

## Article

# Text Mining for Supply Chain Risk Management in the Apparel Industry

Sayed Mehdi Shah <sup>1,2,\*</sup> , Michael Lütjen <sup>3</sup> and Michael Freitag <sup>2,3</sup> 

<sup>1</sup> International Graduate School for Dynamics in Logistics (IGS), University of Bremen, Hochschulring 20, 28359 Bremen, Germany

<sup>2</sup> Faculty of Production Engineering, University of Bremen, Badgasteiner Str., 28359 Bremen, Germany; fre@biba.uni-bremen.de

<sup>3</sup> BIBA—Bremer Institut für Produktion und Logistik GmbH, University of Bremen, Hochschulring 20, 28359 Bremen, Germany; ltj@biba.uni-bremen.de

\* Correspondence: ssm@biba.uni-bremen.de

**Abstract:** Text mining tools are now widely used for the efficient management of information and resources in business, academic and research organizations. This paper provides a comprehensive overview of research articles on the application of text mining techniques in the field of Supply Chain Risk Management and the apparel industry. Research articles published between 2000 and 2020, were obtained from various journals through two online databases, i.e., SCOPUS and IEEE Xplore. Through a systematic approach following PRISMA guidelines, 370 research papers were screened, filtered and finally classified into three main areas: Supply Chain Risk Management and outsourcing in the apparel industry, application of text mining in Supply Chain Risk Management and application of text mining in the apparel industry. In this study, we have identified a comprehensive list of various available data sources for text mining, methodologies and risks associated with outsourcing in the apparel industry. We classify the gaps in expanding the application of text mining in the apparel industry's Supply Chain Risk Management. Extracting useful information from online newspapers through text mining could vividly enhance the ability to monitor supply chain risks and provide the ability to link data to provide decision makers with the right information at the right time.

**Keywords:** supply chain risk management; big data and big data analytics; text mining; apparel industry; data mining techniques; future technologies



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## 1. Introduction

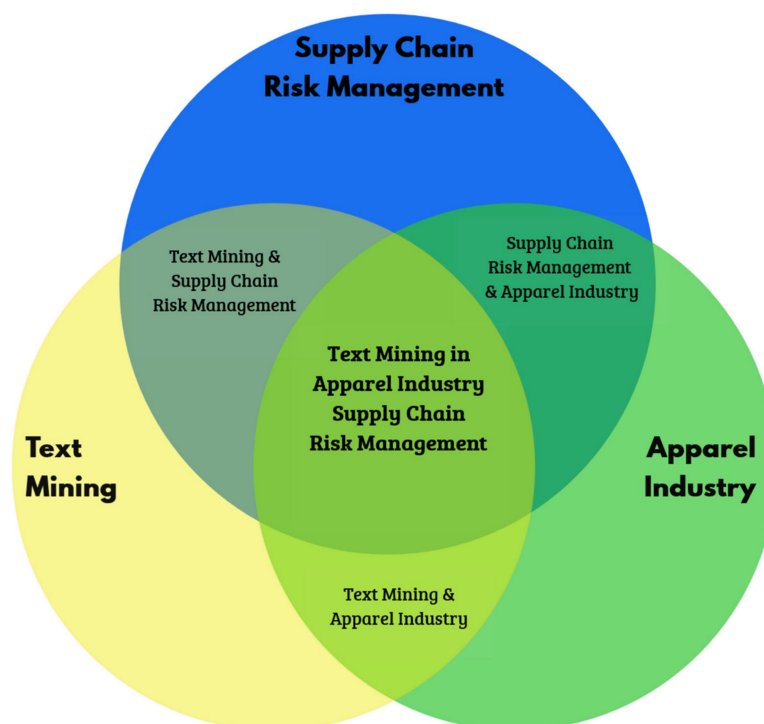
Apparel companies face strong competition in the international market and operate in global value chains. They have to make precise decisions in the different phases of the supply chains and face problems at the strategic, tactical and operational levels of the management processes [1]. Global competitiveness is driving companies to outsource part of their operations to meet market demands. Large apparel companies often use different outsourcing strategies to reduce risks. For textile and apparel outsourcing, China is no longer the only option and certainly not the cheapest. Through China's Belt and Road Initiative (BRI), China is now expanding and reaching out to other countries through various infrastructure, logistics, energy, transport and port projects [2]. With a low price for local supply of cotton and the availability of cheap labor, Pakistan, Bangladesh, Sri Lanka, Vietnam, Cambodia, India and Indonesia are new sourcing destination for apparel manufacturing. All these low-cost countries offer some inherent advantages and disadvantages. This offshore sourcing complicates the system and increases the likelihood of certain disruptive risks occurring [3]. Supply chain disruptions can cause a variety of complications, such as supply bottlenecks, extended delivery times, failure to meet customer demands and upsurges in prices [4]. As a result, these disruptions have a hostile effect on the economic development of the company concerned, e.g., on the share price [5]. In

Bangladesh, for example, a multi-story garment factory called Rana Plaza collapsed in April 2013. Even with immediate local and global rescue efforts, 1133 people were killed and 2438 injured [6]. The stock market reaction to retailers on this particular day of this tragedy was negative and remarkable [7]. As a result, managing supply chain risks in general have received a lot of attention from researchers and practitioners, especially in the global context [8].

In the fashion industry, purchasing decisions for retailers are traditionally made based on various factors such as budget, sales target and interest rate [9]. As market demand is highly impulsive, risk is inherent and it is crucial to include risk consideration in the decision-making framework [9]. On the other hand, the high level of outsourcing in overseas garment manufacturing makes it more dependent on supplier performance, supply chain and associated external risks. In the meantime, however, IT-based inventions have generated and captured more data, changing the business atmosphere. The new generation of analytical tools and data management greatly helps to improve planning and operational performance [10]. Data mining predictive analytics is a new and growing topic in the industry. It offers many opportunities to improve supply chain design and operations in areas such as transportation modes, warehouse design and location, demand forecasting, supplier evaluation and selection. [11]. Data mining covers more than simple numerical analysis, and text mining extends information management to linguistic data [10]. Data mining is about viewing configurations in raw data. Similarly, text mining is related to observing patterns in text and mine useful information for analytical purpose [12]. In other words, text mining is a computational practice of deriving useful information from the data set and presenting the result in a readable form for the next application. This helps us to create a database of configured requirements via data crawling approaches, identify the pattern of a large amount of data and generate useful information and insights by consolidating various factors to make informed decisions [13]. Text mining can be used to derive information to provide summaries for the words that appear in the documents and allow companies to use the research base more in an effective way [14]. Online newspapers and articles describe the latest developments in a country and provide insights into companies in a particular region at an unprecedented speed. Systematic screening of online newspapers can reveal significant additional insights. In developing markets where trustworthy customer data are scarce, research into textual information can also provide insights. Furthermore, newspapers are a very important source of information for scientific research, particularly in the field of social sciences and humanities [15]. An interesting question in this context is therefore: Can we use text mining of online newspaper data to get an overview of external risks in supply chain management in the apparel industry?

Chih-Yuan Chua et al. use texts from the current literature to develop a risk categorization hierarchy and conduct a sentiment analysis of news articles to reveal outlines of risk variation [16]. This research did not specifically address supply chain risks in apparel outsourcing, nevertheless proposed a framework for general global Supply Chain Risk Management using the articles and online news text. Kim examines trends in sustainable supply chain management and companies' strategic positioning and implementation of sustainability in the textile and apparel industry through text mining of news articles and sustainability reports [17]. This study covered the textile and apparel industry based on news articles and sustainability reports, however, was only based on risks related to sustainability. Beheshti-Kashi et al. conducted a survey on the current advancement in the field of sales and fashion forecasting and highlighted its importance in the field of the retail industry through text mining of blogs [18]. Latinovi et al. discusses the applications of big data in fashion industries [19]. Giri et al. conducted a systematic literature review of research articles related to artificial intelligence in the fashion and apparel industry. These were extracted and categorized based on the mostly application of artificial intelligence in different departments and sector apparel manufacturing [20]. However, to our knowledge, no comprehensive review of text mining application in Supply Chain Risk Management in the apparel industry outsourcing has been conducted.

To consolidate our research, we consider three main research areas, i.e., Supply Chain Risk Management, the apparel industry, and text mining, and examine their intersections, as shown in the Venn diagram in Figure 1.



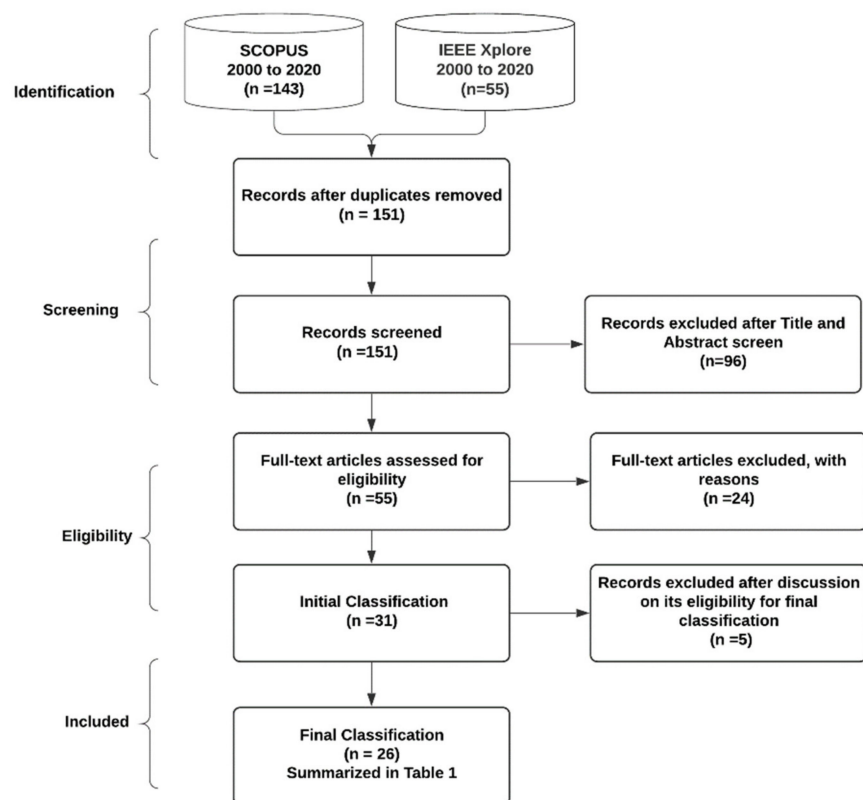
**Figure 1.** A three-part Venn diagram showing Text Mining, Supply Chain Risk Management and Apparel Industry. Three intersection areas are surveyed in three phases.

First, we look for general methods and approaches for Supply Chain Risk Management in the outsourcing of the apparel industry. Since Supply Chain Risk Management is a broad topic, we focus here only on risk management in the context of outsourcing in the apparel industry. Then, we separately consider the application of text mining in Supply Chain Risk Management and the apparel industry, which is comparatively new compared to the traditional methods used to explore various risks in the apparel industry supply chain. This approach is only briefly addressed in the literature; therefore, this paper aims to provide an overview of research articles to gain an understanding of text mining applications in Supply Chain Risk Management of apparel industry outsourcing. In addition, another objective is to provide a classification overview to explore the current literature in this area. This will provide a reference for academics to fully exploit the research gaps in their future research. The remainder of this paper is organized as follows. First, we explain the research methodology used in this study. Then, we analyze the articles that are relevant to our research areas. Then, we present a discussion of the findings and gaps in the studies highlighted in this review article. Finally, we conclude the review articles with the contribution as well as limitations of this study.

## 2. Methodology

To identify the research articles within the literature that are related to this our topic, we followed the PRISMA review methodology [21]. A flow chart represents the flow of information through the various phases of a systematic review. It presents the number of records identified, included, and excluded, as well as the reasons for the exclusions [21]. We followed four steps to include the related articles, as recommended in the PRISMA statement. First, we identified the articles that matched our search criteria using keywords. Then, after initial screening, we excluded the articles that were not related to our topic but were identified during our search of the database. The eligible articles were identified

and read thoroughly, and finally the number of articles that fell within the scope of our review was narrowed down and included. These steps have been highlighted in Figure 2. Ngai et al. used this framework for an academic review of decision support and intelligent systems in the textile and apparel supply chain [22].



**Figure 2.** Phase I: Supply Chain Risk Management in the Apparel Industry Outsourcing research papers selection process.

We selected two leading online accessible databases i.e., IEEE Xplore and SCOPUS. The topic of this paper is related to Supply Chain Risk Management, apparel industry and text mining. SCOPUS covers research topics across all scientific and technical disciplines. It is one of the world largest abstract and citation record of books, scientific journals as well as conference proceedings. SCOPUS online library covers a superior number of journals, and the information specifies the active journals in covering current and relevant research, as well as prominent potential research fields [23]. The IEEE Xplore is more specific to information technology, where popular searches include Internet of Things (IoT), image processing, machine learning, block chain, artificial intelligence, cloud computing and data mining, and so on. For this reason, by combining these two popular online libraries, we can cover both a broader and more precise spectrum of Supply Chain Risk Management and text mining, respectively. Text mining is an emerging field and has made progress recently as data scientists turn their attention to analyzing the free and unstructured data available online in recent years [24]. This research represents a relatively new field that has emerged only in the last two decades. Therefore, we have collected research articles from 2000 to 2020, when online data and the corresponding data analysis fields have evolved significantly. We include journal articles, conference papers, reviews and book sections in this review. Newspapers and doctoral or master's theses and dissertations were excluded from this review because practitioners and researchers alike most often use journals to publish new findings, as journals signify an advanced level of research [25]. We selected keywords based on the problem (Supply Chain Risk Management), technique (text mining), and industry (apparel) addressed in this review.

To explore the different research approaches (with or without text mining techniques), we divided our search into three phases. In the first phase, to guide the search database, we used the keywords “SUPPLY CHAIN RISKS MANAGEMENT” and “APPAREL | TEXTILE | CLOTHING | GAREMENT | FASHION INDUSTRY”. Since the apparel industry uses these terms interchangeably, we used all of them in our search. After a detailed screening and evaluation process, only articles related to Supply Chain Risk Management of outsourcing in the apparel industry were selected. In the second phase, we used the same advanced search option in our database, but with the combination of different keywords. In this phase, our search was limited to text mining and its application in Supply Chain Risk Management. In order to include as many research articles published between the years 2000 and 2020 as possible in our study, we searched for records with the keywords “TEXT MINING” and “SUPPLY CHAIN RISKS MANAGEMENT” or “SUPPLY CHAIN”. In the last phase, our main focus was on text mining and its application in the garment industry, so we used a combination of the keywords ‘TEXT MINING’ and “APPAREL | TEXTILE | CLOTHING | GARMET | FASHION INDUSTRY”. In three phases, all filtered articles were first classified according to the chosen criteria and then discussed again. A final summary of the most related articles is shown in the next section.

### 3. Analysis and Findings

In this section, we summarized the results of the three search phases in Tables 1–3. To get an understanding of the differences between the other techniques/methods and text mining, we have further categorized the individual tables according to the data sources.

**Table 1.** Shortlisted research papers as a result of a screening process related to Supply Chain Risk Management in the Apparel Industry Outsourcing as shown in Figure 2.

Article Ref	Study Purpose	Methodology	Publication Year
[26]	Supply chain resilience	Fuzzy cognitive maps	2020
[27]	Sustainability transformation warehouses	Fuzzy DEMATEL method	2020
[28]	Barriers of sustainable supply chain practice	Fuzzy AHP approach	2020
[29]	Green practices in the supply chain	Structured equation modeling	2019
[30]	Performance evaluation	Performance evaluation process algebra	2019
[31]	Explore sustainable management	Multi-method logical approach.	2019
[32]	Risk related to social sustainability	Pattern matching technique	2018
[33]	Supply chain risk management, life cycle, risk factor and supplier selection	Systematic review	2018
[34]	Supply, demand and process risks	Analytic network process	2017
[35]	Risks in green supplier selection	Genetic algorithm	2017
[36]	Strategy for in-house production, partial production or outsourcing	Explorative qualitative study	2016
[37]	Sustainability-related supply chain risks	Empirical study	2016
[38]	Lead time and delivery delays	Mathematical model via simulation programs	2016
[9]	Financial risks	Mean-variance approach	2016
[39]	Environmental and social risks	Hypothesis testing	2015
[40]	Procurement risk in global sourcing	Interpretive analysis method	2013
[41]	Selecting the location of garment factories	Artificial neural network	2013
[42]	Sustainable textile/clothing supply	Multiple fuzzy criteria	2013
[43]	Production outsourcing risks	Explorative qualitative study	2011
[44]	Supply, manufacturing and demand risk	Graph theoretic approach	2011
[45]	Flexibility in an uncertain environment	Exploratory multi-case study	2011



Table 1. Cont.

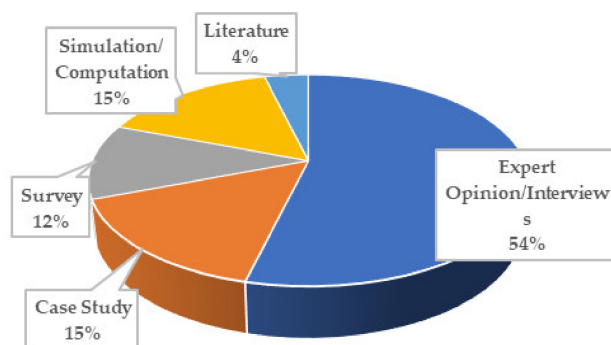
Article Ref	Study Purpose	Methodology	Publication Year
[46]	Risk management actions	Qualitative survey approach	2010
[47]	Foreign trade risks	Exploratory studies	2010
[48]	Natural, demand and supply risk	Delphi method	2009
[49]	Supplier selection and risk management in the supply chain	Empirical analysis	2008
[50]	Quality, costs and reliability risk	Quantitative and qualitative surveys	2008

### 3.1. Supply Chain Risk Management and Apparel Industry Outsourcing

In the first phase, we identified and summarized the articles of research related to Supply Chain Risk Management in apparel industry outsourcing. The total number of research papers and the inclusion and exclusion criteria are shown in Figure 2.

There are numerous publications on both Supply Chain Risk Management and the apparel industry. After carefully reviewing and following the steps outlined in the diagram in Figure 2, we have listed 26 research papers on risk management in the apparel industry in Table 1. In this table, we have highlighted the main purpose of these articles and the methodology that each researcher has used to evaluate risk management in relation to the apparel industry outsourcing. All these articles use the conventional methodology, as shown in Table 1, which has long been used by various researchers, rather than data mining. In other words, this table is a reiteration of the overlap between Supply Chain Risk Management and the apparel industry shown in Figure 1 of the introductory section, focusing on risks related to supply chain.

The data sources used in the research papers listed in Table 1 are shown in Figure 3 in the form of a pie chart. From the graph, it can be seen that the majority of the researchers used expert opinions and interviews as a source of data for applying different techniques.



**Figure 3.** Distribution of data sources used in the articles listed in Table 1, selected via the search criteria related to Supply Chain Risk Management in the Apparel Industry Outsourcing.

Apart from the data sources, if we analyzed the individual methodology techniques given in Table 1, we find that exploratory, expert decision, fuzzy logic and some other models have been used in the study of Supply Chain Risk Management of the apparel industry. Bevilacqua et al., Vedel M. et al., Yi C. Y., conducted an experimental case study in the apparel industry [26,40,45]. Jin et al. also conducted a similar kind of study to observe the dissimilarities in the criteria for the selection of suppliers and to obtain an awareness of benefits and challenges by two firm characteristics [47]. Berdine, Matt et al. conducted an exploratory study of executives. In this study, they examine the dissimilarities in criteria for selection of textile supplier and the awareness of benefits within the fiber and yarn, apparel, textile, and retail industries. Through a questionnaire, they conducted quantitative and qualitative interviews [50]. Köksal et al. conducted interviews in a semi-structured pattern and collected data from companies in Vietnam and Europe [32]. Martino G et al.

adopted the Analytic Network Process (ANP) approach as a means for risk ordering based on specialists' verdict [34]. Likewise, Cerruti et al. conducted a Delphi-method-based literature review, then collected views from a panel of professionals, and finalized the projected framework [48]. Freise and Seuring, conducted interviews of ten experts and combined it with literature on sustainable supply chain management and Supply Chain Risk Management to develop a theoretical model for risk management in sustainable supply chains [39]. However, Hashim et al. proposed a new multi-purpose software design model based on a genetic algorithm to choose sustainable strategic supplier in a fuzzy environment. To check the validity, this design software and algorithm were applied to a real world case in Pakistan [35]. Anbanandam et al. proposed a model for measuring collaboration that considers variables such as top management obligation, information sharing, the conviction among supply chain partners, long-term relationships and risk and incentive sharing [44]. Choi developed, via a mean-variance approach, multi-period risk minimization inventory models for fashion product purchasing [9].

The drawback of exploratory studies, experts' decision, and fuzzy logic are that the results obtained may be influenced strongly by the partiality of the person who assesses the variables. To reduce this human intervention, big data and text mining techniques are used to collect, disseminate and analyze information in the supply chain as well as in the fashion industry [51].

### 3.2. Text Mining in Supply Chain Risk Management

Text mining extends knowledge management beyond numerical data: therefore, the following section analyzes text mining and its applications in Supply Chain Risk Management and the Apparel and Fashion Industry. A classical text mining scheme includes data collection, text parsing, text transformation, text filtering, text mining and visualization. In addition, there are various text-mining tools such as Python Natural Language Understanding (NLTK), Topic Modeling and Sentiment Analysis and so on [12]. In the second phase, we identified and summarized articles related to the use of text mining in the Supply Chain Risk Management. Following the steps shown in Figure 4, we have summarized 21 research papers on text mining and risk management in Table 2, which is a reiteration of the overlap between text mining and Supply Chain Risk Management

In Table 2, we have highlighted the industry sectors covered and the contribution of each research paper. In Table 2, there are only two articles specifically related to the textile/apparel industry. However, apart from supply chain risk management, there is a lot of recent research that uses text mining for fashion and sales forecasting, design, or brand perception in the apparel industry. Table 2 shows the research works related to the application of text mining in Supply Chain Risk Management, but not limited to the textile industry.

The data sources used in the research, which are listed in Table 2, are shown in Figure 5 in the form of a pie chart. From the chart, it can be seen that the majority of the researchers used newspaper texts, followed by various types of reports and research articles. We found that in contrast to the research shown in Figure 3, researchers using text mining techniques used different types of data sources to study supply chain risk management.

### 3.3. Text Mining in the Apparel Industry

In the apparel industry, text mining techniques have been mainly used for predicting fashion trends, sales forecasts, customer reviews or feedback on brands and any items. To achieve a deeper insight into this area, in the last phase we identified and summarized articles dealing with the application of text mining in different areas of the apparel industry. Following the steps shown in Figure 6, we summarized 27 research papers on the application of text mining in the apparel industry in Table 3, which is a repeat of the overlap between text mining and the apparel industry shown in Figure 1 of the introductory section.

**Table 2.** Shortlisted research papers as a result of a screening process related to Text Mining and Supply Chain Risk Management as shown in Figure 4.

Article Ref	Industry	Study Purpose	Publication Year
[52]	Technology sectors	Assess the vulnerability of the supply chain	2020
[53]	Medical items, such as personal protective equipment (PPE)	Response to supply chain disruptions during the COVID-19 crisis.	2020
[16]	Not specific to any industry	Seven global supply chain risk categorization	2020
[54]	Not specific to one industry	Risks associated with multi-echelon supply networks	2020
[55]	Banks as supply chain finance	Identified four key risk management drivers	2020
[56]	Oil market	Risk factors in the oil market	2019
[57]	Not specific to any industry	Selection of the global supply chain region	2019
[58]	Not specific to any industry	To investigate terrorism-related risk	2018
[59]	Manufacturing and construction	To examine the risk associated with child labor	2018
[60]	Automotive, aerospace and general manufacturing	Supply network and buyer–supplier relationships risks	2018
[61]	E-commerce	Study the reviews of fresh and perishable products and create rating indices of supplier	2018
[62]	Textile/Apparel industry	Decision support system for competitive analysis	2017
[17]	Textile/Apparel industry	Risk in relation to the sustainability	2017
[63]	Semiconductor industries	Supply chain decisions and business partner selection	2017
[64]	Not specific to any industry	Evaluate company suppliers in terms of their importance and risk	2017
[65]	Not specific to any industry	Investigate the corporate social responsibility reports of Chinese companies	2016
[66]	News services, IT, logistic and manufacturers	General supply chain risks	2015
[67]	Not specific to any industry	Systematic review of “supply chain risk management” through text mining	2015
[68]	Not specific to any industry	General supply chain risks	2011
[69]	Not specific to any industry	Green supply chain research	2010
[70]	Construction industry	Analysis of post project reviews for risk and opportunities	2008

**Table 3.** Shortlisted research papers as a result of a screening process related to Text Mining and Apparel Industry as shown in Figure 6.

Article Ref	Apparel Sector	Study Purpose	Publication Year
[71]	Fashion industry	Identify fashion trends	2020
[72]	Fashion industry	Assess consumers’ experiences	2020
[73]	Renting fashion industry	Assess consumers’ experiences	2020
[74]	Retail	Decisions in the fashion apparel supply chain.	2020
[75]	E-commerce	Characteristics for the matching of the garments	2020
[76]	E-commerce	Create knowledge database for customer recommendations	2020
[77]	Fashion industry	Identify fashion trends	2020



Table 3. Cont.

Article Ref	Apparel Sector	Study Purpose	Publication Year
[78]	Fashion industry	Extracting fashion attributes from Instagram posts	2019
[79]	Fashion industry	Fashion recommendation	2019
[80]	Branding	Feedback sentiment analysis	2019
[81]	Sports apparel	Assess consumers' experiences and perceptions	2019
[82]	E-commerce	Sentiment review analysis	2019
[83]	Retail	Assess consumers experiences or needs	2019
[84]	Fashion industry	Identify fashion trends	2019
[85]	Branding	Brand perception	2018
[86]	E-commerce	Text-based clothing match	2018
[87]	Retail	Forecasting based on visual looks and assessments	2018
[88]	Retail	Fashion forecasting	2017
[89]	E-commerce	Assess consumers experiences and needs	2017
[90]	Fashion industry	Fashion forecasting	2015
[91]	Retail	Evaluate product ratings for clothing	2015
[92]	E-commerce	Clothing reviews classification	2015
[93]	Branding	Brand perception	2014
[94]	Branding	Brand perception	2014
[95]	Fashion industry	Finding the impact of social media engagement on purchase spending	2012
[96]	Fashion industry	Fashion forecasting	2010
[97]	Fashion industry	Fashion forecasting	2007

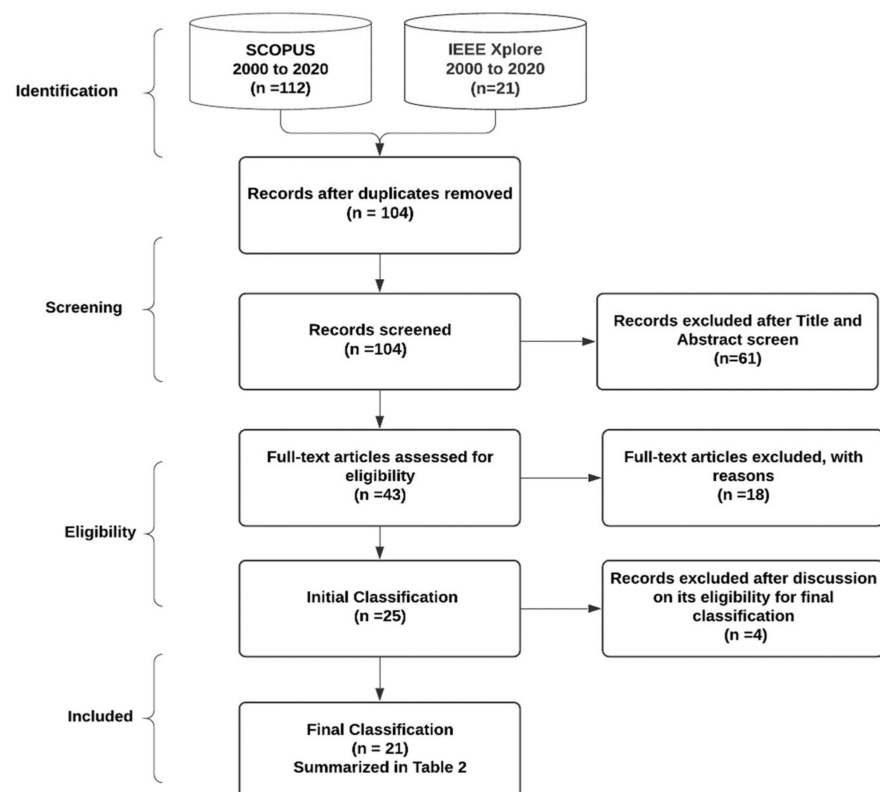
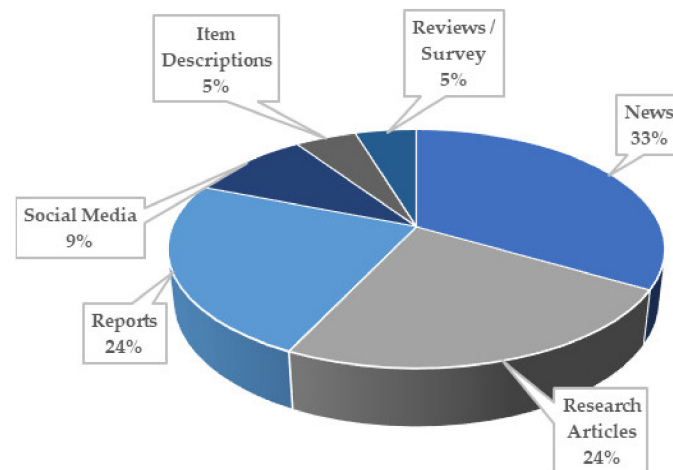
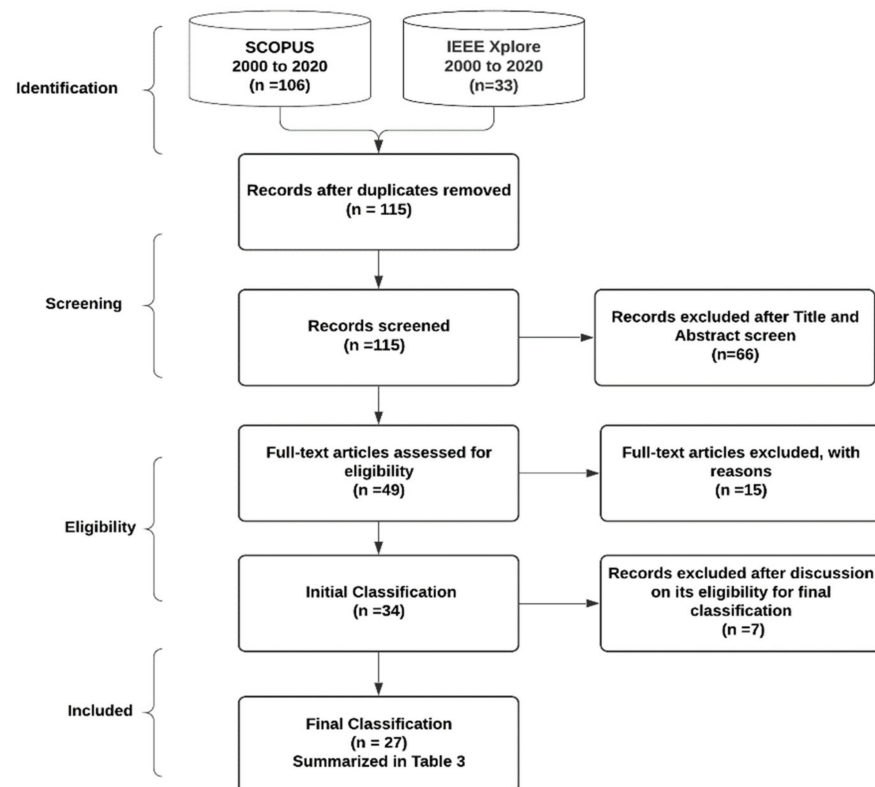


Figure 4. Phase II: Text Mining and Supply Chain Risk Management research papers selection process.



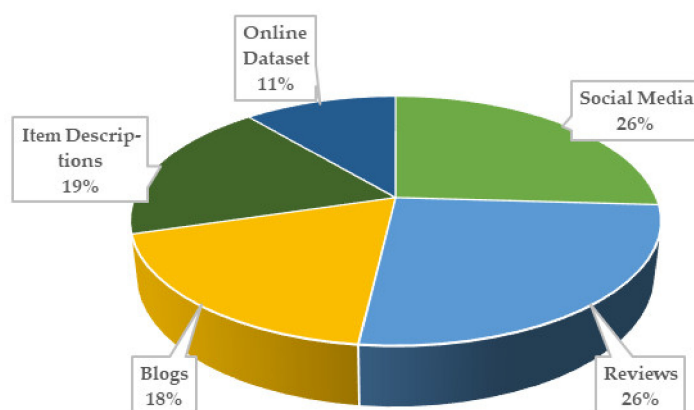
**Figure 5.** Distribution of data sources used in the articles listed in Table 2, selected via the search criteria related to Text Mining in Supply Chain Risk Management.



**Figure 6.** Phase III: Text Mining and Apparel Industry research papers selection process.

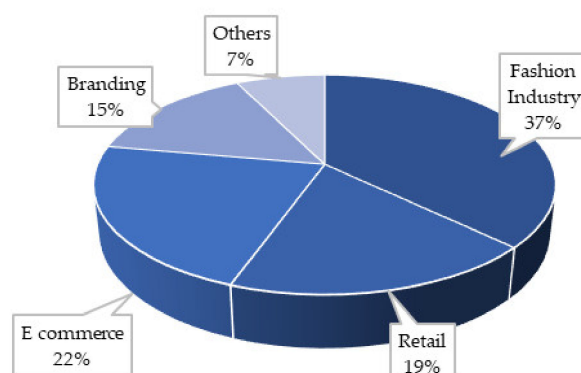
In Table 3, we not only categorized the selected studies by year of publication, but also highlighted the purpose of the study along with different sectors of the apparel industry, i.e., fashion, retail, e-commerce, and branding.

The data sources used in the research, listed in Table 3, are shown in the pie chart in Figure 7. From the chart, it can be seen that social media was used as the main source of data, followed by research and blogs.



**Figure 7.** Distribution of data sources used in the articles listed in Table 3, selected via the search criteria related to Text Mining and Apparel Industry.

The chart in Figure 8 shows the percentage of research papers listed in Table 3 that relate to different areas of the apparel industry. It shows that most of the research papers are the application of text mining in fashion forecasting, followed by e-commerce, retail, branding and few others which include sportswear and apparel rental in the apparel industry.

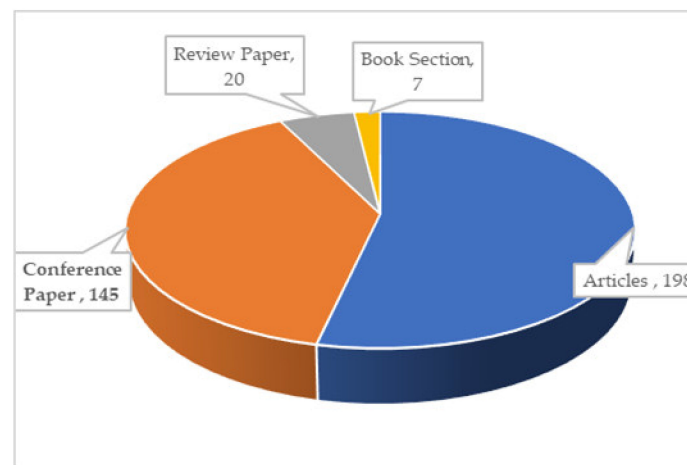


**Figure 8.** Distribution of the different apparel sectors identified in the articles listed in Table 3, selected by the search criteria related to text mining and apparel industry.

### 3.4. The Overall Distribution Of Articles Based on Type and Time

According to our research framework, we selected, reviewed, and classified 370 research papers, which included articles, conference proceedings, reviews, and books section. This distribution of research papers is shown in Figure 9.

The distribution of the number of articles published annually between the years 2000 and 2020 that were shortlisted by the SCOPUS and IEEE Xplore online libraries after applying the Phase I, Phase II, and Phase III search terms is shown in Figure 10. It can be seen that out of these 370 articles, papers related to text mining started in the last decade, but there has been an increase in recent years compared to conventional research on supply chain management.



**Figure 9.** Overall distribution of document types of 370 original articles shortlisted through SCOPUS and IEEE Xplore online libraries after applying search keywords in Phase I, Phase II and Phase III.



**Figure 10.** Overall trend of 370 original articles, based on the number of publications between the years 2000 and 2020, selected through SCOPUS and IEEE Xplore online libraries after applying search terms in Phase I, Phase II and Phase III.

#### 4. Discussion

In the apparel industry, offshore production in low-cost regions is a common practice to reduce manufacturing costs [98]. It is an effective arrangement between an apparel retailer and an offshore supplier whereby the latter will supply the former with a specific range of products or services [99]. Retailers such as Wal-Mart are constantly on the lookout for suppliers and sourcing targets that will enable them to offer products with lower prices and improved services with minimal risk [100]. In general, apparel retailers are no longer directly involved in manufacturing. They source their products from explicit garment manufacturers. Many factors influence the export performance of the garment industry in developing countries, where most factories are located. Some of the major factors are global recession, foreign direct investment, technology, tariff and non-tariff barriers, inflation, imports, technology and changes in trade agreements, transportation costs, compliance costs, dyeing costs, a shift in purchasing power and financing costs. However, according to the 2017 McKinsey Apparel Chief Purchasing Officers Survey, commodity costs, exchange

rates and labor costs are the top three drivers for apparel sourcing in the coming year. [101]. Nowadays, however, various artificial intelligence methods are used to minimize the risk by making early predictions based on the randomly available raw data. Among the techniques, text mining uses different working methods depending on the purpose. Applications of text mining in Supply Chain Risk Management are still in the development stage and need to be thoroughly explored by leading us to review this research area.

To gain insight into text mining, Supply Chain Risk Management and the apparel industry, we conducted a three-stage systematic review. In the first phase, 198 research records were identified in the two online databases SCOPUS and IEEE Xplore using our search terms through various combinations. We removed the duplicates and checked the 151 articles by their abstract and title. Upon further analysis, we found that 31 research papers related to Apparel Supply Chain Risk Management, and among these, 26 were finally classified. The methodologies used are conventional, relying mainly on people opinion, surveys, audit reports and interviews. Other than the possibility of bias in expert opinion, the ability to collect a large amount of data was also limited with these techniques. In the second phase, 133 research records related to the text mining and Supply Chain Risk Management were found in the two online libraries that met our research criteria. We filtered out all duplicate irrelevant articles that were beyond the scope, and 104 articles were then screened through various steps. Finally, we classified 21 research paper related to the text mining and Supply Chain Risk Management based on the data sources such as news, social media, blogs, item descriptions, reviews and online dataset. At this stage, we also found that in addition to newspapers, social media and audit reports, text mining was also applied to a huge amount of literature to analyze Supply Chain Risk Management practices. These data also differ from conventional data sources in a way that is real time. We can also see in Table 2 that these articles were not related to a specific industry, but they generally discussed Supply Chain Risk Management practices. However, there are only two articles specifically related to Supply Chain Risk Management in the apparel and textile industry. Therefore, to find out what are the current main applications of text mining in the apparel industry, we explored text mining in the apparel industry in the last phase. In total, 115 records were screen and 27 articles were finally classified in this category. It was found that, in the apparel industry, text mining is mostly used for predicting, forecasting and consumer feedback analysis. In reviewing the research articles, we also found that there are a number of articles on the application of various AI techniques in textile yarn and fabric production, but they do not relate to Supply Chain Risk Management.

During this process, we came across the encouraging fact that numerous conference papers are available on this topic, which shows that the application of text mining in Supply Chain Risk Management is a growing topic and is gaining massive attention. Recently, there has been a surge in the publication of articles and a large number of conference papers currently available on this topic. As shown in the Figure 10, the growth over the last few years has been particularly significant in the area of the application of text mining in fashion forecasting. Unlike traditional data sources, text mining not only enables the exploration of new data sources such as news, social media, etc., but it also has the advantage of processing a huge amount of data, which not only strengthens the generated result but also minimizes the chances of individual bias towards an opinion. It is extensively used in different areas of the industry, but we can see that there is a great need for work in Supply Chain Risk Management in the apparel industry. Although we broadened our search criteria to find relevant research journals, we found a smaller number of articles in research journals on this topic. This fits well with the fact that risks in apparel outsourcing could be surveyed by text mining, yet this problem is still under researched and a more systematic and theoretical analysis is needed. Furthermore, in the second phase, when we examined the research articles for text mining in Supply Chain Risk Management in Table 2, we also found that text mining techniques were applied to newspaper articles to discover hidden patterns as shown in Figure 5. The newspaper articles highlight various events that impact the factor affecting the garment manufacturer. In light of these findings,

it is conceivable that further experiments specifically related to text mining of newspaper data for Supply Chain Risk Management in the apparel industry are highly useful for both the literature and the application of text mining techniques in the apparel industry. As we have already noted, fuzzy techniques and statistical algorithms are widely used to evaluate expert opinions and improve decision support systems. These techniques can be combined with text mining techniques to improve performance and increase the amount of data that can be processed. Similarly, pairing the classical forecasting model with text mining techniques can contribute to a sustainable supply chain system in the apparel industry as well as in other industries.

## 5. Conclusions, Research Implications and Limitations

In the last century, the average household invested more of its income in clothing than today, but the number of garments per person in the household was lower. Most of the clothing purchased by households was made in local factories in the United States as well as in Europe. Today, only a small portion of the clothing we wear is made in these regions, while factories and textile mills have spread to Asia and other countries with low labor costs. The lower cost of supply chain logistics, materials, and labor required to produce a garment now provides the opportunity to produce more quantity at a lower price, but from a quality perspective, garments are unlikely to last very long. This has led us to a disposable fast fashion society. Today, in the age of globalization and logistics support, companies are still unable to efficiently manage such fast turnaround times, but with the support of artificial intelligence, the supply chain can now be made more streamlined. New research suggests that there is a need to consider other forms of management to combat key challenges that pose a threat to business operations. Our survey of the literature found that more studies are needed on the importance of using artificial intelligence using text versus numbers to predict Supply Chain Risk Management, a consideration that is often marginalized in favor of focusing on supplier–buyer problem relationships and production issues.

Text mining techniques are becoming increasingly important in the post-pandemic era for sustainable supply chain visibility to know in real time about the out-sourcing region around the globe. This paper provides an analysis of the ongoing trend of apparel industry text mining application and supply chain risk management in the industry over the past two decades. This also highlights the understanding of techniques and use of data sources transformation in Supply Chain Risk Management. It also highlights the potential gaps to understand the use of text mining techniques with apparel in industry Supply Chain Risk Management. In this paper, research papers related to the application of text mining in Supply Chain Risk Management in the apparel industry between 2000 and 2020 were identified and reviewed using SCOPUS and the IEEE Xplore. The main purpose of this review article is to provide an overview of the application of text mining in Supply Chain Risk Management and the apparel industry. Nevertheless, this overview is not exhaustive and far-reaching. However, the results presented in this article have several important implications for this research area. Using a classification method of journal articles, this review shows that text mining techniques are rapidly evolving in the apparel industry. By examining the existing study, research gaps are identified, particularly in the area of text mining applications in Supply Chain Risk Management in the apparel industry. Consequently, our recommendation in this study points to excellent opportunities for researchers working in depth to make valuable applied and academic contributions to this topic area. Electronic or online text documents are in abundance, but the importance of text mining revolves around what can be done with them. This paper not only highlights the importance of text mining tools, but also shows the potential of news and other available data to be transformed into a valuable tool for proactively minimizing supply chain risks. In addition, it also shows a possible direction for further exploration of text mining in fashion forecasting and assessment for trends and sales forecasting. This provides a good starting point for discussion and further research. The application of text mining techniques in apparel industry's Supply Chain Risk Management has attracted the attention of both



academics and practitioners. Based on the current rate of publication in the recent past, research on text mining in the apparel industry and Supply Chain Risk Management will increase significantly in the future. We also categorize several research gaps in the existing literature on Supply Chain Risk Management and text mining applications in the apparel industry. This, in turn, provides a basis for setting a research agenda in this focus area.

This work has several limitations: First, this study only analyzed research articles; conference and review paper published during the period 2000–2020, and these were sorted out based on some related keywords. Second, the study is limited to two online search databases, i.e., IEEE Xplore and SCOPUS. The third potential limitation is that only publications published in English were included. Furthermore, this study is focused on the application of text mining in the external risks related to apparel industry. Although the keywords for the article search were carefully selected, some articles may still have been overlooked, as other terms could have been used in these papers. In the future, other industries could be considered, and the study could be extended to some other libraries.

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