

Sustainability in the fashion industry: A review of eco-friendly practices in apparel retailing

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Abstract Sustainability is becoming increasingly important in light of the significant societal and global issues that the fashion industry is facing. This review explores eco-friendly practices in apparel retail, focusing on materials, production processes, circular fashion, supply chains, and consumer engagement to reduce the industry's negative impact. The objective is to analyze these practices and identify effective strategies that apparel retailers can adopt. However, this review is limited by the availability of comprehensive global data and the rapidly evolving nature of technologies and regulations. Machine learning and deep learning methods are increasingly being utilized to enhance supply chain transparency, optimize production processes, and predict consumer behavior, contributing to more sustainable practices. Through a comprehensive analysis of market trends, the review revealed that sustainable practices can greatly benefit the environment, economy, and society. Despite challenges such as scalability, greenwashing, and the need for collaboration among stakeholders, integrating revolutionary technologies such as deep learning (DL) and machine learning (ML) is crucial for substantial progress in a sustainable manner.

Keywords: circular fashion, consumer engagement, eco-friendly plastics, sustainable fashion, machine learning (ML), apparel retailing

1. Introduction

The fashion business uses many resources and produces many types of trash and pollution, making it one of the greatest causes of environmental deterioration (Islam et al., 2021). As people throughout the world became more conscious of these problems, business sustainability became a crucial area of attention for both consumers and industry stakeholders (Sinha et al., 2023). This investigation aimed to identify environmentally friendly strategies for clothing retail. The goal was to reduce the destructive social and environmental impacts of the fashion industry (Chowdhury et al., 2022). Some of the problems that are dire for business include textile waste, chemical contamination, excessive water use, and unethical labor practices (Abbate et al., 2024).

The fast fashion model, which focuses on low prices and rapid production, often to the detriment of sustainability, further exacerbates these problems (Tran et al., 2022). Although many brands had begun to act sustainably, it was necessary to critically analyze the state of the industry and its impact because the scale and success of such initiatives were highly different (Pranta et al., 2024). Mass production using synthetic fabrics and resource-intensive processes has greatly affected the environment. These traditional practices often overlook the sustainability of the business in the long term, leading to the exhaustion of resources and environmental degradation (Younus et al., 2024). Moreover, many businesses have greenwashed or made false claims about their sustainability initiatives.

The thorough review of sustainable practices within different areas of clothing retail, such as materials, manufacturing processes, circular fashion, and consumer engagement, made this assessment unique. The review focused on examples of high-profile and promising sustainable companies that could be utilized to identify which strategies work and which areas could be improved by the sector (Gul & Ahmed, 2024). This method provided an itinerary for potential advances in industry as well as insights into the ecological impact of fashion at that time. To examine sustainable practices in clothing retailing, pinpoint efficient sustainability tactics, and evaluate the fashion industry's effects on the environment, the financial system, and the community.

2. Literature Review



The appropriate method for commencing this conversation to understand the history of sustainability was to examine the capacity of future generations to meet their requirements. Society and the environment are the two essential components of the sector of fashion (Thorisdottir & Johannsdottir, 2020). Time, space, and individuals were later incorporated as additional elements. With its four ecological system-supporting principles, it set a new standard for environmental consciousness, provides a clear explanation of sustainability in action, and outlines a roadmap for achieving sustainability. Figure 1 shows the value hierarchy in the fashion industry.

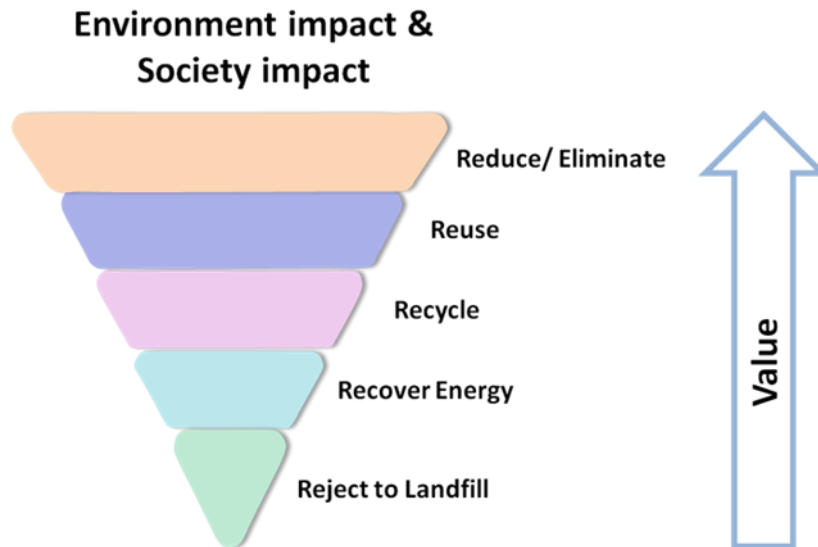


Figure 1 Value Hierarchy in the Fashion Industry. *Source:* Meegoda (2021).

2.1. Environment impact

In the textile industry, organic substances such as hemp, linen, cotton, rayon, silk thread, and cashmere extracts coexist with synthetic alternatives. Polyamide and acrylic, materials derived from petroleum-based chemicals, are the most commonly used synthetic fibers (Pérez et al., 2022). Most of the objects in inventories are composed of polyester, pliable, or Spandex. These low-cost, low-maintenance fibers have turned into the textile industry's magic bullet. However, they are difficult to recycle (nylon takes 30--40 years to degrade), and their manufacturing results in pollution. The textile and clothing industries employ a wide range of raw materials and manufacturing techniques. For each of the six processes that are typically required to create a garment, the negative environmental effects are numerous and varied.

2.2. Society impact

Trademark clothing that is sold in wealthy nations comes from all around the world, frequently from developing nations. This international trade could boost economies and give many people, mostly women, jobs that provide them with financial security and an opportunity to rise out of poverty (Minh & Ngan, 2021). However, there were issues with the process, such as recessions, low wages, poor worker rights (excessive hours, no contracts, inadequate health and safety), and child labor, which were evident in some nations. Aside from recruiting migrant labor from dry agricultural hinterlands, the garment industry was made possible by the increasing inclusion of women and children in the workforce, which served the industry's labor needs. The remarkable increase in the usage of female labor was an observation.

3. Ecologically Conscious Methods in Apparel Selling

To encourage the decrease or modification of consumer clothing habits that harm the environment and to create clothing that better fulfills consumer demands, green design goals for attention were created. A clothing item life cycle analysis (LCA) on green products, green consumers, and green consumerism, along with creative eco-friendly design techniques, was applied (Neupane et al., 2021). Seven eco-friendly clothing design objectives that addressed every facet of a garment's longevity, from materials to disposal, were the result. These objectives were centered on the two decisions that designers had the most power over: product designs and materials. Eco-friendly materials, less care, and effective ends are influenced by material selection. Figure 2 shows the important elements of the fashion industry's sustainable practices.

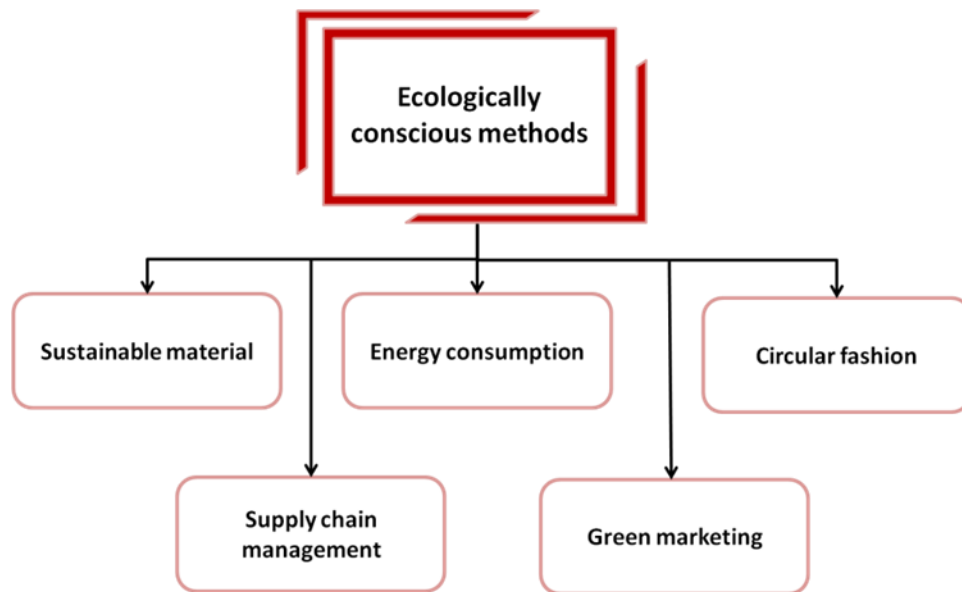


Figure 2 Important elements of fashion industry sustainable practices.

Clothing manufacturing requires the ecological effects of polyester yarn and polyester–cotton mixtures in recycled apparel (Abrishami et al., 2024). Petroleum-based rayon yarn is transformed into fabric through a complex manufacturing process that includes polymerization, twirling, and warping or crocheting. It is practical and enduring, but its predictable manufacturing routine uses many nonrenewable resources, which produce many conservatory gases and consume a large amount of energy.

3.2. Energy consumption

The world's extensive network of fabric and clothing creation, manufacturing, consumption, and disposal involves 430 million people who work, sometimes voluntarily and other times reluctantly (Leal Filho et al., 2024). This extremely sophisticated mode of accumulation, fabrication, and utilization tended to benefit only a minority of people more than the majority. The global textile market is projected to reach a retail sales value of 3 trillion by 2030. However, there are demands for the industry to transmit these benefits and implement significant changes to concentrate its efforts on operations.

3.3. Circular fashion

The tool was intended to assist design entrepreneurs and smaller enterprises; however, it was devoid of important environmental performance metrics that were pertinent to larger companies (Dissanayake & Weerasinghe, 2022). The selection of materials and design procedures is crucial for implementing sustainable practices from the perspectives of resource conservation and organic principles for certified and recycled materials and for conducting evaluations that enhance the planet's resilience. Additionally, the life cycle sustainability of products was significantly improved by employing eco-design, cradle-to-cradle, and circular fashion concepts. However, opinions on how design could mitigate environmental effects were indeed divided.

3.4. Supply chain management

The process of creating an ecologically friendly supply network is known as "green supply chain management." Environmental considerations had to be incorporated into supplier relationships and purchasing decisions. By encouraging resource reuse and decreasing waste production by discouraging single use and disposal, many businesses have moved toward a green supply chain (Huskey & Cho, 2022). There are advantages and difficulties in developing sustainable supply networks. Certain businesses employed reverse logistics, which concentrated on handling a product at the end of its existence through recycling or rehabilitation into the system.

3.5. Green marketing

The growing consumer awareness of sustainability and the emergence of a green economy have made green marketing an essential tool for businesses in a variety of sectors, including fashion, to obtain an intellectual property advantage (Badhwar et al., 2024). Reducing a product's environmental impact through a sustainable manufacturing process redesign and carefully considering marketing efforts is known as "green marketing." Its objectives were to address the growing demand for sustainable

consumption while promoting natural resources and attracting customers who appreciate a green lifestyle, the primary focus of green marketing.

- Enhancing Consumer Behavior Forecasting for Sustainability:

While using the ML and DL approaches, companies can not only analyze patterns but also estimate people's values and their need for eco-friendly goods. This ensures that there is a better way of producing products and of making better products on the production line that reflect the sustainability profile expected by consumers in the market. Predictive analytics is capable of bringing out patterns, especially toward environmentally friendly preferences, thus leading to sustainable products and enhanced conformity to environmental objectives. When consumers' behaviors are understood, brands can create goods that are likely to have longevity and be recycled or repurposed, which is a long way from addressing the circular fashion system.

4. Sustainable Fashion Brand

A potential replacement for fast fashion was sustainable fashion, sometimes referred to as "slow fashion," which had resurfaced. The precise meaning of sustainable or slow fashion is yet unclear, even though it is frequently mentioned in the media and even in the literature (Busalim et al., 2022). Compared with fast fashion, "creators, clients, sellers, and purchasers were more aware of the impacts of products on employees, neighborhoods, and ecosystems." Traditional fashion was similar to the concept of "slow food," which extended the life of clothing through high quality, even though it was more concerned with quality than time. Figure 3 shows the sustainable consumption structures in fashion.

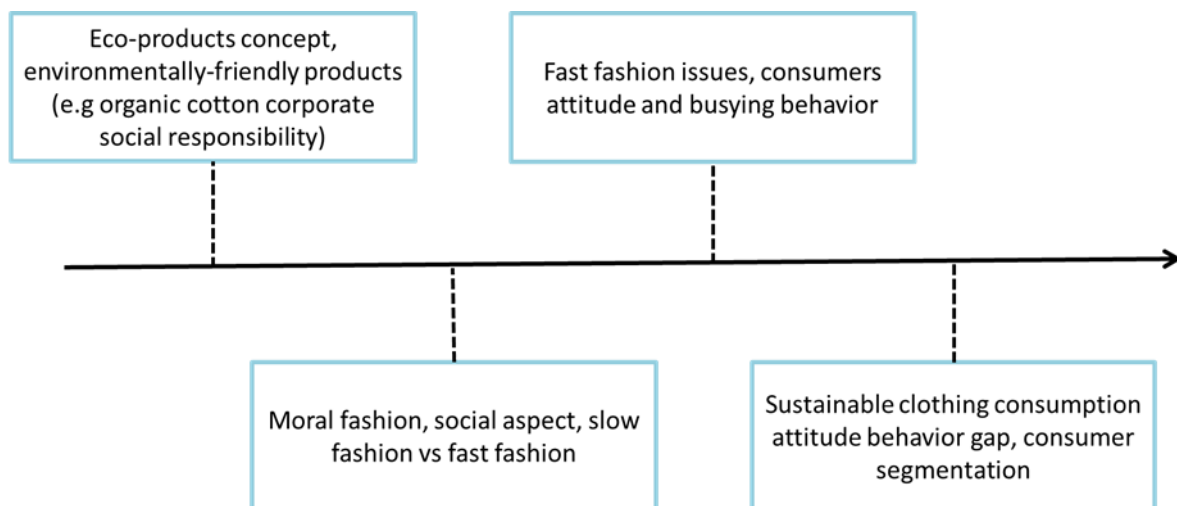


Figure 3 Sustainable consumption structures in fashion. Source: Busalim (2022).

4.1. Emerging sustainable brands

Sustainable fashion was sometimes referred to as an oxymoron since, unlike sustainability's long-term outlook, fashion as a whole controlled what was in or out of style. This also explained why consumers were skeptical of sustainable fashion manufacturers since they thought the phrase was ambiguous (Mandarić et al., 2022). The industry's environmentally damaging supply chain practices have drawn increasing attention. However, the industry continues to grow despite well-known adverse environmental effects, which depend on short-term clothing, occasional usage, and low-cost production. Beyond a passing trend, sustainable fashion takes into account economic, social, and environmental costs.

4.2. Sustainable fashion consumption behavior

According to Balasubramanian and Sheykhmaleki (2024), consumer behavior is the process by which individuals or groups select, pay for, use, or discard products, services, ideas, or experiences to meet their needs and preferences. Consumption appears in an extensive range of forms, with demands and objectives ranging from authority and companionship to spiritual fulfillment and bodily sustenance. In general, consumers were defined as those who identified a need or desire, purchased a product to satisfy it, and then threw it away as part of the consumption process. Consumer involvement refers to a customer's interest in a specific product or area.

- Optimizing Production:

Applying machine learning algorithms over the organization's historical large production datasets is another way of increasing the accuracy of demand prediction and therefore helps to avoid overproduction and the development of inventory. Every company's strategic plans should involve maximizing resource utilization to minimize the consumption of materials,

energy, and working time. For example, in factories, DL can also improve processes and discern where more energy should be saved, or the processes should be optimized.

4.3. Apparel consumption behavior

Customers often prioritized being trendy over purchasing clothing made ecologically because they valued the freedom to express themselves via their wardrobe. The conflict between efforts to reduce consumption and the need for it serves as an example of this (Byrd & Su, 2021). This internal dispute resulted from a lack of information about the environmental damage caused by the disposal of used clothing. Furthermore, the gap between consumers' views and actions was caused by other factors that had greater drawbacks in terms of their purchasing decisions.

4.4. Strong relationship of fashion brands

Customers were more conscious of the link between recycled materials and products. They were aware of materials, natural fibers, secondhand materials, and businesses that used sustainable business models adhering to good social and environmental standards (Paço et al., 2021). The respondents knew the least about the connection between leather goods and sustainable fashion. It also indicated that, despite environmental concerns, the majority of consumers preferred that sustainable clothes cost the same as traditional fast fashion and were unwilling to pay more for products from sustainable fashion brands.

5. Technological Advancements in Sustainability

5.1. Supply chain transparency

ML and DL models are capable of monitoring each supply chain process and making predictions from the source of material through the ordering of components, production, shipment, and delivery of the final product. These technologies enable the examination of large volumes of data generated by suppliers, logistics, and retailers to understand the movement of products to ensure that companies as well as their suppliers stick to the right standards of production and delivery while seeking to use minimal resources and emit less carbon. They can determine areas of waste, monitor carbon footprints, and protect labor rights, which are vital parts of the sustainability management of the supply chain.

- Predicting Consumer Behavior:

ML and DL techniques can potentially capture and analyze consumer purchasing patterns, preferences, and behavior. This leads to effective brand planning since branding assesses future trends and potential demands in the market, and brands adjust their production and marketing processes without causing a buildup of unsold supply. This reduces waste and allows retail strategies to target suitable and sustainable retail products that society deems appropriate with respect to trends and values related to sustainability.

5.2. Impact on sustainability

- Reducing Waste:

These technologies reduce waste in various ways. More precise demand projections prevent overproduction, which reduces the amount of surplus inventory and, eventually, waste. In addition, by focusing on supply chain procedures, which reduce work-in-process inventories, manufacturers reduce demand for resources.

- Improving Efficiency:

The ML and DL models contribute principally to improved resource utilization in each stage of the value chain. For example, they can influence the efficient utilization of energy and raw materials in the manufacturing cycle. In transportation and logistics, they assist in reducing fuel consumption by identifying the most appropriate delivery routes, thereby reducing the impact of the firm on the environment.

6. Performance of Predictive Models in Sustainability

Table 1 shows that forecasting environmentally friendly and sustainable fashion retailing outcomes was encouraging. The maximum accuracy was achieved by the neural network (0.716), with precision and recall values of 0.714 and 0.724, respectively. This demonstrates how well they comprehend intricate consumer behavior and advocate for environmentally sustainable product choices. With an accuracy of 0.884, the K-nearest neighbor (KNN) method has been shown to be able to guarantee sustainable and pertinent product selection on the basis of content attributes such as fabric composition and environmental impact. In contrast, with the highest AUC of 91%, the random forest method demonstrated value in forecasting returns and detecting sustainable purchasing habits, enabling businesses to minimize waste and maximize inventory, which are two crucial aspects of sustainability.

Table 1 Comparison of ML algorithms in fashion retail and recommendation systems.

ML Algorithm	Scope of Application	Significant Findings	Drawbacks	Result
Neural Network (Satinet & Fouss, 2022)	Fashion recommendation system using collaborative filtering	Achieved a high recommendation accuracy by learning complex patterns from user behavior, improving personalization.	Requires large datasets for training and can be prone to overfitting if not tuned properly.	Accuracy: 0.716 Precision: 0.714 Recall: 0.724 AUC: 91%
KNN (chakraborty et al., 2021)	Fashion item recommendation using content-based filtering	Achieved improved item similarity rankings by encoding both visual and textual features.	May struggle with high-dimensional data and requires careful tuning to avoid overfitting.	
Random forest (Giri & Chen, 2022)	Predicting returns and customer preferences in fashion retail	High accuracy in predicting returns and identifying important customer features that influence purchasing behavior.	May be prone to overfitting if too many trees are used and lack interpretability compared to simpler models.	Accuracy: 0.91 MSE: 0.11

7. Conclusion

According to this evaluation, sustainable methods can greatly lessen the negative effects that the fashion industry has on the environment and society. Fashion retailers might help create a more sustainable future by emphasizing ethical supply chains, eco-friendly materials, circular fashion, and effective production techniques. By increasing transparency, maximizing resource utilization and forecasting customer demand, machine learning, and deep learning techniques further strengthened these initiatives. Nonetheless, difficulties such as scalability issues, greenwashing, and the requirement for industry-wide cooperation were indeed present. Overcoming these obstacles requires consumer education, awareness, and strong regulatory frameworks. To improve data-driven sustainability initiatives, further investigations should concentrate on incorporating the latest innovations into every phase of fashion manufacturing and distribution. Furthermore, investigating international case studies and designing sustainability models that are applicable everywhere would have been essential to generating scalable solutions for the fashion sector.

Ethical Considerations

Not applicable.

Conflict of Interest

The authors declare no conflicts of interest.

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References

- Abbate, S., Centobelli, P., Cerchione, R., Nadeem, S. P., & Riccio, E. (2024). Sustainability trends and gaps in the textile, apparel and fashion industries. *Environment, Development and Sustainability*, 26(2), 2837–2864. <https://doi.org/10.1007/s10668-022-02887-2>
- Abrishami, S., Shirali, A., Sharples, N., Kartal, G. E., Macintyre, L., & Doustdar, O. (2024). Textile recycling and recovery: An eco-friendly perspective on textile and garment industries challenges. *Textile Research Journal*, 94(23–24), 2815–2834. <https://doi.org/10.1177/00405175241247806>
- Badhwar, A., Islam, S., Tan, C. S. L., Panwar, T., Wigley, S., & Nayak, R. (2024). Unraveling green marketing and greenwashing: A systematic review in the context of the fashion and textiles industry. *Sustainability*, 16(7), 2738. <https://doi.org/10.3390/su16072738>
- Balasubramanian, M., & Sheykhmaleki, P. (2024). Comprehending the consumer behavior toward sustainable apparel. *Sustainability*, 16(18), 8026. <https://doi.org/10.3390/su16188026>
- Busalim, A., Fox, G., & Lynn, T. (2022). Consumer behavior in sustainable fashion: A systematic literature review and future research agenda. *International Journal of Consumer Studies*, 46(5), 1804–1828. <https://doi.org/10.1111/ijcs.12794>
- Byrd, K., & Su, J. (2021). Investigating consumer behaviour for environmental, sustainable and social apparel. *International Journal of Clothing Science and Technology*, 33(3), 336–352. <https://doi.org/10.1108/IJCS-03-2020-0040>
- Chakraborty, S., Hoque, M. S., Rahman Jeem, N., Biswas, M. C., Bardhan, D., & Lobaton, E. (2021). Fashion recommendation systems, models and methods: A review. *Informatics*, 8(3), 49. <https://doi.org/10.3390/informatics8030049>
- Chowdhury, N. R., Chowdhury, P., & Paul, S. K. (2022). Sustainable practices and their antecedents in the apparel industry: A review. *Current Opinion in Green and Sustainable Chemistry*, 37, 100674. <https://doi.org/10.1016/j.cogsc.2022.100674>
- Dissanayake, D. G. K., & Weerasinghe, D. (2022). Towards circular economy in fashion: Review of strategies, barriers and enablers. *Circular Economy and Sustainability*, 2(1), 25–45. <https://doi.org/10.1007/s43615-021-00090-5>



- Giri, C., & Chen, Y. (2022). Deep learning for demand forecasting in the fashion and apparel retail industry. *Forecasting*, 4(2), 565–581. <https://doi.org/10.3390/forecast4020031>
- Gul, S., & Ahmed, W. (2024). Enhancing the theory of planned behavior with perceived consumer effectiveness and environmental concern towards pro-environmental purchase intentions for eco-friendly apparel: A review article. *Bulletin of Business and Economics*, 13(1). <https://doi.org/10.61506/01.00270>
- Huskey, M., & Cho, E. (2022). Exploring small fashion retailers' green efforts in supply chain management and coping strategies during COVID-19. *Journal of Family & Consumer Sciences*, 114(4), 16–27. <https://doi.org/10.14307/JFCS114.4.16>
- Islam, M. M., Perry, P., & Gill, S. (2021). Mapping environmentally sustainable practices in textiles, apparel and fashion industries: A systematic literature review. *Journal of Fashion Marketing and Management: An International Journal*, 25(2), 331–353. <https://doi.org/10.1108/JFMM-07-2020-0130>
- Leal Filho, W., Dinis, M. A. P., Liakh, O., Paço, A., Dennis, K., Shollo, F., & Sidsaph, H. (2024). Reducing the carbon footprint of the textile sector: An overview of impacts and solutions. *Textile Research Journal*, 94(15–16), 1798–1814. <https://doi.org/10.1177/00405175241236971>
- Mandarić, D., Hunjet, A., & Vuković, D. (2022). The impact of fashion brand sustainability on consumer purchasing decisions. *Journal of Risk and Financial Management*, 15(4), 176. <https://doi.org/10.3390/jrfm15040176>
- Meegoda, J. N., Watts, D., Hsieh, H. N., & Bezerra de Souza, B. (2021). Community-based pollution prevention for two urban cities: A case study. *Clean Technologies*, 3(1), 59–78. <https://doi.org/10.3390/cleantechnol3010004>
- Minh, N. T., & Ngan, H. N. (2021). Vegan leather: An eco-friendly material for sustainable fashion towards environmental awareness. *AIP Conference Proceedings*, 2406(1), 060019. <https://doi.org/10.1063/5.0066483>
- Neupane, S., Chimhundu, R., & Kong, E. (2021). Strategic profile for positioning eco-apparel among mainstream apparel consumers. *Journal of Global Fashion Marketing*, 12(3), 229–244. <https://doi.org/10.1080/20932685.2021.1915836>
- Paço, A., Leal Filho, W., Ávila, L. V., & Dennis, K. (2021). Fostering sustainable consumer behavior regarding clothing: Assessing trends on purchases, recycling, and disposal. *Textile Research Journal*, 91(3–4), 373–384. <https://doi.org/10.1177/0040517520944524>
- Pérez, A., Collado, J., & Liu, M. T. (2022). Social and environmental concerns within ethical fashion: General consumer cognitions, attitudes, and behaviors. *Journal of Fashion Marketing and Management: An International Journal*, 26(5), 792–812. <https://doi.org/10.1108/JFMM-04-2021-0088>
- Pranta, A. D., Rahaman, M. T., Repon, M. R., & Shikder, A. A. R. (2024). Environmentally sustainable apparel merchandising of recycled cotton–polyester blended garments: Analysis of consumer preferences and purchasing behaviors. *Journal of Open Innovation: Technology, Market, and Complexity*, 10(3), 100357. <https://doi.org/10.1016/j.joitmc.2024.100357>
- Satinet, C., & Fouss, F. (2022). A supervised machine learning classification framework for clothing products' sustainability. *Sustainability*, 14(3), 1334. <https://doi.org/10.3390/su14031334>
- Sinha, P., Sharma, M., & Agrawal, R. (2023). A systematic review and future research agenda for sustainable fashion in the apparel industry. *Benchmarking: An International Journal*, 30(9), 3482–3507. <https://doi.org/10.1108/BIJ-02-2022-0142>
- Thorisdottir, T. S., & Johannsdottir, L. (2020). Corporate social responsibility influencing sustainability within the fashion industry: A systematic review. *Sustainability*, 12(21), 9167. <https://doi.org/10.3390/su12219167>
- Tran, K., Nguyen, T., Tran, Y., Nguyen, A., Luu, K., & Nguyen, Y. (2022). Eco-friendly fashion among generation Z: Mixed-methods study on price value image, customer fulfillment, and pro-environmental behavior. *PLOS ONE*, 17(8), e0272789. <https://doi.org/10.1371/journal.pone.0272789>
- Younus, M., Pathan, S. H., Amin, M. R., Tania, I., & Ouboucetta, R. (2024). Sustainable fashion analytics: Predicting the future of eco-friendly textile. *Global Mainstream Journal of Business, Economics, Development & Project Management*, 3(3), 13–26. <https://doi.org/10.62304/jbedpm.v3i03.85>