Sustainable Fashion Design: A Review and Perspective

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ABSTRACT

Fashion sustainability may potentially reduce greenhouse gas emissions and mitigate climate change by decreasing pollution and waste. However, sustainable fashion design received little attention in recent years. Here, the existing literature (237 publications) on sustainable fashion design is synthesized to understand the trends and future directions. Sustainable fashion design lacked systematic research methodology and paid little attention to down-cycling design. The sustainable fashion design can be classified into four categories of design methods, including reducing waste, reducing environmental impacts, redesigning, and extending the lifespan of garments. Slow fashion design was dominant and the hottest research topic in the past two decades. Further studies are required to explore the methodology of remake fashion design in sustainable fashion. Overall, this study has a large contribution to the theory and applications of sustainable fashion design by establishing a comprehensive documentation library, reviewing multiple aspects of studies, understanding the trends and development, summarizing the status and hot topics, identifying research gaps, and providing future research directions.

Keywords: *Sustainable fashion, Fashion design, Bibliometric analysis, Systematic review*

INTRODUCTION

Sustainability in fashion includes multiple aspects such as reducing pollution, waste, and carbon dioxide emissions, addressing overproduction, supporting biodiversity, etc. (Appolloni et al., 2023). It has been reported that the fashion industry has become the second largest polluter in the world (Woodside & Fine, 2019) and current fashion production accounts for approximately 10% of global carbon emissions; if this situation does not change, its proportion is predicted to rise to ~26% by 2050 (Appolloni et al., 2023). Globally, 920,000 tonnes of clothing are discarded each year, and most of these garments go to landfill or are incinerated (Sisodia & Parmar, 2022; Dan et al., 2023). However, six in ten people have prepared to change their consumer behavior to minimize environmental impacts in recent years (Purcărea et al., 2022). Eighty-six percent of 21,000 consumers from 28 countries would like to shift towards a more environmentally friendly company and expect to see more sustainable products on the market. Thus, controlling fashion production and pursuing sustainable fashion play critical roles in reducing greenhouse gas emissions and achieving sustainable development goals. In addition, the design phase of sustainable fashion dominates a product's environmental impact, while little information is available on design research. Some studies indicated that the development processes of products were determined by designers, with effects on the choice of materials, the level of fashion, and the environmental impacts of the product's lifecycle in circularity (Claxton & Kent, 2020). Despite its great importance, there is no systematic review on sustainable fashion design, obscuring our understanding and development of sustainable fashion.

In this study, the growing literature on sustainable fashion design is synthesized through a comprehensive bibliometric analysis and systematic review. The analysis was based on the records in the Web of Science and Scopus database as of 15 October 2023. Specifically, several aspects related to sustainable fashion design were presented, including the conceptual framework, research trends and development, current status and hot topics (i.e., up-cycling, timeless style, digital design, better quality, and flexible design), and future directions on design strategies. Our objective was to improve our understanding of the general aspects of sustainable fashion design, which will provide a baseline for future design strategies in the rapidly changing world.

METHODOLOGY

This study summarized and outlined sustainable fashion design through the combination of the bibliometric analysis with the systematic review. The bibliometric analysis mainly applies quantitative method on bibliometric data, which has been widely applied in diverse research fields, ranging from studying patterns to exploring the intellectual structure of the specific field (Donthu et al., 2021). A systematic review is a well-structured and reproducible approach for exploring patterns and identifying research gaps through searching and screening current literature (Ray & Nayak, 2023). In specific, several procedures for synthesizing sustainable fashion design are shown in Figure 1.

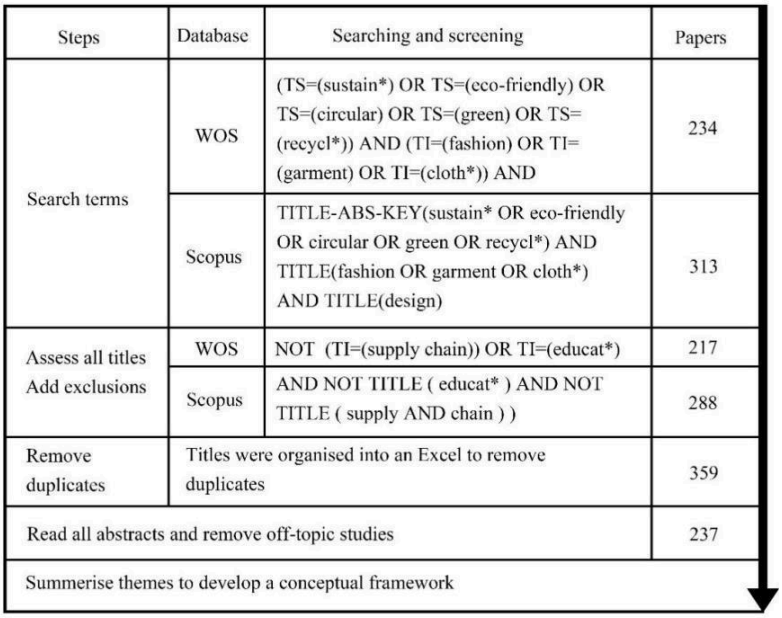

Figure 1. The flow diagram describing the process of screening studies

The first step search the existing literature through keywords related to sustainable fashion design to achieve different themes and sub-themes as complete as possible. A structured search was performed in the databases of the ISI Web of Science (WOS) and Scopus as of October 2023. The used search phrases were "(TS=(sustain*) OR TS=(eco-friendly) OR TS=(circular) OR TS=(green) OR TS=(recycl*)) AND (TI=(fashion) OR TI=(garment) OR TI=(cloth*)) AND (TI=design)" in the WOS database and "TITLE-ABS-KEY(sustain* OR eco-friendly OR circular OR green OR recycl*) AND TITLE(fashion OR garment OR cloth*) AND TITLE(design)" in the Scopus database. Subsequently, all titles were scanned and excluded papers that contained two specific phrases ("NOT (TI=(supply chain)) OR TI=(educat*)" in the WOS database and "NOT TITLE (educat*) AND NOT TITLE (supply AND chain)" in the Scopus database). Furthermore, duplicates were removed and only research papers, book chapters, and perspective papers were considered. Finally, a total of 237 publications were selected for reviewing sustainable fashion design.

A CONCEPTUAL FRAMEWORK OF SUSTAINABLE FASHION DESIGN

By carefully reviewing the abstracts and contents of the screened literature, sustainable fashion design methods were organized and sorted into a systematic framework (Fig. 2). This framework was modified and improved based on the 3R (reduce, recycle, and reuse) Sustainable Design Framework (Manickam & Duraisamy, 2019). Following the life cycle of a sustainable fashion product, the sustainable fashion design can be divided into four parts. First, reducing energy waste needs to be considered at the manufacturing stage, and sustainable design approaches are recommended to utilize digital design and zero-waste methods. Second, the lifecycle of a product can be extended by designing timeless styles, higher quality, and flexible fashion products. Third, green materials (e.g., bio-material) can be used to reduce the environmental impacts resulting from the duration of productivity. Lastly, fashion products can be recycled at the end of their lifespan by redesigning them.

Figure 2. A conceptual framework summarizing the sustainable fashion design

RESEARCH TRENDS AND DEVELOPMENT

The year 2008 seems to be a threshold for the development of sustainable fashion design (Fig. 3). Before 2008, there were very limited publications related to sustainable fashion design, of which conceptualization enlightened. Then, various aspects on sustainable fashion design flourished, including the combinations of design with reducing waste, using green materials, reducing environmental impacts, and extending the lifecycle of garments. Although there were several slightly declining phases (e.g., 2013-2015 and 2017-2019), this field has received much attention and the number of publications has sharply increased since 2008. Based on the proposed conceptual framework, sustainable fashion design can be categorized into four domains, including reducing waste, slow fashion design, reducing environmental impacts, and redesign. The number of publications related to redesign and reducing environmental impacts did not change over the years. Indeed, the number of publications related to reducing wastage and slow fashion design gradually increased over with years, indirectly showing that reducing wastage and slow fashion design dominate sustainable fashion design at the current development stage.

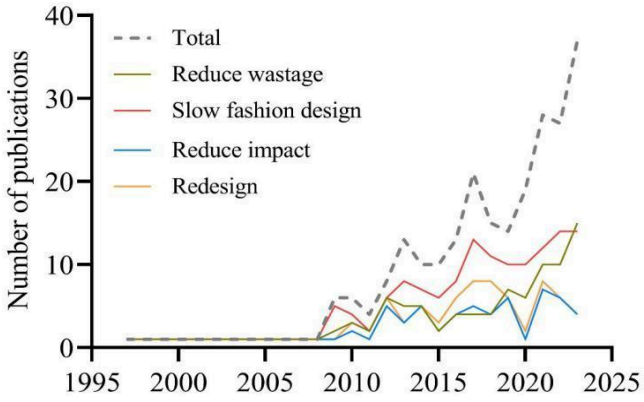

Figure 3. Number of publications over time for sustainable fashion design

Moreover, 19 sub-themes that almost covered sustainable fashion design were also extracted and then their frequency and duration were analyzed (Fig. 4). The post-consumer cycling design was dominant throughout the development of sustainable fashion design (2004-2023), followed by cultural design (2007-), smart clothing design (2005-), multiple functional design (2009-), and 3D design (2009-). Emotional design only had a relatively higher frequency from 2011 to 2021, while clothing materials (better material and bio-material) have received much attention since 2012. The artificial intelligence (AI) design was popular and important in the past years due to its rapid development and application. Nevertheless, other sub-themes (e.g., custom design, laser engraving design, digital printing, after-sales service, quality control, pre-consumer cycling, classic style, minimalist style, genderless style, etc.) had shorter duration and lower frequency, indicating these sub-themes were a minority and received fewer attentions in the sustainable fashion design.

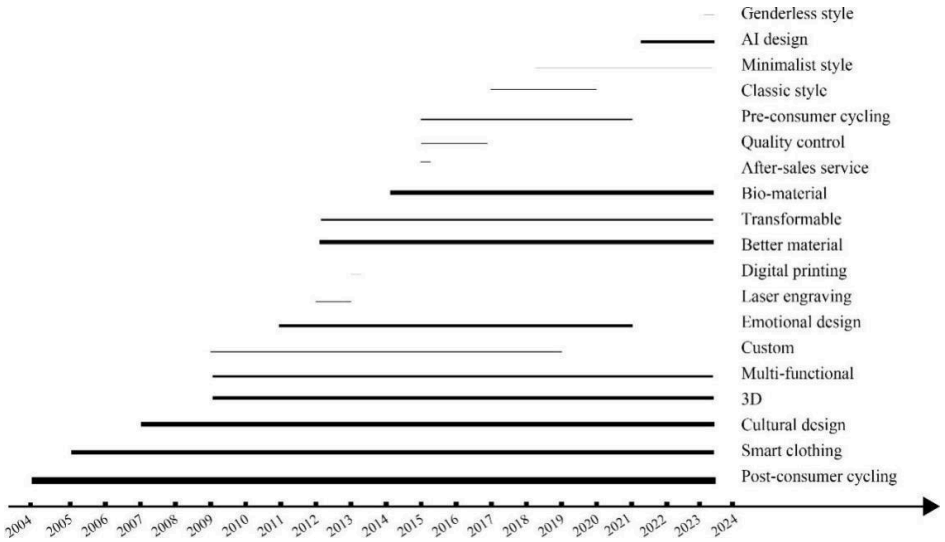

Figure 4. Frequency and duration of primary themes in sustainable fashion design. The length and thickness of the line indicate the duration and frequency of a specific theme, respectively.

CURRENT STATUS AND HOT TOPICS

Up-cycling Design

Redesign can be divided into up-cycling design and down-cycling design, while little information on the down-cycling design of clothing was found. Also, redesign is classified into pre-consumer cycling and post-consumer cycling design, of which post-consumer cycling design was dominant. The sustainable redesign of fashion is to redesign the discarded garbage into useful products. The garbage mainly includes clothing, wastage during the clothing production process, daily necessities such as hospital sheets, plastics, polyethylene terephthalate (PET) materials, marine garbage, etc. Moreover, redesign has four main approaches. First, waste can be transformed into fibers, fabrics, and final clothing. Second, waste clothing can be sewed into fabrics and remade into garments. Third, original clothing may be deconstructed and then reconstructed into new clothing. Lastly, original clothing can also be redesigned and improved through adding decorations. Among them, plastic bottles, PET materials, and marine garbage are mainly processed into fibers and then clothing. For instance, discarded clothing was transformed into protective clothing during the COVID-19 pandemic (Li & Liu, 2021), which not only prevent the spread of the virus but also alleviate the growing demand for personal protective equipment

during the pandemic. At present, this kind of redesigned clothing brand is mostly distributed in Europe and the United States, whereas there are very limited redesigned clothing brands in high-consumption countries.

Based on the literature regarding up-cycling design, the waste caused by fashion is increasing and has become the second largest source of pollution in the world. The major reason is that fashion is updated faster and faster due to the improvement of the clothing industry and consumption power. Although the number of published articles increased, the research contents and methods have not advanced in recent years. Most of the studies focused on clothing products and did not consider users' experiences. Only 5 of 32 papers considered the investigation and validation of design methods for consumers. Thus, further studies should combine fashion redesign with consumer demands.

Timeless Style Design

A timeless style can be achieved through minimalist design, classical design, genderless style, and cultural design (Goldsworthy et al., 2018). The selection of traditional elements mostly depends on the cultural heritage of the country, such as traditional fabrics and craftsmanship in China. Although modern clothing has been designed using traditional elements, incorporating of traditional elements into sustainable fashion design has been discussed intensely in recent years. In addition, classical style, minimalist style, and genderless style are also mentioned, which have been proven to be more timeless and lasting fashion styles. Furthermore, classic clothing style is more timeless and sustainable, including the works of Alexander van Slobbe, the use of personalized low-frequency, and the application of golden geometry and the Fibonacci geometric elements in fashion (Maldini et al., 2019). Suárez et al. (2023) concluded that minimalism can reduce incentives to discard clothing through lots of interviews and market investigations with company and consumer representatives, allowing us to accurately capture the sustainable fashion style. Reis et al. (2022) also constructed the genderless style design theory by using the triangulation method.

Digital Design

Digital design refers to the applications of digital technologies (i.e., 3D and AI) in clothing design (Akram et al., 2022) due to reduction in energy consumption, faster and more accuracy, and more resource efficiency, which is a more sustainable way to design using the python language and the AI approach (Lee, 2022). The 3D technology has been applied in clothing design of sustainable fashion since 2009. Compared with traditional clothing design, it is more efficient, personalized, and has low energy consumption (Kang et al., 2021). The 3D clothing design technology has been largely enhanced by using machine learning and deep learning algorithms. Through users' personalized demands and genetic algorithms, the 3D software can help designers quickly provide high-quality personalized designs for users. Wang et al. (2023) used a machine learning algorithm to realize a new interactive design method for sustainable fashion customized clothing, allowing designers to provide consumers with high-quality personalized design solutions through the combinations of artificial neural network, genetic algorithm, probabilistic neural network, and supporting vector regression. In addition, Deng et al. (2023) used the artificial intelligence tool named the Multimodal Unsupervised Image to Image Translation algorithm to generate diverse and fashionable designs, thereby enriching the uniqueness of national costumes and synergistically integrations of traditional craft methods and modern technology. Finally, digital design has also developed new design processes, such as digital printing and laser engraving. Compared with traditional manufacturing processes, digital processes have greatly improved manufacturing efficiency and have been widely used in the market.

Better quality

Technological development has led to diverse directions in smart clothing design, such as health monitoring, sports benefits, fitness tracking, and social activities (Muhammad Sayem et al., 2020). Some clothes with medical functions bring great convenience to patients and the elderly, and designed clothes using bio-sensors can monitor electrocardiograms (Sundaram et al., 2019). In addition to smart clothing, clothing materials have shown better quality in recent years. In this field, it mainly serves both aesthetic and functional aspects. In terms of aesthetics, 3D printing technology is mainly used to design fabrics with originality, personalized style, or additional decorative functions (Lekeckas et al., 2023). Regarding functions, the primary focus is on cooling or heat preservation, self-cleaning fabrics, dyeing capabilities, flame-retardant fabrics, UV protection, etc.

Most studies showed that garment quality is the main reason for its short lifespan (Goworek et al., 2020). The main quality problems with garments are fading and pilling, and researchers must improve the quality of garments by improving dye formulations and strengthening the quality testing process (Cooper & Claxton, 2022). However, some studies have proposed that it is very difficult to form management standards due to differences in business culture, operating practices, and knowledge between companies. Apart from pre-consumption quality management, after-sales service is much more important than before-sales quality standards for extending garment lifetime. Some studies also showed that the main reason people discarded clothing was out of fashion. Garment products are unique, and their lifespan depends not only on their material properties but also on their ideology. Extending the user's time with a product is often related to the emotional strength of the product by consumers (Wu et al., 2021). Currently, there are some ways to create more emotionally valuable products based on consumer personalization. For example, the emotional value of collaboratively designed clothing is along with a longer lifetime (Townsend et al., 2019), especially for custom-made clothing. The higher price of custom-made clothing than regular clothing has been one of the reasons why it has not been available for most consumers. However, decreased manufacturing costs and improved digital design technologies may lead to the better development of custom clothing in the future.

Flexible design

The flexible design with deformable product characteristics may be more adaptable, with two major strategies of multi-functional and transformable. Multi-functional garments have adhered to the design concept of "one thing for multiple uses, one garment for multiple wear" which achieves the multifunctionality of clothing and the purpose of sustainable fashion (Jalil & Shaharuddin, 2020). Users want clothing to be transformable from three aspects: functional, hedonic, and social; among the variable functions, the most popular ones are the deformation of color and sleeve length. Five of six documents on deformable clothing design are about modular design, showing that scholars consider modular design to be an important design method for realizing deformable clothing. Modular design has been proven to be one of the most effective sustainable fashion design methods. By using draping, folding, paneling, and gathering elements, the structure and style of a garment can be changed to enhance the flexibility of the product (Ibharim & Mohd Tajuddin, 2021). There are three kinds of modular design approaches: whole into parts, parts to the whole, and compounded modular between the two. Garments have been designed for children that can grow as they grow, from one size up to seven, which effectively reduces the number of garments that consumers must buy. Nevertheless, there are also some studies on slow fashion that goes beyond the single-user lifetime to multiple-user lifetime regarding one production (Goldsworthy et al., 2018), while it seems that it is far away from entering the market and be used by everyone for a long time. Thus, future studies need to develop flexible design theories to achieve sustainable fashion goals.

FUTURE DIRECTIONS

Although previous studies advance our understanding of sustainable fashion design, several aspects should be addressed in the future. First, many studies have shown that the most critical factor affecting the longevity of a garment is the quality of the garment; in contrast, few studies have been conducted on quality control and after-sales service of clothing. After-sales service can directly solve the problem of end-of-life of the product and help consumers improve the quality and prolong the lifespan of the fashion. Second, current studies are more subjective and less objective, and more descriptive and less quantitative, future studies need more objective and quantitative studies to accurately and effectively advance sustainable fashion design. Third, fashion messaging has become more populist and flattened (Kalbaska et al., 2019), while there is a gradual rise in fashion concepts (e.g., remaking) amongst a small section of the population. Remake fashion can effectively improve unsustainable fashion (O'Donnell & Pranger, 2020), and it is an inevitable trend based on the current fashion trends. This is demonstrated by the rapid popularity of vintage fashion and second-hand clothing (Michalowska, 2023).

CONCLUSION

In summary, this study systematically reviews the literature on past trends and future directions for sustainable fashion design through bibliometric analysis and systematic review. A conceptual framework for sustainable fashion design is developed, in which each sustainable fashion design method is categorized and organized into a circular process framework of sustainable fashion. Sustainable fashion design can be classified into four parts, including recycling, reducing wastage, reducing environmental impacts, and extending the lifespan of garments. This study also reviews and organizes the current state of studies, finding that the topic of slow fashion design is the most focused. Finally, remade fashion may be dominant in sustainable fashion design in the future.

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