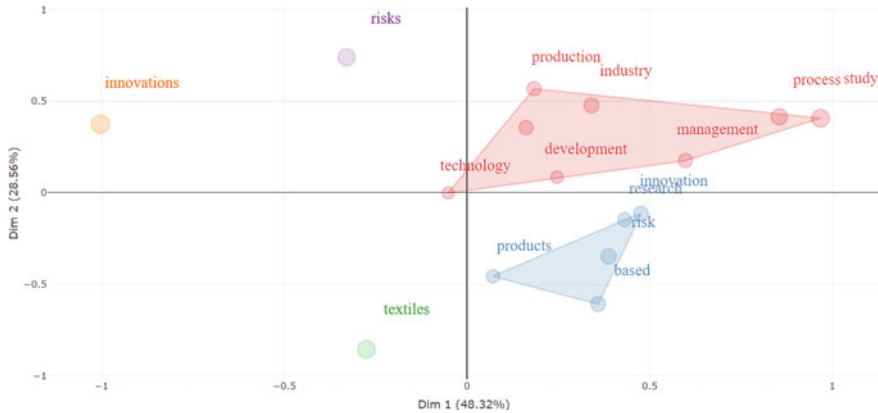


Fig. 14 Word map of the researched publications factorial analysis

this specific area. This may indicate a relative decline in the importance of the textile sector in the US or a shift in research priorities.

Countries like Switzerland, the UK, Australia, Canada, France, and the Netherlands, though having fewer publications compared to the leaders, demonstrate consistent dedication to research. Their contributions can be seen as pivotal, providing diverse perspectives and insights, especially from regions with different industry challenges and dynamics.

Figure 14 presents the results of a factorial analysis which maps out selected words based on their scores in two dimensions (Dim.1 and Dim.2) and then groups them into clusters. Most of the words are positive in Dimension 1 (Dim.1) with “innovations” being the only outlier having a score of -1. The words are more spread out in Dimension 2 (Dim.2), ranging from -0.86 to 0.74.

There are five distinct clusters. Cluster 1 is the most populated and contains words primarily associated with the core theme of the textile industry. Words such as “textile”, “industry”, “development”, “technology”, “production”, “process”, “study”, and “management” are part of this cluster. The words in this cluster are mostly positive in both dimensions, suggesting these concepts may be closely related in the literature and are central to discussions on the textile industry.

Cluster 2 focuses on aspects related to research, risks, and the basis of innovations. Words include “risk”, “innovation”, “research”, “based”, and “products”. These words, especially “based”, “risk”, and “products”, have a negative score in Dim.2, hinting that they might be set in contrast or opposition to some of the concepts in cluster 1.

“Textiles” is the only word in cluster 3, and it is distinctly different from “textile” found in cluster 1. It has negative scores in both dimensions, which suggests it might represent a different context or perspective in the literature compared to cluster 1’s “textile”.

Cluster 4 contains only the word “risks”, which stands out due to its high positive score in Dim.2. This suggests that while “risk” (cluster 2) is closely related to research