

VIRTUAL VERSUS SUSTAINABLE FASHION: A SYSTEMATIC LITERATURE REVIEW

Jolanta BIENKOWSKA

University of Lodz, Faculty of Management; jolanta.bienkowska@uni.lodz.pl, ORCID: 0000-0002-4566-4906

Purpose: The aim of the study was to determine the extent of convergence between the concepts of virtual and sustainable fashion.

Virtual reality is gaining popularity due to its immersive nature, which enables “involvement of the senses”. Owing to dynamic technological development, it is expanding into numerous fields of application and provides the potential to offer innovative products. Among those is virtual fashion, i.e., clothes and accessories that have no physical equivalent, being available to “wear” only in virtual reality. Virtual clothing is part of the premium and exclusive product segment, to which, in particular, the value added by the consumer is attributed. These products are therefore communicated as an environmentally friendly alternative to physical clothing, as they do not require the consumption of materials, thus generating no waste, using less energy and water, etc.

Design/methodology/approach: The research consisted of two phases. The main phase was conducted with a method of systematic literature review according to PRISMA standards, by means of data extracted from the databases: Scopus and Ebsco (n = 13). In a supplementary phase, there was used a method of co-occurrence keywords analysis via VOSviewer to compare the description of strictly virtual fashion (n = 218) and sustainable fashion (n = 402). Documents were searched in the Scopus database.

The conclusion was reached using the induction method.

Findings: The findings from the researched documents indicate that virtual fashion is predominantly presented accordingly to the new technological possibilities it offers. Indeed, its ecological qualities and its potential for fulfilling pro-environmental goals in the fashion industry are briefly stated in broad terms, without reference to the specific measures or data, mentioned, by comparison, in papers devoted solely to sustainable fashion.

Originality/value: The findings from the researched documents indicate that virtual fashion is predominantly presented accordingly to the new technological possibilities it offers. Indeed, its ecological qualities and its potential for fulfilling pro-environmental goals in the fashion industry are briefly stated in broad terms, without reference to the specific measures or data, mentioned, by comparison, in papers devoted solely to sustainable fashion.

Keywords: virtual reality, sustainable fashion, sustainability, fashion industry.

Category of the paper: literature review.

1. Introduction

Despite virtual reality (VR) has been created since the early 1960s (Sutherland, 1965; Lum et al., 2020), it has become extremely popular in recent years. The term “virtual” refers to something that exists or functions in a digital environment.

The widespread interest in virtual reality is being driven by several factors. First and foremost is the development of hardware and software technologies (The Business of Fashion, McKinsey & Company, 2022), including more powerful processors, better displays, advanced sensors and algorithms, which have enabled the creation of more realistic and immersive experiences. VR's popularity has also been boosted by the increased availability of advanced technology at affordable prices. Consequently, virtual reality has been implemented in many fields such as gaming, education, medicine, architecture, tourism, trainings, and many others (Mazuryk, Gervautz, 1999). Another factor was the rapid growth of the virtual reality gaming market (Sherstyuk, Vincent, Treskunov, 2009). Many players were drawn to the opportunity to dive into another reality - an immersive world (Galimberti et al., 2003). Through game plots, virtual reality has invited users to experience extraordinary adventures, travel to faraway places, meet virtual characters and explore fantastic worlds (Fu, Liang, 2022).

Due to the growing trend of virtual life, there is a constantly expanding pool of virtual items or objects being created to be experienced through computer technology such as applications, software or virtual reality platforms. The other examples are virtual images, virtual simulations, virtual environments, virtual characters, virtual objects or virtual events. Virtual realities and technologies, such as Augmented Reality (AR), Virtual Reality (VR) or Extended Reality (XR), allow users to interact with virtual objects and environments, thereby creating the illusion of being present in a digital space (The Business of Fashion, McKinsey & Company, 2022).

Virtual reality is gradually becoming more prevalent as technology advances, consumer interest grows, and it is being applied in a wide range of fields. According to experts, the future of virtual reality looks promising as the technology continues to develop and evolve, providing more sophisticated and immersive experiences (Future Of Virtual Reality..., 2023). Based on the report “Global Virtual Goods Market: Growth, Future Prospects, and Competitive Analysis, 2016-2028” by Credence Research, Inc., the global virtual goods market had generated revenues of approximately US\$67.5 billion in 2021 and is expected to grow at a CAGR of more than 20.2% during the forecast period from 2022 to 2028 to reach approximately US\$203.6 billion in 2028 (Credence Research, Inc., 2022).

Currently, the main target groups of the virtual market are the aforementioned players and digital content creators. The former group is interested in purchasing virtual items, participating in virtual games, developing characters, or interacting in a virtual environment (Jordan-Kulczyk, Zajac, 2022). Digital content creators such as graphic designers, virtual world creators, animators or musicians can offer their work in virtual worlds - in unreal as well as

simulated real places, for instance accompanying interactive experiences such as tours, as well as training simulations or product presentations. Furthermore, there are also designed virtual objects: furniture, tools, vehicles, etc., that can be used and manipulated in virtual reality (Earnshaw, Vince, 2001).

Virtual reality has also become an effective marketing tool. VR enables companies to present their products or services in an innovative way. In place of traditional presentations, virtual demonstrations are being created to engage customers' senses and shape memorable experiences (Farra, 2021). The examples of virtual marketing campaigns are contests and games played in virtual reality. A number of virtual shops are also being created, where customers can browse products, select options and make purchases via a VR interface. This provides customers with a “try before you buy” opportunity and involves them more in the purchasing process.

Accordingly, the fashion industry has also begun to use the possibilities of virtual reality. Virtual fashion is turning into strategic part of global physical fashion brands. Staying ahead of technology enables the strengthening of competitive advantage (The Business of Fashion, McKinsey & Company, 2022). Modern solutions are being implemented mainly by companies in the premium and luxury segment of the market. They accentuate their offer's exclusivity and the uniqueness of the experience provided to the customer (Black, 2022). Virtual fashion is being communicated as a new business model contributing to the implementation of sustainable development policies, especially environmental protection (Ellen MacArthur Foundation, 2022). There is a belief that the concept of virtual fashion has the potential to reduce the amount of waste generated by the traditional fashion industry. Rather than producing real clothes, virtual clothes are being created and presented in a digital environment, thus eliminating the production of physical items, and generating material waste (Mesjar et al., 2023). Moreover, it is emphasised that the production of virtual clothes does not require the use of natural resources or the emission of harmful substances (Durocher, 2022). In this regard, virtual fashion is credited with having the potential to significantly reduce negative environmental impacts, such as water consumption, greenhouse gas emissions or water and air pollution (Wagner, Kabalska, 2023). However, it should be borne in mind that virtual fashion does not directly deal with the environmental and ethical concerns related to the physical production of clothing essential to daily human existence (Pucker, 2022). This leads to the question: to what extent does virtual fashion fit in with sustainable fashion goals?

The research issue approached in this study centres on assessing the potential of virtual fashion as an emerging opportunity to support the sustainability of the fashion industry through a systematic literature review.

2. Background

2.1. Sustainable fashion

Underpinning the search of an answer to the abovementioned issue is a reference to the essence and objectives of sustainable fashion. A synthetic illustration of the problems, predominantly environmental ones, posed by the fashion industry since the beginning of the industrial age is taken as a jumping-off point.

Since the fashion industry established attractive markets in the mid-nineteenth century (Berry, 2018), it has simultaneously become one of the world's greatest environmental threats. This type of market is highly specific, as it has always existed as a supply market. Manufacturers dictate what to wear and how much the customer has to pay. Leading apparel and accessory brands owe their rapid growth in recent decades to the fast, even ultra-fast, changes in fashion trends and the popularisation of the fast fashion model (Aspers, 2016). It, thereby, contributed to ecological degradation on a global scale, as evidenced by the statistics regarding (Ellen MacArthur Foundation, 2017; Greenpeace, 2022):

- volumes of production and consumption,
- CO₂ emissions throughout production, transportation and combustion of clothes,
- microplastic recycling,
- quantities of textile waste,
- the presence of dangerous substances in textile products.

Therefore, it became imperative to undertake measures towards sustainable economic development based on producing in a way neutral for climate, energy- and resource-efficient, as well as nature-friendly (Sverko Grdic, Krstinic Nizic, Rudan, 2020). The transition from a linear, to a circular economy model is designed to fulfil these objectives (Kumar et al., 2020).

Sustainable fashion, hence, refers to the practice of designing, producing and consuming clothing in an environmentally friendly, socially responsible and economically viable way (Marcella-Hood, 2023). It attempts to solve the problems of mass production by utilising eco-friendly materials, reducing waste and pollution in addition to fostering ethical working practices (Henninger, Alevizou, Oates, 2016). Other examples of sustainable fashion practices involve the reusing of recycled or organic materials, the minimisation of water and energy consumption during production, and the reduction of textile waste through upcycling and recycling, etc. (Köhler et al., 2021).

In this sense, sustainable fashion is focused on ecology, nature and naturalness, all of which are reflected across the process of production, distribution and consumption of clothing (Niinimäki et al., 2020). It opposes the fast-fashion model based on multiple, short-term annual collections. Thus, favouring slow fashion, the long-term use of clothes made from sustainable materials (Fletcher, 2010).

Sustainable fashion, i.e. production incorporating sustainability objectives, amounts to the following specific objectives listed and discussed in EU, UN, OECD legislation and expert papers (European Commission, 2022; United Nations, 2021; OECD, 2017):

- curbing overproduction and overconsumption,
- educating consumers to make conscious choices,
- reducing greenhouse gas emissions,
- reducing energy and water consumption in production processes,
- cessation the use of hazardous chemicals,
- minimising the emission of microplastics and microfibres to the environment,
- discontinue the destruction of unsold and returned textile products,
- waste management to include:
 - prevention of textile waste,
 - collecting, reusing and recycling of textile waste,
 - gradual elimination of textiles from landfill sites,
- sewage management,
- undertaking cooperation with logistics providers with a view to switching to emission-free air shipment, maritime and road logistics for both own and outsourced transport,
- using electricity from renewable energy sources,
- using as priority materials recyclable ones within a circular cycle, not causing deforestation or conversion in their origin,
- implementing ecological product design requirements for all textile and footwear items,
- providing decent workplace and salary,
- termination of greenwashing practices,
- ensuring fair and ethical commercial principles,
- stimulating competitiveness and innovation.

To disseminate sustainable production practices, there have been introduced a range of certifications and standards for sustainable fashion, such as the Global Organic Textile Standard (GOTS) (<https://global-standard.org/>) and the Fairtrade Certification Mark ([https://www.fairtrade.net/...](https://www.fairtrade.net/)), which ensure that products meet certain environmental and social criteria.

It must be mentioned that sustainable fashion becomes notably famous among consumers, who are deeply disturbed by the ecological and social impact of the purchased apparel goods (Shaik et al., 2022). Responding to this demand, numerous fashion brands are incorporating sustainable practices into their business models. Yet, this is unfortunately a more convincing motivation for brands rather than a genuine concern towards the environment (Changing Markets Foundation, 2021; Fashion Revolution, 2022). Furthermore, the fashion industry is looking for new business models that are designed to meet both eco-friendly and ethical fashion criteria as well as enabling the constant growth of the clothing market worth and the value of fashion brands (Ellen MacArthur Foundation, 2017).

2.2. Virtual fashion

This study approaches the issue of virtual fashion not digital fashion, even though these terms are often used interchangeably, yet they have slightly different applications and product references.

Digital fashion refers to the development and presentation of clothing and accessories in digital form. It involves the use of computer-generated imagery (CGI) and other digital tools to project and demonstrate virtual apparel (Baek, 2022). Digital fashion can be delivered by means of digital art, online platforms, social media and digital marketing campaigns. It blurs the boundary between physical and virtual fashion, empowering the creation of innovative designs way outside the box. On the other hand, virtual fashion, as mentioned above, focuses specifically on integrating fashion into virtual environments or virtual reality (VR) experiences. Virtual fashion is about designing virtual clothing to be worn by digital avatars or models in virtual reality setups. It allows users to visually experience and interact with garments within immersive virtual worlds. Virtual fashion can be demonstrated on virtual fashion shows, virtual reality games and other VR applications (Casciani, Chkanikova, Pal, 2022). To conclude, digital fashion encompasses the broader concept of digital design and presenting of clothing, whereas virtual fashion is primarily concerned with the integration of fashion into virtual reality experiences.

Virtual fashion offers all sorts of new opportunities for designers to demonstrate their creations in a digital environment and to experiment with innovative forms and materials free from the constraints of physical production. Indeed, it can be generated using various tools and techniques, such as 3D modelling software or augmented reality applications (Shaik, 2022).

The market is for newcomers, virtual fashion brands and designers, at the same time as for the current big players who offer limited edition collections. The Fabricant is a pioneering company in the field of virtual fashion. They develop virtual clothes that can be worn in the form of digital renders and animations. Their mission is to change the way of perception and consumption of fashion products by leveraging digital technologies (<https://www.thefabricant.com/>). Another example is brand Carlings, a Scandinavian clothing brand. Their customers are encouraged to acquire digital garments, and to feature them in their social media photos via application (Baron, 2019).

Among the well-known brands entering the virtual fashion market is Gucci, which has developed a digital virtual fashion collection available on the Gucci app. The range includes a variety of accessories: shoes, handbags and glasses, for the personalisation of the virtual image (Marr, 2022). Burberry customers can preview and purchase virtual products displayed on models in a virtual environment (Jackson, 2017). Ralph Lauren, for its part, has launched virtual fashion collections that can be experienced via a mobile app. Clients can design their own virtual outfits and then share them on social media (Debter, 2021).

Another form of virtual fashion is virtual fashion shows where designers and fashion brands can present their collections in an innovative way, having great freedom in creating scenery, visual effects and narrative. A virtual environment where models show the fashion outfits is developed using computer graphics, animations, special effects and interactive technologies. Taking as an example the Balenciaga Afterworld: The Age of Tomorrow event, which presented the autumn/winter 2021 collection in a form of a virtual experience. The show was set in a post-apocalyptic virtual world, in which the audience could explore using virtual reality goggles. The presentation combined elements of a computer game with fashion, resulting in an innovative virtual fashion show experience (Deloitte, 2021).

By hosting virtual fashion shows, brands have the potential to reach a larger audience, regardless of their geographical location. Shows can be transmitted on streaming platforms, websites, social media or special VR apps. Spectators can watch the shows from everywhere, using mobile devices, computers or virtual reality goggles (Ahn, Bae, Kim, 2023). Virtual fashion eliminates geographical borders, letting people from all over the world discover and exhibit the designs as well as to establish networks in a virtual environment. This gives an opportunity for young designers and fashion artists coming from smaller markets to find their audience and gain recognition.

Along with the widespread popularity of virtual reality, the market for virtual fashion and related digital merchandise is expanding. That has led to the emergence of new business models such as virtual garment rental platforms and virtual fashion marketplaces to serve this market. DressX is an online platform for purchasing virtual clothes from various fashion brands (<https://www.thefabricant.com>). TwinOne, on the other hand, provides technology solutions to create hyper-realistic digital twin and display realistic 3D graphics in real time. This start-up is also the developer of a software system based on the Unreal Engine enabling the creation of high-quality virtual images that users can edit and interact with in real time and at their own pace. TwinOne's joint project with down jacket manufacturer Jacob Becon - a virtual show, was noted at Milan Fashion Week in February 2021 (Wagner, Kabalska, 2023).

It is believed that virtual clothing and fashion shows offer the potential for sustainable fashion, as they eliminate the need for organising physical shows involving high attendance and generating huge energy consumption (Mesjar et al., 2023). By reducing CO₂ emissions, no fashion and raw materials consumption and waste reduction, virtual fashion is expected to contribute to a greener and more sustainable fashion production. Citing Forbes: "DressX states that digital fashion production uses 97% less carbon dioxide than physical clothing production" (Durocher, 2022). Another press release citing The Normative report informed that the carbon footprint of Helsinki Fashion Week per visitor dropped from 137 kg to 0.66 kg carbon dioxide equivalent after switching to a purely digital format in 2020 (Zhang, 2020).

The abovementioned information is a background to the study that aims to provide its context. It actually has two perspectives in this article. The first one, standardly, is focused on a factual presentation of the context of the research problem. And the second one, adopted for

this research project, is the methodological justification of the problem undertaken. The “Background” section, in particular, regarding virtual fashion was prepared substantially on so-called grey literature, i.e., non-academic sources (Garousi, Felderer, Mäntylä, 2019). These are the most popular available studies approaching the topic of virtual sustainable fashion. They have a business-oriented approach and focus primarily on forecasting the development of the virtual market. They have been sourced from publishers such as Forbes, McKinsey & Company. Even though the grey literature is nowadays recognised as a reliable source of information (due, among other things, to a clear presentation of the research methodology) (Paez, 2017), in the case of the undertaken research problem, it prompts an attempt at verification on the basis of available reviewed studies.

Therefore, the aim of this study was to determine the extent of convergence between the concepts of virtual and sustainable fashion on the basis of systematic review of available scientific studies.

3. Methods

3.1. Research questions

Main RQ: Does virtual fashion fit into the issue of sustainable fashion?

Detailed RQ:

1. What is the specification of the description of virtual sustainable fashion?
2. What are the similarities and differences between the description of virtual sustainable fashion identified in the literature review and the description of virtual fashion assessed by the co-occurrence analysis of the keywords assigned to the studies?
3. What are the similarities and differences between the description of virtual sustainable fashion identified in the literature review and the description of sustainable fashion assessed by the co-occurrence analysis of the keywords assigned to the studies?

3.2. Research design

The undertaken research project consisted of two phases:

1. The main one: a systematic literature review conducted according to PRISMA standards (Page et al., 2021b). This type of research was prompted by the necessity to review a specific thematic area in order to evaluate the state of existing knowledge (Snyder, 2029). Inference was drawn by the induction method, an approach that relies on conclusions based on observations and input data in order to deduce general rules, patterns or dependencies (Patton, 2025).

2. Supplementary phase is based on a comparative analysis. This process of comparing and analysing two or more elements is to identify differences, similarities, strengths and weaknesses in order to better understand its characteristics (Given, 2008). This part of the research was conducted through VOSviewer, a software tool for constructing and visualising bibliometric networks (Van Eck, Waltman, 2023). VOSviewer analyses the co-occurrence of terms in a database, for example keywords in scientific articles or research topics. From the imported data, a graph is created with nodes representing terms or topics, and connections between them reflecting co-occurrences and they are grouped into clusters, i.e. sets of closely related items. The co-occurrence analysis exposes the frequency of two words occurring together in the same text. Correlations between words indicate the intensity of co-occurrence.

For the purpose of this comparative study, there have been created co-occurrence networks for following search keywords: “virtual AND fashion” and “sustainable AND fashion”. Developing a graph for a selection of studies on virtual sustainable fashion was not applicable due to insufficient data resources.

The selection of the different methods for the main and supplementary research was based on a targeting criterion - the need to identify a way of describing the selected topics and being matched according to the quantity of available data.

3.3. Data collection

The scope of the search were keywords, which function makes locating documents or web pages easy for indexers and/or search engines by providing a view on text/content. Narrowing the search area to keywords results in higher relevance (Gil-Leiva, Alonso-Arroyo, 2007).

For the purposes of the main phase of the research, three interdisciplinary bibliographic databases were explored: Scopus, Web of Science and Ebsco. Searched studies for the following phrase: “virtual AND fashion AND sustainable”. The procedure of sampling according to PRISMA standards is illustrated in the provided diagram in section below “PRISMA flow diagram”.

For the purpose of the supplementary research, documents were searched in the Scopus database for the words: “virtual AND fashion” published between 2017 and 2023, i.e. within the last 5 years, adopting the relevance criterion, and “sustainable AND fashion” published between 2017 and 2023 (as above). These two searches served as the basis for a comparative analysis. The search results were also narrowed down concerning subject area and keyword. A thorough description of the data can be found in the “Identification of studies via database” section.

The obtained data was saved in the author's profile and exported in RIS and CIS format.

4. Results

4.1. Results of the literature review on virtual sustainable fashion

PRISMA flow diagram

The diagram below illustrates the two-stage process of identifying and selecting literature items for review, conducted in accordance with the PRISMA guidelines (Page et al., 2021a).

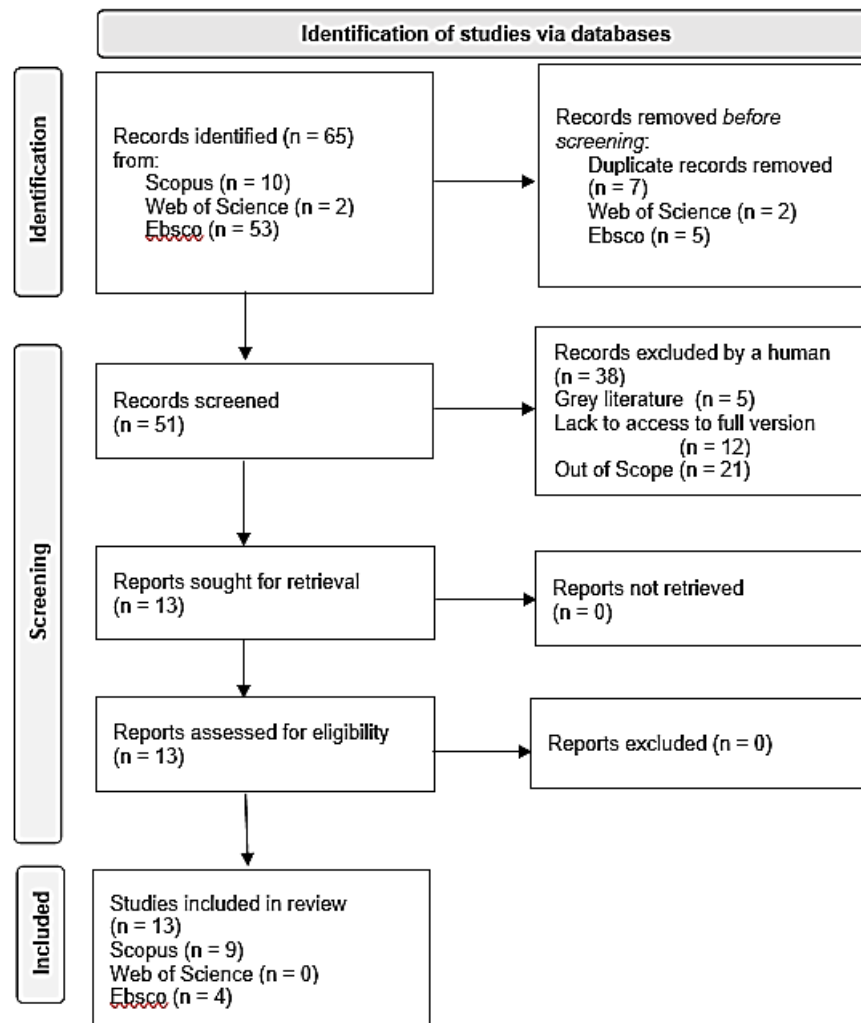


Figure 1. PRISMA 2020 flow diagram for selection of sources.

Source: own, based on: Page, McKenzie, Bossuyt et al.

Thematic overview

A content analysis of the articles selected for review has revealed the six topics presented below.

1. Virtual fashion presentation

Initially, the major focus is placed on one of the primary applications of virtual reality in the fashion industry - the presentation of both products and the space for experiencing them.

Technology, such as virtual wardrobes, perhaps implies options that may reduce overconsumption (Band, Su, 2022). It even helps users to figure out what they already have in their wardrobes as well as might recommend suitable clothing styles based on a wardrobe analysis. It is primarily consumers' socially responsible consumption behaviour and open-mindedness to innovative technology that positively influence their attitude towards virtual wardrobes, thus boosting their willingness to use virtual wardrobes. A corresponding content concerning the utility value of the virtual wardrobe is provided in an article on consumer behaviour in a virtual fashion service via a mobile app that has virtual fitting room functions. According to the authors, digital transformation within the apparel industry can improve efficiency in designing, manufacturing, distribution, sales and inventory control (Sakaguchi, Aoki, Nagamatsu, 2023).

The problem of using the virtual representation of fashion to encourage sustainable consumption was specifically addressed by narrowing the scope of the research to luxury fashion, by referring to examples of the concrete actions (Zhou, Baek, Jang, 2022):

- online product visualisation and customisation services to reduce the demand for large stocks of multiple product options;
- the use of virtual fitting rooms to reduce the carbon footprint caused by consumers travelling to stationary shops;
- offering virtual products (exclusively digital, adding virtual products to existing online gaming environments, offering digital and physical versions of products) in order to reduce consumer demand for material goods, to create or to change a digital persona linked to a concept of oneself in physical reality (e.g. a digital persona with a focus on sustainability), to eliminate problems with product disposal, to avoid unethical supply chains as raw materials are being encoded in computers, and to minimise resource consumption for transport and packaging.

2. Designing

Another core application of VR technology that has been tested and reviewed from a sustainability perspective is apparel designing tools. This subject domain included articles devoted to the problems of optimisation and innovation of the fashion design template from a 3D technology perspective and the use of relevant algorithms in 3D technology to perform multidimensional execution of fashion 3D design (Zhang, 2022) in addition to computer-aided design (CAD) and digital garment fitting using three-dimensional (3D) body scanning, virtual simulation and the application of sizing systems (Lee, 2014). A different perspective was embedded in the study about dynamic 3D fashion garments with changing styles, colours and textile patterns, especially by using a virtual 3D simulation system. Its objective was to explore the potential opportunities on online fashion platforms and the future prospects of 3D virtual clothing within the fashion and gaming industry Choi, 2022).

3. Support for cultural heritage

The AR and VR technology are proving widely applicable in supporting cultural heritage, amongst others through projections accessible in museum venues. It is evident from the conducted revision that it could also be exploited to communicate the value of cultural fashion. These are two examples: 1. the Sinification of digital fashion. The authors proposed to transfer traditional Chinese costumes into a series of digital merchandise, serving as computer game skins for selling online (Fu, Linag, 2022). 2. A case study of the Harris Tweed Authority and Harris Tweed Hebrides brands, which through immersive technology can communicate the worth of traditional (sustainable) textiles, their history and the value of handmade products, thereby promoting slow fashion (Cross, Steed, Jiang, 2021).

4. Virtual community

Despite the title of the article containing the word 'new technology' as well as the conclusion stating that the respondents noticed and realised that modern technology can lead to green consumerism, the findings of the researchers mainly show that social media supports the fostering of eco-sensitive consumer attitudes (Joe Waheed Sayyed, Erum Sherieff, Gupta, 2021).

5. Virtual identity

An intriguing research perspective was adopted in a research project that aimed to explore how virtual fashion has been used to create new forms of identity for those who have abandoned their physical bodies and to search for an answer to the question: does wearing the virtual fashion with an avatar mean abandoning one's own body and being free to follow one's own desires, unfettered by the boundaries of different "selves"? (Koma, 2023).

6. Overviewed articles

The literature reviews featured in the search results are gripping from the perspective of the research project covered in this article. One piece of literature was noticed in all three bases. It concerns the potential of applying immersive technologies to the fashion industry in order to make it sustainable (Mesjar et al., 2023). Based on content analysis of 74 articles, the authors concluded that AR and VR technologies are part of transformational changes like reducing online returns, cutting waste through various design and production processes, eliminating the need for physical objects and allowing to educate consumers. Due to the limited number of available academic studies, they also included grey literature as relevant elements in the review.

Subsequently, the opportunities and challenges presented by the implementation of digital technologies for the fashion industry 4.0 were assessed (Akram, 2022). The authors did not specify the exact number of articles reviewed, so judging from the total citation count there are about 80, which is equivalent to the article mentioned above. A section covering the use of VR technology highlighted the user experience aspect of undergoing virtual fashion. It refers to the statement in the primary source that the immersive type has a higher UX than the non-immersive type, since fashion product purchases in immersive virtual reality enable users to effectively experience telepresence, the acuity of use intention and entertainment parameters.

With respect to the entire research area, one of the authors' recommendations is the widespread use of blockchain in the fashion supply chain and the integration of IoT, AI, and edge computing.

The third and final reviewed article presents the results of a content study of Twitter posts published between October 2020 and May 2022. A total of 528,915 records were collected (Yixin, Ding-Bang, Shizhu, 2022). According to the authors' findings, there is a large number of posts as well as a wide range of topics related to digital fashion and virtual fashion. Basically, these are informative posts about brands and the sales of their products that include virtual clothing and accessories, as well as the impact of digital fashion on the industry, the modification of marketing strategies and related to this phenomenon attitudes and judgements of the users. However, there was no reference noted regarding the potential of digital and virtual fashion towards the promotion and development of a sustainable fashion industry.

None of the above-mentioned papers provided extensive data related to the potential of virtual fashion in tackling the environmental problems of the fashion industry. So far, the authors make general statements about the potential benefits.

4.2. Results of the keyword co-occurrence analysis

In view of the insufficient number of academic studies revealed through a systematic literature review on the topic of virtual sustainable fashion, a comparative study of publications dealing with the topics of virtual fashion and sustainable fashion was carried out.

Therefore a co-occurrence analysis of keywords undertaken for publications addressing the topics of virtual fashion and sustainable fashion serves to conduct a comparative analysis alongside the results obtained in the main study - the literature review - all in order to identify similarities and differences based on the keywords assigned to the studies.

The number of scientific papers selected for the study increased significantly and has reached: 218 studies for virtual fashion and 402 for sustainable fashion. Therefore, keywords are essential for conducting a comparative analysis, enabling one to explore the content of large collections. A details of identification of studies via database presents table below.

Table 1.

Identification of studies via database

"virtual AND fashion" search within keyword	218 documents published in 2017-2023
subject area limited to	Computer Science, Engineering, Business, Management and Accounting, Social Sciences, Materials Science, Arts and Humanities, Decision Sciences, Economics, Econometrics and Finance, Psychology, Environmental Science, Physics and Astronomy, Energy
Keywords excluded	Students, E-learning, Current

Table 2.*Clusters of high-frequency keywords related to virtual fashion*

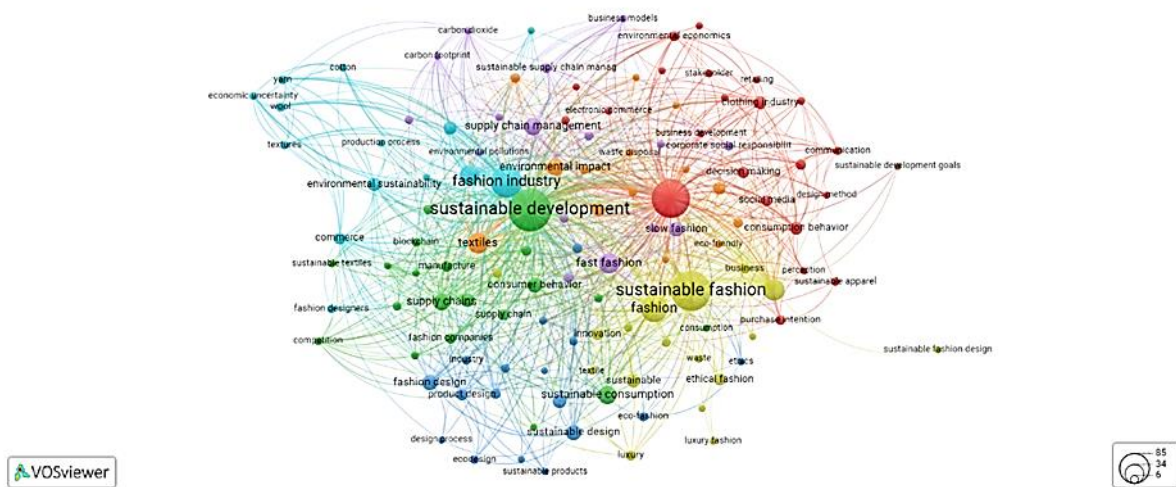
main node greatest weight total link strength in cluster	cluster	other nodes in the cluster
virtual reality	1	color, customer experience, design, e-commerce, electronic commerce, fashion retailing, human computer interaction, interactive computer graphics, online shopping, sales, social networking (online), technology, virtual fashion, virtual worlds
fashion industry	2	digital fashion, fashion, internet, marketing, personalization, product design, supply chains, sustainability, sustainable development, virtual corporation
fashion design	3	clothing design, computer aided design, computer technology, deformation, textiles, three dimensional, three dimensional computer graphics, virtual clothing, virtual fashions
user interfaces	4	virtual prototyping, visualization, animation, cloth simulation, computer graphics, computer simulation, garment manufacture
virtual try-on	5	clothes, computer vision, hosiery manufacture, human bodies, image-based, textures
augmented reality	6	artificial intelligence, computer software, fashion designers, on-line fashion, virtual fitting room

Source: own work.

The results of the analysis of the keywords co-occurrence in publications describing virtual fashion indicate that the description of virtual fashion basically refers to the application of new IT possibilities for creating new products together with their modern presentation and sale. Therefore, there is no significant difference of approach to describing virtual sustainable fashion in the context of the sustainability of the fashion industry. In fact, there is a relatively small number of articles ($n = 9$) referring to sustainability.

Sustainable fashion

The results of the analysis of the keywords co-occurrence are presented in Figure 3.

**Figure 3.** VOSviewer co-occurrence network visualization mapping of most frequent all keywords for studies of sustainable fashion.

Source: own work.

The graph 'sustainable AND fashion' distinguishes 7 clusters. As indicated in the figure above, the keywords with the highest relevance are “sustainability” (cluster 1) and ‘sustainable development’ (cluster 2). The main nodes in the following clusters are “fashion design”, “sustainable fashion”, “supply chain management”, “fashion industry” and “textiles” (see Table 3). Among the related words are 48 words directly relevant to the issue of sustainable fashion, including: “environmental protection”, “sustainable supply chains”, “sustainable textiles”, “sustainable consumption”, “sustainable design”, “sustainable production”, “sustainable products”, “upcycling”, “circular economy”, “circular fashion”, “ethical fashion”, “fashion consumption”, “sharing economy”, “sustainable business models”, “sustainable fashion design”, “water pollution”, “slow fashion”, “sustainable supply chain management”, “carbon dioxide”, “carbon footprint”, “corporate social responsibility”, “environmental pollutions”, “fast fashion”, “greenhouse gases”, “environmental sustainability”, “climate change”, “eco-friendly”, “environmental management”, “life cycle analysis”, “recycling”, “sustainable fashion consumption”, “textile recycling”, “textile waste”, “waste management”.

However, the entire set of 122 keywords selected in the study did not include “virtual”, “virtual reality”, “augmented reality”, “digital”, “digital fashion”, “immersive”, “immersive technology”.

Table 3.

Clusters of high-frequency keywords related to sustainable fashion

main node greatest weight total link strength in cluster	cluster	other nodes in the cluster
sustainability	1	sustainable apparel, business development, clothing industry, communication, consumption behavior, decision making, design method, electronic commerce, environmental economics, environmental protection, factor analysis, industrial development, integrated fashion, literature review, marketing, perception, purchase intention, retailing, social media, stakeholder
sustainable development	2	sustainable supply chains, sustainable textiles, transparency, block-chain, blockchain, competition, consumer behavior, consumption, fashion companies, fashion supply chain, information management, manufacture, planning, purchasing, sales, social and environmental, supply chain, supply chains, sustainable consumption
fashion design	3	industrial economics, industrial engineering, industry, product design, sustainable business, sustainable design, sustainable production, sustainable products, consumer behaviour, design, design process, eco-fashion, ecodesign, environment, ethics, upcycling
sustainable fashion	4	business, circular economy, circular fashion, ethical fashion, fashion consumption, innovation, luxury, luxury fashion, sharing economy, sustainable, sustainable business models, fashion, sustainable fashion design, textile, waste, water pollution
supply chain management	5	manufacturing, profitability, slow fashion, sustainable materials, sustainable practices, sustainable supply chain management, business models, carbon dioxide, carbon footprint, clothing, corporate social responsibility, economic and social effects, environmental pollutions, fast fashion, greenhouse gases

Cont. table 3.

fashion industry	6	commerce, consumer perception, cotton, economic uncertainty, environmental sustainability, fashion designers, garment industry, life cycle, product development, production process, textile industry, textures, wool, yarn
textiles	7	climate change, covid-19, eco-friendly, environmental impact, environmental management, life cycle analysis, population statistics, recycling, sustainable fashion consumption, textile recycling, textile waste, waste disposal, waste management, sustainable development goals

Source: own work.

To conclude, the obtained results based on a comparative keyword analysis indicate a gap in the literature contributions between sustainable fashion and virtual sustainable fashion. Inferring from keyword analysis, the former approaches the specific issues concerning the sustainability of the fashion industry, whereas the latter only alludes to them in general terms.

5. Discussion

According to the results of the research conducted, there is little academic interest in the issue of virtual sustainable fashion. One can assume that it is driven by the premise of virtual fashion's limited potential to influence the development of sustainable fashion, due to its specific nature and still narrow market. Referring to research findings published in the 2022 report 'Metaverse & Sustainability in Fashion', virtual fashion clothing has been acquired by only 8% of consumers worldwide. It was slightly higher in Asia reaching 13 percent (BCG, 2022). In contrast, according to a survey conducted in 2022 by Ipsos, only 3% of consumers across the USA have purchased virtual clothing via an AR app (Ipsos, 2022).

Virtual fashion is recognised as an opportunity to support the development of sustainable fashion through the use of virtual 3D prototyping, 3D visualisation, 3D body scanning and virtual fitting technology in order to reduce waste. What is more, it reinforces eco-friendly consumer attitudes by encouraging using the virtual wardrobe. Nevertheless, the concept of virtual fashion does not explicitly match the core principles / objectives of sustainable fashion. Virtual fashion is characterised from the perspective of new technological features providing opportunities to develop creative designs that move far beyond the patterns and standards familiar hitherto. For example, with means of immersive technologies the new ways to contribute towards fostering cultural heritage (the promotion of traditional clothing and textiles) have been found. Yet only occasionally and as a downstream factor, virtual fashion is inscribed the potential of contribution to the sustainability goals of the fashion industry. Nonetheless, it is not a priority nor a primary objective. Besides, virtual fashion targets a narrow group of consumers who possess the tools of virtual reality technology. That may also be closely related to the demonstrated interest in entering the virtual fashion market by globally known fashion brands, especially premium and luxury brands (Harba, 2019).

Moreover, Virtual Reality still has not become a permanent element of life. Even though, it is particularly favoured by young people who are open-minded for the new technologies. It is therefore worth following the further development of the virtual fashion trend, which is demand-driven. In spite of being characterised as relatively unpopular and sceptically approached nowadays, as previously indicated, there are still other research evidence suggesting that it might change over time. In accordance with the results of a 2021 survey conducted by The Business of Fashion and Altiant on a representative sample of American consumers from generations X, Y and Z, a total of 49 percent of respondents were interested in purchasing virtual fashion items from a luxury brand. Additionally, the rate was slightly lower for those who expressed an interest in purchasing digital assets from a mass fashion brand (The Business of Fashion, 2022). Another 2021 global survey amongst digital communities of fashion companies reported that consumers' interest in trying out new technologies was the main reason for engaging in virtual worlds (The Business of Fashion, 2022). Virtual fashion fulfils the objectives set by fashion creators too, which is to provide an opportunity to experiment with looks. The chief reason for young American consumers aged 14-25 being interested in virtual clothing was the diversity offering the opportunity to experiment. The respondents noted simultaneously their unwillingness to accept the offer as well as to wear those created designs in real life (Roblox, 2022).

Therefore, the validity of the statement “virtual fashion will never replace physical fashion” may be verified in a matter of years' time, as it can become a popular addition to life. After all, this diversification of the fashion industry is likely to rebalance it, since virtual fashion is expected to influence the reduction of overproduction and overconsumption (Von Horn, 2021). For this reason, an important research problem is the one regarding consumer behavior, their changes towards sustainable consumption and the impact of virtual fashion consumption on this change. (United Nations Alliance for Sustainable Fashion, 2021; Ruiz-Navarro, Hintzmann, Corrons, 2021).

Advances in the application of artificial intelligence, IoT and blockchain technologies may also contribute to the sustainability of the fashion industry (Akram, 2022). Artificial intelligence can help fashion companies better assess the sustainability of their supply chain by analysing information about suppliers and their environmental and ethical standards (Lee, 2021). IoT, which is a network of physical objects equipped with sensors, software and other technologies to connect and exchange data with other devices and systems via the internet, offers opportunities to improve sustainability efforts by using sensors to track energy consumption, waste management and water use. As a result, companies can identify areas where they can reduce their environmental impact (Jagtap, Garcia-Garcia, Rahimifard, 2021). Blockchain technology is seen as an opportunity to establish transparency in fashion production (Good on You, 2023) as called for by, among others, the European Union in its plans to introduce digital product passports (Damen, 2023).

Whereas, upcoming research tackling the topic of virtual fashion in the context of sustainability ought to involve developing a knowledge resource about the energy consumption of IT devices, tools and technologies, energy sources, emission levels, CO₂, water consumption (for cooling servers). This concern is being progressively raised by references to EU data claiming that already in 2016 data centres were consuming over 2% of the world's electricity and a volume of fuel comparable, in terms of carbon dioxide emissions, to the aviation industry (ICT Sector Helping..., 2016). This issue has already been accentuated, inter alia by the aforementioned report “Metaverse & Sustainability in Fashion” in which various scenarios of CO₂ reduction alternatives are considered, contingent on a globally implemented programme on the subject (Jordan-Kulczyk, Zając, 2022).

The limitations of the main research conducted for the purposes of this article are the acquisition of data from only three databases and concluding based on the results obtained for a small sample. However, the authors of the two other literature reviews analysed in this paper have encountered exactly the same problem, as shown in the results of the two studies. Thus, this affected the final conclusion reached on the basis of the research, unlike its predecessors, which do not confirm a direct connection between virtual and sustainable fashion.

6. Summary

Virtual fashion and sustainable fashion are two separate concepts with limited degree of overlap. Sustainable fashion refers to the practical application of designing, producing and consuming garments in an environmentally friendly, socially responsible and economically viable manner. It addresses issues such as environmental impact and consumer behaviour. Virtual fashion refers to the creation of digital clothing and accessories designed to be worn by digital avatars or used in virtual and augmented reality environments. This trend is relatively new and expanding within the fashion industry, it has potential benefits including a reduction in textile waste as well as its exceptional impact on the environment connected to the physical production of the garment. Notwithstanding, virtual fashion does not actually solve the nowadays problems regarding the ecological and ethical physical production of garments.

References

1. Ahn, D.K., Bae, B.C., Kim, Y. (2023). User Experience of a Digital Fashion Show: Exploring the Effectiveness of Interactivity in Virtual Reality. *Applied Sciences*, Vol. 13, 2558. doi: 10.3390/app13042558.
2. Aspers, P. (2016). *Orderly Fashion: A Sociology of Markets*. Princeton: Princeton University Press.
3. Baek, E., Haines, S., Fares O.H., Huang, Z., Hong Y., Lee, S.H.M. (2022). Defining digital fashion: Reshaping the field via a systematic review. *Computers in Human Behavior*, Vol. 137, 107407. doi: 10.1016/j.chb.2022.107407.
4. Bang, H., Jin, S. (2022). Who Uses Virtual Wardrobes? Investigating the Role of Consumer Traits in the Intention to Adopt Virtual Wardrobes. *Sustainability*, Vol. 14, No. 3: 1209. doi: 10.3390/su14031209.
5. Baron, K. (2019). Carlings Phygital T-Shirt Gives Virtual Fashion The Accessible Vibe Brand Land's Been Waiting For. *Forbes*. Retrieved from: <https://www.forbes.com/sites/katiebaron/2019/12/09/carlings-phygital-t-shirt-gives-virtual-fashion-the-accessible-vibe-brand-lands-been-waiting-for/?sh=6b80f28f13a8>, 25.05.2023.
6. BCG (2022). Proportion of worldwide consumers who purchased digital-only fashion items as of 2022, by region. *Statista*. Statista Inc. Retrieved from: <https://www-1statista-1com-1id5lnmbw0d9f.han3.lib.uni.lodz.pl/statistics/1356705/digital-fashion-purchasers/>, 25.05.2023.
7. Berry, J. (2018). *House of Fashion: Haute Couture and the Modern Interior*. London: Bloomsbury Publishing.
8. Black, S. (2022), Digital Luxury: Towards a Sustainable Future? In: P.Y. Donzé, V. Pouillard, J. Roberts (eds.), *The Oxford Handbook of Luxury Business* (pp. 591-614). Oxford: Oxford University Press. doi: 10.1093/oxfordhb/9780190932220.013.22.
9. Casciani, D., Chkanikova, O., Pal, R. (2022). Exploring the nature of digital transformation in the fashion industry: opportunities for supply chains, business models, and sustainability-oriented innovations. *Sustainability: Science, Practice and Policy*, Vol. 18, Iss. 1, pp. 773-795. doi: 10.1080/15487733.2022.2125640.
10. Changing Markets Foundation (2021). *Synthetics Anonymous. Fashion brands' addiction to fossil fuels*. Retrieved from: http://changingmarkets.org/wp-content/uploads/2021/07/SyntheticsAnonymous_FinalWeb.pdf, 12.06.2022.
11. Choi, K.H. (2022). 3D dynamic fashion design development using digital technology and its potential in online platforms. *Fashion and Textiles: International Journal of Interdisciplinary Research*, Vol. 9. doi: 10.1186/s40691-021-00286-1.
12. Create Build Optimize (2023). *Future Of Virtual Reality – Market Trends And Challenges*. Retrieved from: <https://www.softwaretestinghelp.com/future-of-virtual-reality/>, 25.05.2023.

13. Credence Research, Inc. (2022). *Global Virtual Goods Market: Growth, Future Prospects, and Competitive Analysis, 2016-2028*. Retrieved from: <https://www.credenceresearch.com/news/global-virtual-goods-market-press-release>, 25.05.2023.
14. Cross, K., Steed, J., Jiang, Y. (2021). Harris Tweed: A glocal case study. *Fashion, Style & Popular Culture, Vol. 8, Iss. 4*, pp. 475-494.
15. Damen, D.A., Stepke-Müller, M., Meyer zum Felde, A., Rubel, H., Turner, J., van Doorne, L., Sukailo, D., Holtorf, M., Eggert, F. (2023). *The EU Digital Product Passport shapes the future of value chains: What it is and how to prepare now*. The World Business Council for Sustainable Development and Boston Consulting Group. Retrieved from: <https://www.wbcds.org/contentwbc/download/15584/226479/1>, 15.07.2023.
16. Debter, L. (2021). Fashion And The Metaverse: Why Ralph Lauren Wants To Sell You Digital Clothing. *Forbes*. Retrieved from: <https://www.forbes.com/sites/laurendebter/2021/12/25/fashion-and-the-metaverse-why-ralph-lauren-wants-to-sell-you-digital-clothing/?sh=52cfe58ebe89>, 25.05.2023.
17. Deloitte (2021). *Global Powers of Luxury Goods. Breakthrough luxury (2021)*. Retrieved from: <https://www.deloitte.com/content/dam/assets-shared/legacy/docs/industry/consumer/2022/gx-02-GPLG2021-Report-online.pdf>, 25.05.2023.
18. Durocher, Y. (2022). The Sustainable Side Of Digital Fashion. *Forbes*. Retrieved from: <https://www.forbes.com/sites/forbesagencycouncil/2022/09/09/the-sustainable-side-of-digital-fashion/?sh=42e06fd66002>, 25.05.2023.
19. Earnshaw, R., Vince, J. (eds.) (2001). *Digital Content Creation*. London: Springer. doi: 10.1007/978-1-4471-0293-9.
20. Ellen MacArthur Foundation (2017). *A new textiles economy: Redesigning fashion's future*.
21. Ellen MacArthur Foundation (2022). *Circular Design for Fashion*. London: Thames Hudson.
22. Esser, F., Vliegthart, R. (2017). Comparative Research Methods. In: J. Matthes, C.S. Davis, R.F. Potter (Eds.), *The International Encyclopedia of Communication Research Methods* (pp. 1-22). doi: [org/10.1002/9781118901731.iecrm0035](https://doi.org/10.1002/9781118901731.iecrm0035). Retrieved from: <https://onlinelibrary.wiley.com/doi/10.1002/9781118901731.iecrm0035>, 15.03.2023.
23. European Commission (2022). Communication From The Commission To The European Parliament, The Council, The European Economic And Social Committee And The Committee Of The Regions EU. *Strategy for Sustainable and Circular Textiles*. Brussels.
24. Farra, E. (2021). How Will Fashion Shows Evolve? Are Virtual Clothes the Next Frontier? Designers, Tech Leaders, and CEOs Discussed What's Next at Vogue's CES Panel. *Vogue*. Retrieved from: <https://www.vogue.com/article/ces-panel-futureof-fashion-shows-video-games-technology-social-media>, 15.05.2023.

25. Fashion Revolution (2022). *Fashion Transparency Index 2022*. Retrieved from: <https://www.fashionrevolution.org/about/transparency/>, 12.06.2022.
26. Fletcher, K. (2010). Slow Fashion: An Invitation for Systems Change. *Fashion Practice: The Journal of Design, Creative Process & the Fashion*, Vol. 2, pp. 259-266.
27. Fu, Y., Liang, H. (2022). Sinicized Exploration of Sustainable Digital Fashion: Chinese Game Players' Intention to Purchase Traditional Costume Skins. *Sustainability*, Vol. 14, 7877. doi: 10.3390/su14137877.
28. *Future Of Virtual Reality – Market Trends And Challenges* (2023). Retrieved from: <https://www.softwaretestinghelp.com/future-of-virtual-reality/>, 10.07.2023.
29. Galimberti, C, Ignazi, S, Vercesi, P., Riva, G. (2003) *Characteristics of interaction and cooperation in immersive and nonimmersive virtual environments. Towards CyberPsychology: Mind, Cognitions and Society in the Internet Age*. Amsterdam: IOS Press.
30. Garousi, V., Felderer, M., Mäntylä, M.V. (2019). Guidelines for including grey literature and conducting multivocal literature reviews in software engineering. *Information and Software Technology*, Vol. 106, pp. 101-121. doi: 10.1016/j.infsof.2018.09.006.
31. Gil-Leiva, I., Alonso-Arroyo, A. (2007). Keywords given by authors of scientific articles in database descriptors. *Journal of the American Society for Information Science and Technology*, Vol. 58, Iss. 8, pp. 1175-1187. doi: 10.1002/asi.20595.
32. Given, L.M. (2008). *The SAGE Encyclopedia of Qualitative Research Methods*. Indie: SAGE Publications.
33. Good On You (2023). *Can Blockchain Technology Make Fashion More Transparent?* Retrieved from: <https://goodonyou.eco/blockchain-technology-fashion-transparency/>, 15.07.2023.
34. Greenpeace (2022). *The UK's Fast Fashion Habit Is Getting Worse and It's Destroying the Planet*. Retrieved from: https://www.greenpeace.org.uk/news/the-uks-fast-fashion-habit-is-getting-worse-and-its-destroying-the-planet/?gclid=Cj0KCQjwkOqZBhDNARIsAACsbfIA7w59DKpgFYZplw6SL2UvRKTRw2kmY03npavHG0FOYdWQq1pzIaAk-g-EALw_wcB, 23.06.2023.
35. Harba, J. (2019). New approaches to customer experience: where disruptive technological innovation meets luxury fashion. *Proceedings of the International Conference on Business Excellence*, Vol. 13, Iss. 1, pp. 740-758. doi: 10.2478/picbe-2019-0066.
36. Henninger, C.E., Alevizou, P.J., Oates, C.J. (2016). What is sustainable fashion? *Journal of Fashion Marketing and Management*, Vol. 20, Iss. 4, pp. 400-416. doi: 10.1108/JFMM-07-2015-0052.
37. <https://dressx.com/>, 15.05.2023.
38. <https://global-standard.org/>, 15.05.2023.
39. <https://www.fairtrade.net/about/certification>, 15.05.2023.
40. <https://www.thefabricant.com/>, 15.05.2023.

41. *ICT Sector Helping to Tackle Climate Change* (2016). Retrieved from: <https://unfccc.int/news/ict-sector-helping-to-tackle-climate-change>, 25.05.2023.
42. Ipsos (2022). Consumer likelihood to try on fashion items virtually with an AR app in the United States in 2022 [Graph]. *Statista*. Statista Inc. Retrieved from: <https://www-1statista-1com-1id5lnm1a02f9.han3.lib.uni.lodz.pl/statistics/1356550/virtual-fitting-room-consumer-interest-united-states/>, 25.05.2023.
43. Jackson, C. (2017). Burberry Launches Exclusive Virtual Handbag Collection On Roblox Arm candy for avatars. *Elle*. Retrieved from: <https://www.elle.com/uk/fashion/a40598330/burberry-virtual-handbags-roblox/>, 25.05.2023.
44. Jagtap, S., Garcia-Garcia, G., Rahimifard, S. (2021). Optimisation of the resource efficiency of food manufacturing via the Internet of Things. *Computers in Industry*, Vol. 127, 103397. doi: 10.1016/j.compind.2021.103397.
45. Joe Waheed Sayyed, B., Erum Sherieff, S., Gupta, R. (2021). *New Technology: Impact on Green Consumerism via Social media and AI in Fashion Industry*. International Conference on Advance Computing and Innovative Technologies in Engineering (ICACITE), Greater Noida, India, 2021, pp. 320-326. doi: 10.1109/ICACITE51222.2021.9404721.
46. Jordan-Kulczyk, K., Zając, O. (Eds.) (2022). *Metaverse & Sustainability In Fashion. Opportunity or Threat?* Warszawa: Vouque Polska & Boston Consulting Group.
47. Köhler, A., Watson, D., Trzepacz, S., Löw, C., Liu, R., Danneck, J., Konstantas, A., Donatello, S., Faraca G. (2021). *Circular Economy Perspectives in the EU Textile sector, EUR 30734 EN*. Luxemburg: Publications Office of the European Union.
48. Koma, K. (2023). Fashion and Identity in Virtual Spaces. In: M.Á. Gardetti, R.P. Larios-Francia, R.P. (Eds.), *Sustainability Challenges in the Fashion Industry. Sustainable Textiles: Production, Processing, Manufacturing & Chemistry*. Singapore: Springer. doi: 10.1007/978-981-99-0349-8_12.
49. Kumar, J., Singha, K., Pandit, P., Maity, S., Ray, A. (2020). Challenges for Waste in Fashion and Textile Industry. In: P. Pandit, S. Ahmed, K. Singha, S. Shrivastava (Eds.), *Recycling from Waste in Fashion and Textiles: A Sustainable and Circular Economic Approach*. Hoboken: John Wiley & Sons.
50. Lee, Y.A. (2014). Computer design and digital fit of clothing. In: D. Gupta, N. Zakaria (Eds.), *In Woodhead Publishing Series in Textiles, Anthropometry, Apparel Sizing and Design* (pp. 305-319). Woodhead Publishing. doi: 10.1533/9780857096890.2.305.
51. Lee, Y.K (2021). Transformation of the Innovative and Sustainable Supply Chain with Upcoming Real-Time Fashion Systems. *Sustainability*, Vol. 13, 1081. doi: 10.3390/su13031081.
52. Lum, H.C., Elliott, L.J., Aqlan, F., Zhao, R. (2020). Virtual Reality: History, Applications, and Challenges for Human Factors Research. *Proceedings of the Human Factors and*

- Ergonomics Society Annual Meeting, Vol. 64, Iss. 1, pp. 1263-1268. doi: 10.1177/1071181320641300.*
53. Marcella-Hood, M. (2023). Augmenting Sustainable Fashion on Instagram. *Sustainability, 5, 3609.* doi: 10.3390/su1504360.
 54. Marr, B. (2022). Gucci Enters The Metaverse. *Forbes*. Retrieved from: <https://www.forbes.com/sites/bernardmarr/2022/11/30/gucci-enters-the-metaverse/?sh=59097e941d66>, 25.05.2023.
 55. Mazuryk, T., Gervautz, M. (1999). *Virtual Reality - History, Applications, Technology and Future*. Retrieved from: <https://www.cg.tuwien.ac.at/research/publications/1996/mazuryk-1996-VRH/TR-186-2-96-06Paper.pdf>, 15.05.2023.
 56. Mesjar, L., Cross, K., Jiang, Y., Steed, J. (2023), The Intersection of Fashion, Immersive Technology, and Sustainability: A Literature Review. *Sustainability, Vol. 15, 3761.* doi: 10.3390/su15043761.
 57. Niinimäki, K., Peters, G., Dahlbo, H., Perry, P., Rissanen, T., Gwilt, A. (2020). The Environmental Price of Fast Fashion. *Nature Reviews Earth & Environment, Vol. 1,* pp. 189-200.
 58. OECD (2017). *OECD Due Diligence Guidance for Responsible Supply Chains in the Garment and Footwear Sector.*
 59. Paez, A. (2017). Gray literature: An important resource in systematic reviews. *Journal of evidence-based medicine, Vol. 10, Iss. 3,* pp. 233-240. doi: 10.1111/jebm.12266.
 60. Page, M.J., McKenzie, J.E., Bossuyt, P.M., Boutron, I., Hoffmann, T.C., Mulrow, C.D., Shamseer, L., Tetzlaff, J.M., Akl, E.A., Brennan, S.E., Chou, R., Glanville, J., Grimshaw, J.M., Hróbjartsson, A., Lalu, M.M., Li, T., Loder, E.W., Mayo-Wilson, E., McDonald, S., McGuinness, L.A., ... Moher, D. (2021a). The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. *BMJ (Clinical research ed.), Vol. 372,* n71. doi: 10.1136/bmj.n71.
 61. Page, M.J., McKenzie, J.E., Bossuyt, P.M. et al. (2021b). The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. *Systematic Reviews, Vol. 10.* doi: 10.1186/s13643-021-01626-4.
 62. Patton, M.Q. (2015). *Qualitative Research & Evaluation Methods: Integrating Theory and Practice.* Saint Paul: SAGE Publications.
 63. Pucker, K.P. (2022). The Myth of Sustainable Fashion. *Harvard Business Review*. Retrieved from: <https://hbr.org/2022/01/the-myth-of-sustainable-fashion>, 15.05.2023.
 64. Radhakrishnan, S., Erbis, S., Isaacs, J.A., Kamarthi, S. (2017). Correction: Novel keyword co-occurrence network-based methods to foster systematic reviews of scientific literature. *PLOS ONE, 12(9): e0185771.* doi: 10.1371/journal.pone.0185771.
 65. Roblox (2022). Leading expectations of Gen Z consumers from digital fashion designers and brands in the United States in 2022. *Statista.* Statista Inc. Retrieved from:

- <https://www-1statista-1com-1id5lnmbw0d9f.han3.lib.uni.lodz.pl/statistics/1356715/digital-fashion-consumer-expectations/>, 3.06.2023.
66. Ruiz-Navarro, R., Hintzmann, C., Corrons, A. (2021). *Sharing Economy and Fast Fashion (Sustainability and virtual consumer behavior: A review and research agenda)*. SAGE Open. doi: 10.31124/advance.17331182.v2.
 67. Sakaguchi, M., Aoki, E., Nagamatsu, K. (2023). A Study on Changing Consciousness of Post Coronavirus Pandemic in Fashion Society and Use of Digital Technology. In: L. Barolli (Ed.), *Complex, Intelligent and Software Intensive Systems. CISIS 2023. Lecture Notes on Data Engineering and Communications Technologies, Vol. 176* (pp. 367-376). Cham: Springer. doi: 10.1007/978-3-031-35734-3_37.
 68. Shaik, V.A., Malik, P., Singh, R., Gehlot, A., Juyal, A., Ghafoor, K., Shrestha, S. (2022). Implementation of Digitalized Technologies for Fashion Industry 4.0: Opportunities and Challenges. *Scientific Programming*, pp. 1-17. doi: 10.1155/2022/7523246.
 69. Sherstyuk, A., Vincent, D., Treskunov, A. (2009). *Towards Virtual Reality games*. 8th International Conference on Virtual Reality Continuum and its Applications in Industry, VRCAI, Yokohama, Japan, pp. 315-316. doi: 10.1145/1670252.1670322.
 70. Snyder, H. (2019). Literature review as a research methodology: An overview and guidelines. *Journal of Business Research*, Vol. 104, pp. 333-339. doi: 10.1016/j.jbusres.2019.07.039.
 71. Sutherland, I.E. (1965). *The Ultimate Display. Multimedia: From Wagner to Virtual Reality*. New York, NY: Norton.
 72. Sverko Grdic, Z., Krstinic Nizic, M., Rudan, E. (2020). Circular Economy Concept in the Context of Economic Development in EU Countries. *Sustainability*, Vol. 12, No. 7, 3060. doi:v10.3390/su12073060.
 73. The Business of Fashion (2022). Level of interest in purchasing digital assets from luxury and mass fashion companies among Gen Z, Gen Y and Gen X consumers in the United States in 2021. *Statista*. Statista Inc. Retrieved from: <https://www-1statista-1com-1id5lnmbw0d9f.han3.lib.uni.lodz.pl/statistics/1311669/digital-fashion-asset-buying-interest/>, 3.06.2023.
 74. The Business of Fashion, McKinsey & Company (2022). *The State of Fashion Technology*.
 75. The Business of Fashion (2022). Motivations for participating in virtual worlds among digital fashion users globally in 2021. *Statista*. Statista Inc. Retrieved from: <https://www-1statista-1com-1id5lnmbw0d9f.han3.lib.uni.lodz.pl/statistics/1311731/virtual-world-participation-reasons-fashion-consumers/>, 3.06.2023.
 76. United Nations (2021). *Fashion Industry Carter for Climate Act*. Retrieved from: https://unfccc.int/sites/default/files/resource/Fashion%20Industry%20Carter%20for%20Climate%20Action_2021.pdf, 15.05.2023.
 77. United Nations Alliance for Sustainable Fashion (2021). *Synthesis Report on United Nations System-wide Initiatives related to Fashion*.

78. Van Eck, N.J., Waltman, L. (2013). Vosviewer Manual. *Leiden: Univeriteit Leiden, Vol. 1, Iss. 1*, pp. 1-53.
79. Von Horn, M. (2021). *Cyfrowa moda: Jak ją nosić?* Retrieved from: <https://www.vogue.pl/a/cyfrowa-moda-podpowiadamy-jak-ja-nosic>, 25.05.2023.
80. Wagner, R., Kabalska, A. (2023). Sustainable value in the fashion industry: A case study of value construction/destruction using digital twins. *Sustainable Development, Vol. 31, Iss. 3*, pp. 1652-1667. doi: org/10.1002/sd.2474.
81. Yixin, Z., Ding-Bang, L., Shizhu, L. (2022). Public perceptions of digital fashion: An analysis of sentiment and Latent Dirichlet Allocation topic modeling. *Frontiers in Psychology, Vol. 13*, pp. 1-21. doi: 10.3389/fpsyg.2022.986838.
82. Zhang, K. (2022). Application of 3D Technology in Garment Design Template. In: J. Macintyre, J. Zhao, X. Ma (Eds.), *The 2021 International Conference on Machine Learning and Big Data Analytics for IoT Security and Privacy. SPIoT 2021. Lecture Notes on Data Engineering and Communications Technologies, Vol. 97*. Cham: Springer. doi: 10.1007/978-3-030-89508-2_37.
83. Zhang, T. (2020). Digital Helsinki Fashion Week Saw Significant Drop in Carbon Emissions. *Women Wear Daily*. Retrieved from: <https://wwd.com/fashion-news/fashion-features/digital-helsinki-fashion-week-saw-significant-drop-in-carbon-emissions-1234613901/>, 25.05.2023.
84. Zhou, S., Baek, E., Jang, J. (2022). The Rise of Virtual Representation of Fashion in Marketing Practices: How It Can Encourage Sustainable Luxury Fashion Consumption. In: C.E. Henninger, N.K. Athwal (Eds.), *Sustainable Luxury. Palgrave Advances in Luxury* (pp. 271-292). Cham: Palgrave Macmillan. doi: 10.1007/978-3-031-06928-4_13.