


## Article

# Semantic Network Analysis to Explore the Concept of Sustainability in the Apparel and Textile Industry

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**Abstract:** Consumers are becoming increasingly aware and sensitive to the negative environmental impact caused by the fashion industry and by consumers' high consumption of fashion. This study analyzes people's unfiltered comments and behaviors on social media sites related to the sustainability of fashion products. Recently, the number of social media data, called big data, has exploded, transcending the level that can be analyzed with existing tools. This study aims to identify consumers' perceptions of sustainable fashion using the search words "sustainable fashion" to examine public opinion trends found in SNS big data. Text mining was employed to extract meaningful words from the SNS texts using semantic network analysis to analyze the connectivity and propagation trends. The text data were collected from Facebook using the Google search engine to detect tendencies in the occurrence of keywords related to sustainable fashion in SNS over the past five years (2016~2020). The results revealed that the keywords "eco-friendly", "ethical", and "recycle" had the highest frequency and centrality. As a result of grouping the keywords based on their correlations, sustainable fashion texts from the SNS data could be classified into four groups: "supply chain of sustainable fashion", "circular fashion", "fashion business concepts for sustainability", and "academic importance of sustainable fashion". This study strengthens the extent of research by using SNS big data and provides guidelines for product development and communication strategies for a sustainable fashion industry based on customers' meaningful opinions.

**Keywords:** sustainability; apparel and textiles; semantic network analysis; social media; big data; text mining



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## 1. Introduction

The globe faces the challenge of shifting toward sustainable consumption and forming an ecologically friendly market [1]. Although sustainability has become a megatrend in our society, individual consumers' unsustainable patterns of consumption are still a major barrier to sustainable development [2]. Thus, an individual consumption lifestyle is important for an ongoing sustainable development. Fortunately, young consumers, particularly Millennials and the Generation Z, have strong behavioral intentions to engage in sustainable consumption [3,4]. Considering the leading power of the young generation in the market, it is clear that the unsustainable consumption patterns will soon face change.

Research has been conducted on sustainable consumption and the topic of sustainable consumption research has evolved progressively [5]. The focus of sustainable consumption has initially shifted from sustainable manufacturing of consumer goods to individual shopper's responsible choice [6,7], and recently has reached a systemic change of the social and institutional arrangements leading to a sustainable lifestyle [8]. However, research on sustainable manufacturing occupies a large proportion in the fashion field [9–11], while more studies on individual sustainable fashion consumption are still needed. To move to the next step, it is necessary to understand the consumers' perceptions and behaviors

related to the sustainable fashion. Several researchers investigated sustainable fashion consumption, such as consumers' responses including their attitudes and intentions toward the sustainable fashion goods [12–14], and consumers' motivation for sustainable fashion consumption [15–18]. They have rarely used purposeful sampling to study the actual sustainable fashion consumers as the respondents. On the quantitative research such as conducting consumer survey, the sampling issue has been issued as a limitation to investigate consumer behaviors [19], thus, decision-makers who are operating or plan to start a sustainable fashion business need an alternative of this limit. As an option of the sampling restrictions, recently, network analysis approaches using text mining methods from big data have been proposed to expand both quantitatively and qualitatively beyond the boundaries of accessibility to survey responses [20–25]. Applying the network analysis of text mining from massive volumes of user-created data, social sustainability [20,21], fashion [22], and fashion ethics studies [23,24] have been established. Tehrani et al. [25] indicated that the network analysis using text mining from big data of social media can analyze individuals' thoughts and extract meaningful information or predict trends in specific fields and they gathered user unstructured data collected on Twitter [25]. Network analysis using text mining is consequently an increasingly applied technique whose request in business can help companies discover new possibilities for performance improvement to achieve a competitive advantage.

Understanding individuals' actual perspectives could help researchers and practitioners in the industry and suggest solutions to overcome the gaps in pro-environmental and sustainable business and management in the apparel and textile sector. Therefore, this study aims to explore what the real sustainable fashion consumers are thinking and talking about sustainable fashion by analyzing people's unfiltered comments in the social media (i.e., Facebook) by applying the semantic network analysis with a text mining technique. Analyzing the keywords mentioned by individuals in the social media can be helpful to identify consumers' values, gain insightful ideas for product development, and develop the right directions by finding key factors that consumers are dissatisfied with [26]. Text mining gives the capability to obtain information and trends from a large volume of textual data, providing an outline of the main issues related to sustainable fashion and practices discussed in the social media. Therefore, the purpose of this study is to analyze people's perceptions of sustainable fashion using network analysis based on text mining from Facebook and to provide a direction for fashion companies and retailers that propose sustainable fashion to strengthen and supplement it. We believe that the results of this study can give representative and meaningful insights on the sustainable fashion in the apparel and textile area.

## 2. Literature Review

### 2.1. Sustainable Consumption

Sustainability is understood intuitively, but there is no consistent definition [27]. Understanding sustainability depends on the context and may be defined differently by each individual [28]. Nevertheless, sustainability is generally accepted as "meeting the needs of the present without compromising the ability of future generations to meet their needs" [29], which is the most cited definition [30]. Sustainable consumption is associated with people's awareness of the long-term consequences of their consumption for nature or society [31,32]. In general, consumption is associated with a good life, regardless of whether or not it reflects sustainability objectives [33]. Because each individual pursues a different aspect of their personal good life and the good life for all humans, it is difficult to define sustainable consumption as a universal concept and standard without considering each individual's unique cultural, historical, and individual background.

Within the environmental social sciences, Spaargaren [34] supposed that the analysis of sustainable manufacturing should be accompanied with establishing the issues of sustainable consumption and lifestyles. Consumers have their own sustainable consumption range from the minimum of satisfying individual goodness to the maximum of not

endangering the satisfaction of objective needs of other humans, in terms of the natural or social environment, now or in the future [33]. Environmental and sustainable sociologists need to conceptualize sustainable consumption patterns, lifestyles, and daily routines as to prevent the drawbacks of many of the so-called micro-approaches that have been formed to date [35]. Shifting consumption patterns towards more sustainable behaviors relies on a vigorous understanding not just of what motivates consumers, but also on how behavioral change arises [35,36]. Thus, to identify consumers' numerous concepts of the sustainable fashion, it is appropriate to conduct quantitative research using big data to gather broader and authentic information from a large number of individuals.

In addition to consumers' perceptions of what they identify as sustainable consumption, individual differences are found in consumers' motivations for and engagement in sustainable consumption, and patterns of sustainable consumption behaviors. Researchers have explored consumer values [16,37], and psychological variables such as self-identity [38,39], personal norms [40], and emotions [41,42] as the motivations and engaging factors of sustainable consumption. We expect to find the obvious consumer values and psychological variables and identify the link to sustainable fashion and concrete fashion consumption behaviors related to sustainability.

## 2.2. Sustainable Fashion Consumption

In terms of the sustainable consumption, fashion goods have been perceived as the prodigal among consumer goods [19]. The short life cycle of fashion with clothing and accessories going in and out of style, especially in fast fashion, is contradictory to the principles of sustainability that focus on a long-term perspective [43,44]. The fashion industry is considered one of the most wasteful consumer industries in the world [45]. Nevertheless, efforts to incorporate sustainability into the fashion industry have been around for quite some time and have steadily increased. The anti-seal campaign was the first anti-fur campaign in the 1970s and expanded anti-fur campaigns began in the 1980s [46]. As the use of sweatshops also became controversial, consumers pressured fashion companies to monitor their manufacturers and the current sustainable consumer movement began [47]. Given the increasing interest in sustainable fashion, famous fashion houses and retailers launched sustainable fashion. Stella McCartney launched her clothing line eliminating leather and fur in 2001 [16]. The first Ethical Fashion Show was held in Paris in 2004 [47], and the first Eco Fashion Week was held in New York in 2009 [48]. H&M and Zara also launched their sustainable collections branded as Conscious Collection and Join Life. New sustainable fashion brands such as Komodo and People Tree were also launched selling only sustainable fashion goods, which reflected consumers' continuing interest in sustainable fashion [16].

Like sustainability, sustainable fashion does not have a single definition. The term sustainable fashion frequently replaces other terms, such as green, eco, ethical, and slow fashion [16,49]. The literature frequently defines sustainable fashion as fashion products that incorporate fair trade principles with sweatshop-free labor conditions while not harming the environment or workers by using eco-friendly materials [50,51]. However, this definition misses a very influential aspect of sustainable fashion: consumption. Researchers have focused on the products, the manufacturing process, and the raw materials, while ignoring use: the real consumption stage. The use stage has the greatest impact on the natural environment [52]. Most of the water and energy are consumed at the use stage during the whole fashion product life cycle [53,54]. Thus, the last users have a key role to play in sustainability in the fashion field. Early research on sustainable fashion showed that a few consumers were interested in sustainable fashion [55–58], but more recent research shows that young consumers have a high interest in sustainable fashion [4,59]. Therefore, identifying the concept, consumer values, motivations, and behaviors associated with sustainable fashion is meaningful by analyzing current consumers' thoughts based on the words they use in the social media.

### 2.3. Semantic Network Analysis Using Text Mining from Big Data in the Apparel and Textiles Industry

Consumers actively participate in various social media platforms to exchange their thoughts, opinions, and information about fashion purchases and consumption [60]. Recently, the number of meaningful network studies using big data of social media has increased due to the advantage of obtaining more customer-centered and in-depth information compared to the results derived from surveys or interviews with consumers [21,61,62]. Big data refers to large-scale data including unstructured data, such as text and video data, as well as large-scale, digitized data generated within digital environments such as the Internet and SNS [61]. The most important key to the fashion industry is the internal needs of consumers, and research based on social big data has been conducted to analyze consumers' voices in-depth. Since the fashion industry and products are often promoted in web- and mobile-based technology environments, the use of social media and communication by both fashion companies and consumers has been extremely valuable [22,24]. As a result, there have been many changes in the data and analysis methods used in research [51]. Many programs have been used to collect, analyze, and visualize data on social media with numerous ways to present the results [61,62]. Furthermore, research using big data analysis methods shows that the scope of research has expanded both quantitatively and qualitatively beyond the limitations of the small number of people in the study and the boundaries of accessibility to survey responses [22].

Given that new informatics techniques are considered an advanced approach to investigate the segmented fashion market (i.e., sustainable fashion market), the fashion industry has used SNS data to understand and forecast fashion consumers' behavior [63]. Text mining, a method to extract extensive knowledge from unstructured text in SNS, has been conducted using natural language processing, a form of machine learning that takes massive amounts of language text and converts it into a useful form for researchers or practitioners by mining and extracting important keywords [62,64]. Semantic network analysis reveals knowledge and information about semantic networks between words in a network by demonstrating the information in a visual graph with labeled nodes [61]. Principally, any words in semantic networks that may be related to other words can be deemed nodes [62].

Consumer opinions in the social media can quickly be converted to valuable data and provide insights to help make fashion business decisions based on consumers' preferences and thus become an advantage of marketing strategies [65]. A few studies have explored the potential application of semantic network analysis in fashion research. An and Park [62] incorporated text mining and semantic network analysis into the fashion trend analysis process to analyze fashion collections using social media applications. Kim et al. [24] also identified top actors leading the green consumption network (i.e., eBay Green Team Facebook) and characterized keywords/word-pairs as user messages. Choi and Lee [66] explored consumers' previous and current general awareness of the animal materials and the alternate materials and observed how the interest in environmental rights and animals affect interests in vegan materials applying social big data analysis.

The rapid progression of SNS big data from social media has attracted considerable attention in the apparel and textile sector, particularly as the techniques have improved. As a result, text mining has technically enabled the extraction of consumer-driven words and become a helpful methodology in fashion research. Professionals in academia and industry have also been struggling to solve the "attitude-behavior" gap in sustainable fashion, a phenomenon whereby consumers who admit to having solid environmental or sustainable values do not transform these values into purchases of sustainable fashion products [67,68]. Data mining-driven SNA (Semantic Network Analysis) refers to the analysis of massive volumes of user-generated data that integrate computational intelligence and include but are not limited to big data analytics and machine learning [69,70]. Accordingly, we attempt to fill this gap by applying a semantic network analysis using text mining to explore the concept of sustainability in the apparel and textile industry. This study aims to

investigate sustainable fashion relative keywords, keyword frequency, and connectivity degrees between keywords, and to construct an association map of sustainable fashion relative keywords. In addition, we analyze the connected network structure by clustering sustainable fashion-related keywords. We propose the following research questions:

Research question 1: What are the keywords related to sustainable fashion, how frequently have these keywords been mentioned, and how connected are these keywords?

Research question 2: How are the sustainable fashion-relative keywords grouped?

### 3. Methods

To investigate the opinions of consumers related to sustainable fashion, this study attempts to use text mining techniques and semantic network analysis as analysis methodologies. Text mining is an objective method of analyzing large amounts of text data and has the advantage of exploring key topics, sustainable fashion issues, and trends from multiple angles. Using semantic network analysis techniques, it is easy to identify connections between thematic words and key words. Recently, text mining and semantic network analysis have been applied to analyze consumer awareness and behavioral patterns more systematically in various academic fields [24]. This study established the following analysis process to determine the meaning based on the relationship between social media users' words and consumers' opinions on sustainable fashion.

#### 3.1. Subjects and Data Collection

Selecting the comments and reviews of consumers is an important process to predict consumer behavior and make important business decisions [71]. This research aims to explore individuals' thoughts, opinions, and behaviors on sustainable fashion by text mining comments from SNS and using semantic network analysis methods. To achieve the purpose of the research, words with "sustainable fashion" in the title and text were selected as a sample. The research subjects were selected, and the data were gathered based on the following criteria and process. First, we applied text mining for the keyword phrase "sustainable fashion" from Facebook using Textom 4.5, as an analysis tool for data collection and preprocessing. Textom 4.5 supports data collection and analysis in various languages including English, Chinese, and Korean as a solution that facilitates data collection, refining, analysis matrix, and visualization in the web environment [72]. Several studies utilized this program to automatically collect data from various Internet channels and refine them as a big data processing solution. An and Park [62] identified fashion design trends and Kim and Lee [72] investigated consumer perception of fashion show based on big data applying text mining and semantic network analysis using the Textom program.

We mined text data of keywords related to "sustainable fashion" posted from 1 January 2016 to 31 December 2020, then, the data from the collected keywords were refined referring to previous research [62,72]. During the refining process, the collected data were reprocessed to delete, combine, or unify unnecessary post-positions, keywords, and synonyms. Keywords representing synonyms and similar information were integrated into one word. For example, we changed to "cloth" or "clothes" to "clothing". Common words were excluded such as "a", "about", "across", "all", and "also". We deleted unnecessary data such as numbers and symbols that are not related to the study.

#### 3.2. Analytical Methods

Based on social big data, this research analyzed words related to sustainable fashion using semantic network analysis applying NodeXL for semantic network analysis and Netdraw for network visualization [73,74]. Semantic network analysis is a method of recognizing a word constituting a text as a point (node), connecting the relation between nodes by a line, and grasping the meaning using a visualized connection network [74]. Network analysis is widely used as a method of research in fashion and marketing, as it allows researchers to analyze individuals' opinions and ideas posted on unstructured online boards [66,75,76].



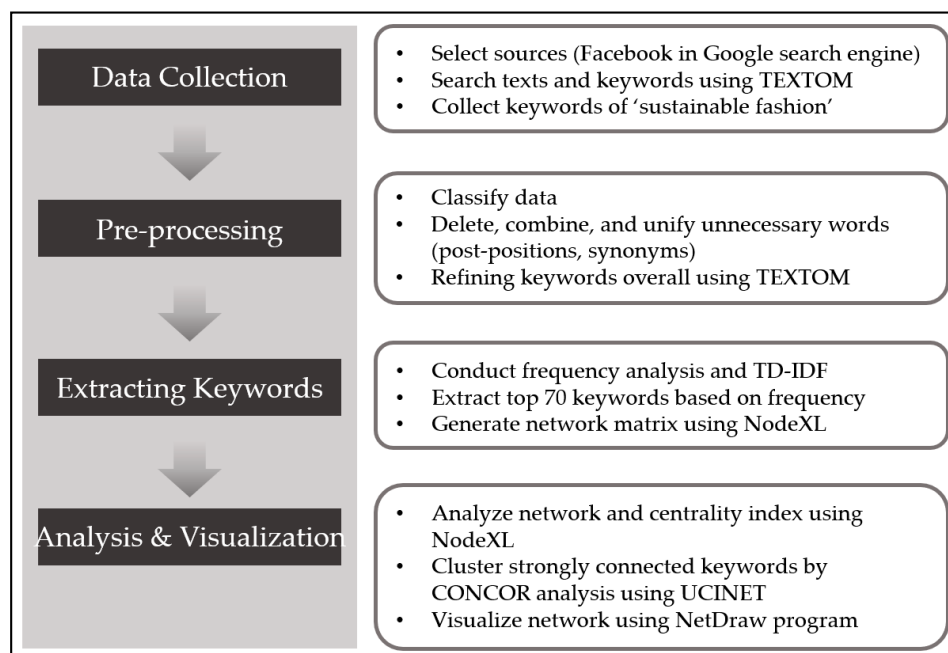
Frequency analysis and TF-IDF models were conducted, and a matrix was generated by analyzing keywords employing NodeXL for network analysis. NodeXL were used to identify the structure of the linkage between words and to analyze the centrality and TF-IDF, thus quantifying the degree of the relationships [77,78]. For semantic network analysis using text mining, to simplify the network, researchers suggested to extract up to 30 to 200 top keywords that were often mentioned to simplify the data based on the frequency of appearance [76,79]. Therefore, for the keyword extraction stage, this study mined the top 70 nouns, adjective, and verb keywords with a frequency of 60 or more, which were selected using frequency analysis. Then, a unified mode matrix ( $70 \times 70$ ) was derived based on the frequency at which two words appeared simultaneously in one sentence for the next step. A matrix is constructed with rows and columns of entities in semantic network analysis [73]. As nodes represent words, certain design features can quantitatively be characterized by the degree, which indicates the number of relevant nodes (adjacent nodes, connected nodes) and their relationships (links, ties, evaluations) [74,80].

After constructing the matrix, the keyword density was calculated, and the centrality analysis and the convergence of iterated correlations (CONCOR) analysis were performed. The centrality analysis measures the number and location of a single word that is connected to other words and quantitatively characterizes the dominant words in a network [61]. A CONCOR analysis was conducted for the structural analysis of the relationships between the hidden key subgroups related to sustainable fashion in the complicated network clusters [62]. The CONCOR analysis technique is an assessment that uses a matrix representing the frequency of simultaneous emergence between keywords based on Pearson's correlation to identify the relationship between networks. The CONCOR analysis is intended to analyze the Pearson correlation of the co-occurrence matrix between words, identify blocks of nodes (keywords), and investigate the relationships between blocks. Words with similarities form a cluster and grouped text words gain insight into the occurrence of other words and represent meaningful social networks between words [72,81]. It is not just a frequency analysis of how much a particular concept has emerged, but also a structural analysis that identifies interrelationships with other concepts and specific patterns between words can identify joint meanings among concepts [82]. It is a useful way to identify the meaning between the nodes through the word clusters to which individual words belong, and to identify the main meaning that texts convey [82]. The CONCOR analysis will help establish marketing strategies for sustainable fashion products. With the advantages of the CONCOR analysis, we use Ucinet 6.0 to perform CONCOR so that meaningful nodes form one cluster. Based on the results of the CONCOR analysis, NetDraw was utilized to visualize the network. The NetDraw program, a graph visualization software, was used to clearly express the relationships between the words and to visualize the network between the keywords (i.e., sustainable fashion) [66]. Network visualization aims to provide a meaningful visual representation of a network dataset [73]. The specific research procedure is shown in Figure 1.

## 4. Results

### 4.1. Frequency and TF-IDF Analysis of Keywords Related to Sustainable Fashion

In this research, we analyzed words on SNS webpages with a title containing the words "sustainable fashion" mentioned in Facebook over five years from 2016 to 2020. A total of 1564 data (289 in 2016, 296 in 2017, 321 in 2018, 304 in 2019, and 354 in 2020) and 23 Facebook web pages were collected related to sustainable fashion. In order to find out what people mentioned about sustainable fashion, the most frequently presented Facebook accounts were targeted.



**Figure 1.** The data collection and analysis process.

The keywords are listed in Table 1. For research question 1, the researcher analyzed the keywords “sustainable fashion” and related words. The results showed that the most frequent keywords (besides sustainable and fashion) were “eco-friendly” (778 times), and “clothing” (494 times), followed by “sustainability” (430 times), “ethical” (331 times), “conference” (259 times), “fast fashion” (248 times), “business” (233 times), “recycle” (177 times), “McCartney” (176 times), “designer” (175 times), “environmental” (174 times), and “demand” (170 times). Term occurrence also called term frequency or TF is the count of a term in a document which indicates the number of times that term occurs in a document. Unlike TF, Term Frequency Inverse Document Frequency (TF-IDF) is utilized to detect terms that are unique to a specific document in a larger sample. This helps to identify rare terms that occur in an individual SNS in a score. Calculating the TF-IDF value results in the term “eco-friendly (690.90)” having the highest TF-IDF value. Since TF-IDF indicates the scarcity a word has in a sentence, a word with a higher TF-IDF value can be an important word [23,66]. This is because the word “eco-friendly” is not just a common term that people often use in the social media, but it is considered to be the core of the topic word in terms of “sustainable fashion” at the moment. Next are “ethical (668.99)”, “business (661.93)”, “fast fashion (562.86)”, “recycle (519.86)”, “designer (485.24)”, “demand (432.31)”, “green (376.03)”, “collection (364.17)”, “consumer (346.16)”. This confirms the previous findings based on term occurrence (frequency). Most words with higher frequencies also ranked higher in TF-IDF values, as the word purification process excluded words that were not needed in the analysis [66].

#### 4.2. Sematic Network between Keyword

##### 4.2.1. Centrality Analysis of Keywords

To identify the semantic network structure of sustainable fashion, the frequency of the simultaneous appearance between the keywords was examined, targeting 70 extracted keywords to derive a one-way mode (1-mode) symmetric matrix. Based on the derived matrix, the network centrality was calculated to analyze the semantic network between the keywords related to sustainable fashion as shown Table 2. Indicators used in semantic network analysis to identify network structures include density, degree centrality, betweenness centrality, closeness centrality, eigenvector centrality, and page rank [83,84]. “Density” is an indicator of how many relationships are between the nodes in the entire

semantic network and measures of how many total words in the network relate to each other, with the density increasing when words are highly linked and “centrality” is an indicator of how much each node constituting the semantic network is in the center of the entire network [80,85,86]. Centrality includes “degree centrality”, “closeness centrality”, and “between centrality” [87].

**Table 1.** Frequency and Term Frequency Inverse Document Frequency (TF-IDF) of keywords for sustainable fashion.

Rank	Keyword	Frequency	TF-IDF	Rank	Keyword	Frequency	TF-IDF
1	fashion	2277	986.43	36	accessories	109	227.13
2	sustainable	1627	882.02	37	supply chain	108	225.91
3	ecofriendly	778	690.90	38	vegan	107	225.85
4	clothing	494	697.84	39	fair	107	216.31
5	sustainability	430	738.88	40	movement	107	222.91
6	ethical	331	668.99	41	animal	106	219.91
7	conference	259	328.21	42	Zara	106	222.05
8	fast fashion	248	562.86	43	leather	106	198.28
9	business	233	661.93	44	social responsible	105	204.27
10	recycle	177	519.86	45	trade	101	198.28
11	McCartney	176	192.69	46	carbon	99	206.21
12	designer	175	485.24	47	style	99	207.26
13	environmental	174	328.21	48	circular	98	173.47
14	demand	170	432.31	49	climate	88	214.09
15	green	161	376.03	50	platform	88	205.94
16	collection	158	364.17	51	garment	87	195.95
17	H&M	153	325.19	52	impact	87	189.88
18	materials	151	333.56	53	community	86	156.11
19	consumer	150	346.16	54	industry	86	152.00
20	waste	145	311.79	55	conscious	86	198.28
21	earth	144	283.11	56	reformation	85	196.25
22	launch	141	280.32	57	media	84	191.31
23	create	137	265.36	58	plastic	84	195.95
24	eco-textile	137	262.14	59	reduce	84	192.69
25	retailer	134	250.38	60	advocate	83	191.31
26	trend	133	187.23	61	lifestyle	83	189.88
27	organic	132	232.23	62	pollution	81	187.23
28	global	132	491.30	63	upcycle	80	165.24
29	cotton	131	152.31	64	denim	79	165.24
30	luxury	131	250.75	65	Burberry	70	156.11
31	production	131	249.64	66	shoes	69	150.67
32	China	130	232.07	67	startups	67	151.96
33	UK	130	199.95	68	swap	65	152.00
34	textile	110	238.32	69	transparency	65	150.22
35	New York	110	187.23	70	good	60	150.13

First, the “degree centrality” index was analyzed to identify keywords that are centered on the network among the extracted keywords in the network [80]. Degree centrality is an indicator of how many nodes connect to other nodes, and a high degree of centrality means that there are many connectivity relationships between nodes (keywords). Second, the “betweenness centrality” was calculated to identify the degree to which a node is located between other points in the network. Keywords with high betweenness centrality are important in that even if they simply appear in the semantic network and the degree is low, it will be easier to communicate smoothly when they are excluded [82,88]. Third, closeness centrality, which indicates the distance between indirectly linked nodes in addition to directly linked nodes, is a measure of centrality on the basis of the distance between nodes [89]. These three indicators are the most frequently used in network analysis and contribute to the development of various types of centrality concepts and indicators [85,87]. Fourth, we analyzed the “eigenvector centrality” which is an extension of the degree centrality and measures the influence of nodes in a network. This value is assessed based



on the assumption that links to nodes with high values (nodes with high degree centrality) have a greater influence than links with nodes of similar or lower values [74]. A high eigenvector centrality score indicates that a node is linked to many nodes with a high value. Lastly, we analyzed the page rank which is a centrality measure of one node's influence based on the influence of its connected nodes [83].

The results of extracting sustainable fashion-related keywords indicated that the semantic network density (Density) is 0.677. In a one-way mode network, a density with a value between 0 and 1, 0 represents a network with no connection between words, and a density of 1 represents a network in which all words are connected. Therefore, the density of sustainable fashion-associated semantic networks is remarkably high, indicating that the number of people expressing words associated with sustainable fashion in the social media is consistently high.

We looked at the degree centrality in the top 70 keywords. In general, "centrality" is a measure of how much each node is in the center of the semantic network [80]. This indicator is the most frequently used in network analysis [85,87]. Degree centrality, which shows how many links a node has with other nodes, is an ideal indicator [80,90]. The degree centrality analysis revealed that "fashion" had the highest degree centrality, followed by "sustainable", "clothing", "sustainability", "eco-friendly", "earth", "ethical", "industry", "create", "fast fashion", "demand", "McCartney", "H&M (fashion brand names)", "environmental", "green", "UK", and "textile". To sum up, words such as "clothing", "eco-friendly", "earth", "ethical", "industry", "create", "fast fashion", "demand", "McCartney", "H&M (fashion brand names)", "environmental", "green", "UK", and "textile" are considered important subjects in "sustainable fashion"-related texts in SNS.

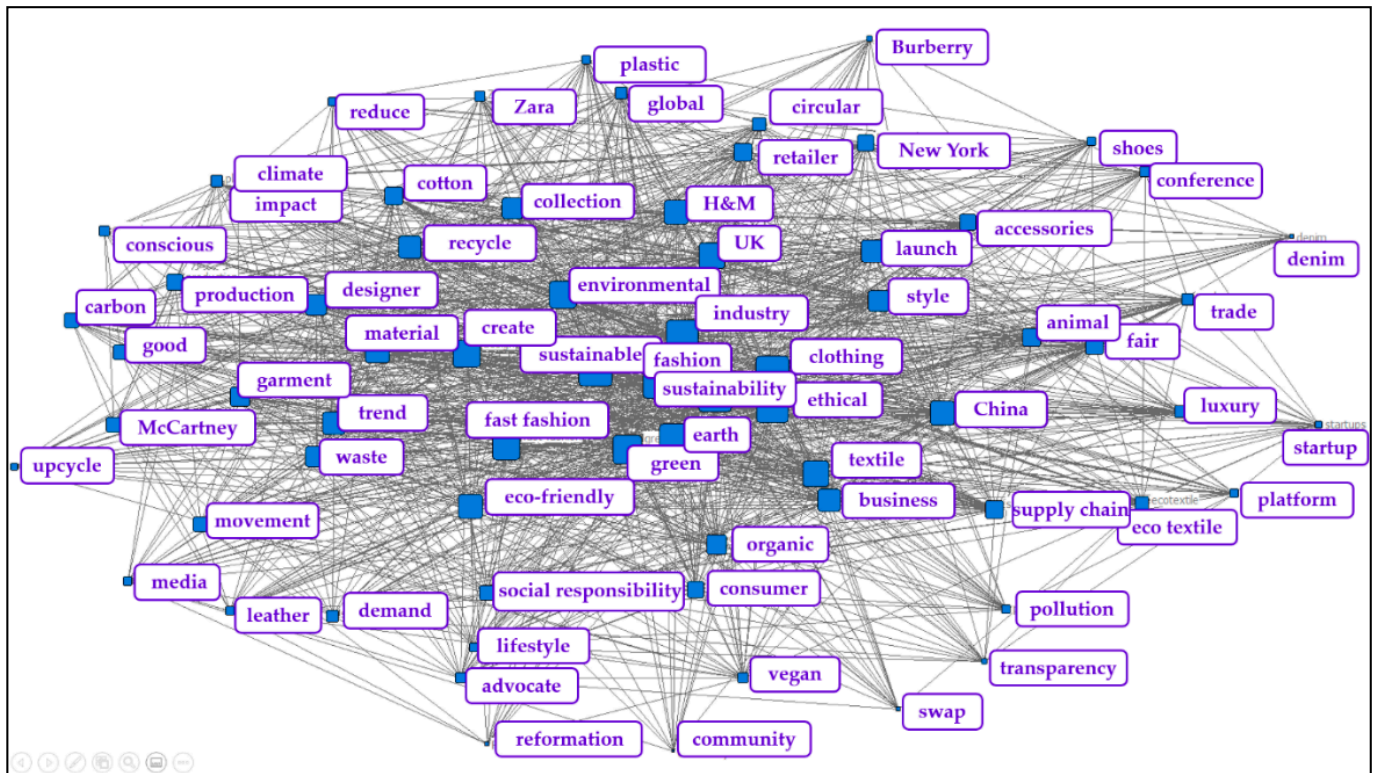
As a result of analyzing the betweenness centrality, it was found that "recycle" played the major role in mutually mediating and intervening keywords among other keywords, followed by "create", "textile", "business", "green", "earth", "global", and "fast fashion". As a result of analyzing the closeness centrality, it was found that the closeness to other nodes was highest in "recycle", followed by "earth", "create", "textile", and "global". A result of the eigenvector centrality assessment revealed that "recycle" had the highest value, followed by "business", "create", "textile", "earth", "green", and "designer". As a result of analyzing page ranks, it was found that influences on other nodes was highest in "recycle", followed by "business", "create", "earth", "textile", and "green". In conclusion, words, such as recycle, create, textile, earth, business and green, in general, appeared most frequently in the degree centrality, betweenness centrality, closeness centrality, eigenvector centrality and page ranks and are considered important subjects in terms of sustainable fashion.

We visualized the entire semantic network in the "sustainable fashion"-related SNS texts using the NetDraw program. As shown in Figure 2, the thicker the blue square is, the more often it is mentioned and posted with sustainable fashion, and a high centrality indicates that the keywords are very related to sustainable fashion concepts.

Table 2. Centrality analysis results.

Frq. Rank	Keyword	C <sub>d</sub> <sup>a</sup>	C <sub>b</sub> <sup>b</sup>	C <sub>c</sub> <sup>c</sup>	C <sub>e</sub> <sup>d</sup>	Page Rank	Frq. Rank	Keyword	C <sub>d</sub> <sup>a</sup>	C <sub>b</sub> <sup>b</sup>	C <sub>c</sub> <sup>c</sup>	C <sub>e</sub> <sup>d</sup>	Page Rank
1	fashion	0.055	19.859	0.014	0.019	1.284	30	luxury	0.009	8.918	0.012	0.015	1.041
2	sustainable	0.054	21.461	0.015	0.019	1.302	31	production	0.009	5.443	0.010	0.011	0.791
3	clothing	0.041	18.752	0.014	0.018	1.266	35	New York	0.009	5.119	0.011	0.013	0.920
4	sustainability	0.036	21.461	0.015	0.019	1.302	36	accessories	0.009	5.770	0.012	0.015	0.986
21	eco-friendly	0.036	6.083	0.011	0.014	0.970	37	supply chain	0.009	4.195	0.010	0.009	0.709
5	earth	0.035	14.201	0.014	0.018	1.211	38	vegan	0.009	0.396	0.009	0.006	0.499
54	ethical	0.034	4.444	0.011	0.012	0.836	39	fair	0.009	8.870	0.012	0.015	1.041
23	industry	0.033	6.777	0.011	0.014	0.956	40	movement	0.009	11.078	0.013	0.017	1.141
7	create	0.032	16.951	0.014	0.018	1.247	42	Zara	0.009	7.166	0.011	0.013	0.940
14	fast fashion	0.028	13.272	0.013	0.017	1.177	43	leather	0.009	3.895	0.011	0.012	0.852
11	demand	0.027	11.548	0.013	0.017	1.174	44	social responsibility	0.009	6.937	0.011	0.014	0.971
13	McCartney	0.026	10.124	0.013	0.016	1.092	45	trade	0.009	10.536	0.012	0.015	1.060
15	environmental	0.025	10.529	0.012	0.015	1.061	46	carbon	0.009	4.748	0.011	0.013	0.902
17	green	0.023	14.689	0.013	0.017	1.147	48	circular	0.008	3.914	0.011	0.012	0.851
33	H&M	0.022	12.400	0.013	0.016	1.096	49	climate	0.008	1.486	0.009	0.007	0.569
34	UK	0.02	6.010	0.011	0.014	0.970	51	garment	0.008	10.212	0.013	0.017	1.124
6	textile	0.02	16.144	0.014	0.018	1.214	52	impact	0.008	8.766	0.012	0.015	1.025
8	conference	0.019	11.376	0.012	0.015	1.078	55	conscious	0.008	11.001	0.013	0.016	1.109
9	business	0.018	14.153	0.014	0.018	1.250	57	media	0.008	4.993	0.011	0.013	0.919
10	recycle	0.018	17.222	0.014	0.018	1.264	70	good	0.008	4.135	0.010	0.011	0.805
12	designer	0.018	11.010	0.013	0.017	1.125	50	platform	0.004	9.563	0.011	0.014	1.082
16	collection	0.018	9.484	0.012	0.016	1.074	53	community	0.004	4.209	0.011	0.013	0.886
20	waste	0.017	9.391	0.012	0.015	1.058	56	reformation	0.004	10.223	0.012	0.016	1.075
26	trend	0.016	6.045	0.011	0.014	0.971	58	plastic	0.004	4.779	0.011	0.013	0.903
18	materials	0.015	5.787	0.011	0.014	0.970	59	reduce	0.004	6.039	0.011	0.013	0.890
32	China	0.015	6.137	0.011	0.014	0.970	60	advocate	0.004	3.585	0.010	0.011	0.771
41	animal	0.015	9.084	0.012	0.015	1.009	61	lifestyle	0.004	1.691	0.009	0.008	0.619
47	style	0.015	3.254	0.011	0.012	0.834	62	pollution	0.003	8.322	0.012	0.015	1.023
19	consumer	0.013	11.113	0.013	0.016	1.125	63	upcycle	0.003	5.374	0.011	0.014	0.953
22	launch	0.013	7.836	0.012	0.015	1.022	64	denim	0.003	3.454	0.010	0.011	0.786
24	eco-textile	0.013	6.352	0.012	0.015	1.003	65	Burberry	0.003	6.022	0.012	0.015	0.986
25	retailer	0.012	5.883	0.011	0.013	0.922	66	shoes	0.003	3.227	0.010	0.011	0.785
27	organic	0.012	6.562	0.011	0.014	0.956	67	startups	0.001	4.476	0.011	0.014	0.918
28	global	0.011	14.586	0.014	0.018	1.212	68	swaps	0.001	4.404	0.011	0.012	0.854
29	cotton	0.011	11.548	0.013	0.017	1.174	69	transparency	0.001	4.072	0.011	0.013	0.868

<sup>a</sup>. degree centrality, <sup>b</sup>. betweenness centrality, <sup>c</sup>. closeness centrality, <sup>d</sup>. Eigenvector centrality.



**Figure 2.** Visualization of the semantic network map for “sustainable fashion”.

#### 4.2.2. Results of CONCOR Analysis

The CONCOR analysis was conducted to visually derive and cluster the network connectivity and patterns of sustainable fashion-related texts in SNS. The CONCOR analysis is a method of clustering words based on the relationship of structural equivalence by analyzing Pearson correlation in a co-occurrence matrix [82]. The CONCOR analysis is a clustering method that considers the connectivity of nodes (words) in a similar structure across the entire network structure and organizes them into a single block or cluster (Group). After setting up a split count of 3 and a convergence criterion of 0.05, 70 keywords converged into eight sub-clusters in the third dimension and formed four groups in the second dimension. As a result, the keywords were classified into eight subclusters and four groups and keywords by each subcluster, as listed in Table 3. Next, hierarchical relationships between groups were derived from the CONCOR analysis and visualized as a network using NetDraw (see Figure 3). As a result, eight sub-clusters of 70 keyword networks were derived and four groups were categorized into the second dimension of CONCOR and were located adjacent to each other. As shown Table 3, the density of each of the eight sub-clusters is high, meaning that the networks that make up each cluster are highly cohesive (i.e., there are many connections between words).

**Table 3.** Results of the convergence of iterated correlations (CONCOR) analysis.

Sub-Cluster	Keywords <sup>a</sup>	Number of Nodes	Density of Sub-Clusters	Group Characteristics
1	fashion, clothing, demand, consumer, eco textile, retailer, production, textile, supply chain, garment, industry	11	0.684	Group 1. Supply chain of sustainable fashion
2	designer, material, create, collection, trend, China, cotton, luxury, accessories, fair, trade, carbon, media, pollution	14	0.651	
3	recycle, waste, circular, upcycle	4	0.639	Group 2. Circular fashion
4	organic, reduce, reformation, swap sustainable, sustainability, eco-friendly, ethical,	4	0.536	
5	fast fashion, business, earth, launch, green, social responsibility, good, lifestyle, ZARA, H&M, denim, shoes, startups, transparency	18	0.683	Group 3. Fashion business concepts for sustainability
6	McCartney, UK, animal, style, New York, vegan, leather, Burberry conference,	8	0.735	
7	environmental, climate, conscious, impact, community, movement	7	0.598	Group 4. Academic importance of sustainable fashion
8	global, plastic, advocate, platform	4	0.611	

<sup>a</sup>. List of keywords in order of frequency within each cluster.

Group 1, named “Supply chain of sustainable fashion”, with two sub-clusters (i.e., cluster 1 and cluster 2 in Figure 3) were formed into a group with keywords, such as “fashion”, “clothing”, “demand”, “consumer”, “eco-textile”, “retailer”, “production”, “textile”, “supply chain”, “garment”, and “industry”. These words were extracted from the supply chain components from production to retailing and consumption of sustainable fashion products. Group 2, named “Circular fashion” included keywords, such as “recycle”, “waste”, “circular”, “upcycle”, “organic”, “reduce”, “reformation”, and “swap”. Group 3, named “Fashion business concepts for sustainability” are associated with the fashion business based on sustainable concerns for the environment, people, and animals. Group 3 consisted of keywords, such as “sustainable”, “sustainability”, “eco-friendly”, “ethical”, “fast fashion”, “business”, “earth”, “launch”, “green”, and “social responsibility”. Group 4, named “Academic importance of sustainable fashion”, included words, such as “conference”, “environmental”, “climate”, “conscious”, “impact”, “community”, “movement”, “global”, “plastic”, “advocate”, and “platform”.

The most frequently mentioned keywords in Group 1 (“Supply chain of sustainable fashion”) were “demand”, and “consumer”. In Group 2 (“Circular fashion”), “recycle”, and “waste” were the top words. The top words were “eco-friendly” and “ethical” in Group 3 (“Fashion business concepts for sustainability”) and “conference” and “development” in Group 4 (“Academic importance of sustainable fashion”).

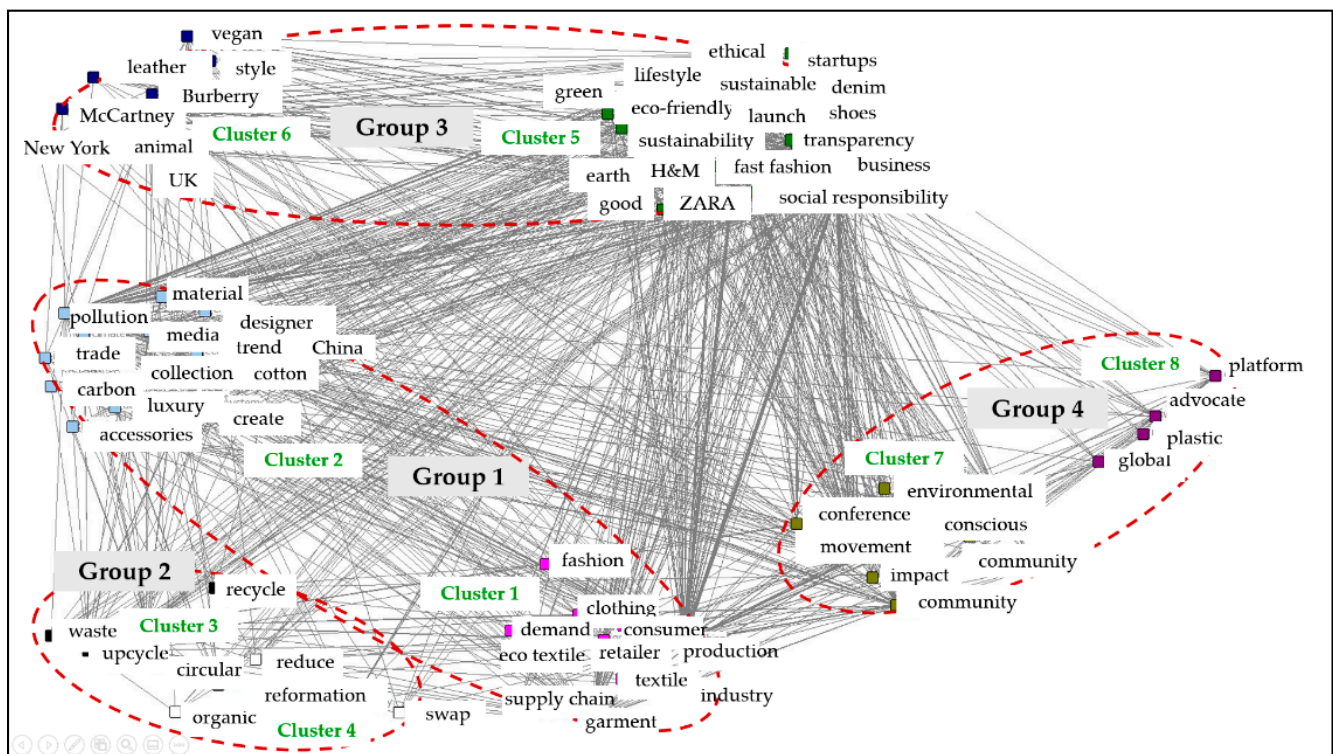


Figure 3. Visualization of convergence of iterated correlations (CONCOR) analysis.

## 5. Conclusions

In the apparel and textile industry, sustainability is not an option but a necessity. It is time for this industry to reconsider its efforts to promote sustainability due to unsustainable outcomes in the process of producing and consuming clothing, such as environmental pollutants, energy use, and increased waste. With the expanding availability of text mining, fashion practitioners are using social media data as an opportunity to gain insights and guide strategic business decisions [24,91]. This study aimed to collect sustainable fashion-related keywords based on posts on social media and analyze semantic networks to examine consumer opinions and issues related to sustainable fashion. To this end, we collected sustainable fashion-related words based on SNS big data and analyzed the frequency of related words, connection centrality and the network structure using semantic network analysis.

To identify consumer opinions about sustainable fashion, a frequency analysis was conducted using text mining to identify and classify people's opinions on SNS. We also used grouping between keywords using a CONCOR analysis. The results and implications of the study are as follows.

High frequency keywords were "fashion", "sustainable", "eco-friendly", "clothing", "sustainability", "ethical", "conference", "fast fashion", "business", and "recycle". These keywords related to sustainable fashion indicate that these topics were important for people on social media sites. Among sustainable fashion-related words, the most basic and important words for sustainable fashion were "eco-friendly" and "ethical". Based on the frequency of keywords and TF-IDF values, in terms of online articles and social media, such as Facebook, "eco-friendly" and "ethical" are mentioned more frequently than other topics. Sustainability has been a deep concern worldwide and the concepts of eco-friendly and ethical can partially explain people's focus on sustainable fashion [16,48,49]. Sustainability has been achieved and developed in various ways, but it is still centered around being eco-friendly and ethical and is condensed in these two concepts. Furthermore, the degree of centrality of "recycle" was the highest compared to other keywords, indicating that this concept has the greatest influence on the sustainable fashion network. Consequently, fash-



ion companies should continue to promote their current efforts and apply these concepts since they are familiar to consumers. They should also focus on their eco-friendly products and circular fashion communication strategies to encourage consumers to make purchase decisions related to sustainable fashions.

The CONCOR analysis results identified four sustainable fashion categories: supply chain of sustainable fashion, circular fashion, fashion business concepts for sustainability, and academic importance of sustainable fashion. Sustainability is applied throughout the supply chain from design planning to production, distribution, and consumption of fashion products. Previous research [17,27] has shown that companies along the supply chain in the apparel and textiles industry are also paying attention to environmental threats posed by the fashion industry. The recent overconsumption of fashion has also highlighted the importance of zero-waste and a circular economy in fashion [92].

The results of this study support this fashion phenomenon as well, and reinforce that sustainable fashion is important in both industry and academia. Based on the results of this study, sustainable fashion companies must commit to changing consumers' understanding of sustainable fashion. In fashion, sustainability has had a more significant relationship with "ethical", "eco-friendly", and "recycle". Thus, sustainable fashion companies should emphasize "ethical", "eco-friendly", and "recycle" in their marketing efforts.

Industries and consumers should continue to embrace sustainability in the whole supply chain process before the products are delivered to consumers. Both efforts should be established to ensure sustainable fashion product production, distribution, and consumption. Actual changes in consumer consciousness and consumption behavior are important through the practice of sustainability of fashion. Proper consumption is also needed by promoting recycling and reuse, and reducing excessive consumption. For this, a positive change in the perception of fashion products made from recycled fabric is required. In addition, fashion companies should focus on designing and marketing products to prevent textile apparel waste.

This study is meaningful in that it analyzes consumers' perceptions and thoughts about sustainable fashion by utilizing big data from social media texts at a time when the growth of the sustainable fashion market is stagnant. Specifically, understanding consumers' opinions and perceptions of sustainable fashion helps set the groundwork for establishing industry marketing and policies. However, despite the significance of the research findings, this study is limited in representing the perceptions of consumers who are not active in online word-of-mouth activities. Thus, caution should be taken in generalizing the research results as the methods used in this study potentially limit the data quality and redundancy. More sophisticated investigations can be designed in future research using big data, and cross-validation of the research results are needed using quantitative empirical studies such as surveys. In this study, we used the CONCOR analysis to generate subgroups of nodes. Lyu and Choi [71] recently proposed and applied the Latent Dirichlet Allocation (LDA) method as a method of topic generation. LDA is a network analysis technique using topic models and researchers used LDA for extracting keywords and pinpointing important factors for selling products and suggesting web marketing strategies for product sales volume. With the tremendous advancement of technology, up-to-date network analysis techniques using big data are rapidly developing [93], and the authors hope to propose research using these new analysis techniques in the future.

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