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# Using Bio-Sustainable Materials in Clothing Design: An Analysis of Environmental and Cultural Impacts in Different Societies

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**Abstract**

The present study aims to explore the use of bio-sustainable materials in contemporary clothing design and to analyze their environmental and cultural impacts across different societal contexts. This research follows an applied approach and employs a survey-based methodology for data collection. The statistical population consists of experienced experts and active professionals in the clothing and textile industry in Mazandaran Province, Iran. From this population, a targeted sample of ten participants was selected.

Data were collected using a researcher-designed questionnaire and analyzed through the Analytic Hierarchy Process (AHP) method. The findings indicate that reduced energy and water consumption, minimization of textile waste and environmental pollutants, positive impacts on ecosystems, and reduced greenhouse gas emissions are the most significant priorities, respectively. Based on these results, the study emphasizes the importance of using durable, high-quality fibers and fabrics that maintain performance through repeated use and washing, thereby extending garment lifespan and reducing replacement rates. Additionally, the study highlights the value of timeless design approaches that enhance long-term functionality and sustainability in clothing.

**Keywords :**Sustainability; Environmental Impact; Cultural Impact; Clothing Design

## 1. Introduction

Growing attention to environmental and sustainability issues in the fashion industry has led to an increasing body of research focused on evaluating the use of bio-sustainable materials and examining their environmental, cultural, and economic impacts across different communities. This study addresses an existing gap in the literature by offering a multi-faceted analysis of these impacts (Dieguez et al., 2024). The findings may support designers, manufacturers, and policymakers in making informed decisions aligned with sustainable development goals within

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the clothing industry, thereby encouraging broader adoption of bio-sustainable materials (Vrablikova et al., 2024).

Bio-sustainable materials, particularly bio-based polymers, are engineered to maintain structural integrity and functional performance under various environmental conditions, including biological and soil environments. Such materials are especially significant in applications requiring long-term durability, such as biomedical devices and environmental systems (Mantrova, 2021). In the context of clothing design, bio-sustainable materials represent a transformative shift toward fashion practices that prioritize eco-friendly and biodegradable resources. This transition responds to the growing need to reduce reliance on synthetic fibers and to promote sustainability within the fashion industry.

Research into biopolymers, natural fibers, and innovative materials such as bacterial cellulose demonstrates the potential for garments that combine functionality with environmental compatibility (Antunes et al., 2024). Nevertheless, challenges including high production costs and limited accessibility in certain regions contribute to ongoing debates regarding the practical implementation of these materials (Aatamila, 2023). While some studies highlight materials such as organic cotton and recycled polyester as sustainable alternatives, questions remain regarding their overall environmental performance, as their production

## 2. Literature Review

Key bio-based materials used in clothing design include biopolymers and natural fibers, which are derived from plants and microorganisms and offer sustainable alternatives to conventional textiles. For example, polyester-based biopolymers and natural fibers can be integrated into clothing designs to enhance overall sustainability (Ferreira et al., 2023). Previous studies have demonstrated the feasibility of materials such as sodium alginate and corn starch, highlighting properties including water resistance and flexibility, as well as their respective strengths and limitations, which can inform designers' material selection processes (Barauna et al., 2022).

Bacterial cellulose represents another significant bio-based material with considerable potential for clothing applications. Research indicates that it can be used to produce nonwoven fabrics suitable for apparel, owing to its favorable mechanical properties and environmental compatibility. These characteristics position bacterial cellulose as a promising candidate for sustainable fashion and textile innovation.

Sustainable clothing design seeks to minimize environmental impacts throughout the entire garment life cycle by emphasizing waste reduction, efficient use of resources, and the adoption of environmentally friendly materials. Core strategies in this approach include zero-waste pattern design, the selection of sustainable materials, and the implementation of energy-efficient manufacturing processes (Popescu et al., 2024). Zero-waste pattern design, in particular, aims to maximize fabric utilization and has been shown to reduce textile waste sent to landfills by up to 13% compared to conventional pattern-making methods (Ding, 2024).

The choice of eco-friendly materials—such as renewable, recycled, or biodegradable fibers—is also critical for reducing the environmental footprint of clothing products. In addition, the application of circular economy principles, including recycling and reuse, further contributes to sustainability and improved resource efficiency within the fashion industry (Ma et al., 2024). Energy-efficient production methods support global carbon reduction objectives and require close collaboration with environmentally responsible suppliers, as well as transparent and traceable supply chains (Ding, 2024; Ma et al., 2024).

Despite the numerous advantages associated with sustainable fashion, significant challenges remain, particularly with regard to widespread industry adoption and consumer acceptance. Overcoming these barriers is essential for the long-term success and scalability of sustainable fashion initiatives (Busalim et al., 2022). Key drivers that support the advancement of sustainable clothing design include growing consumer demand for environmentally friendly products, ongoing innovation in sustainable materials, and effective collaboration across the fashion supply chain (Ray et al., 2023)

Rad (2023) conducted a study entitled "Bio-Sustainable Approaches with an Examination of Aesthetic Discourses in Fashion and Clothing Design." This research conceptualizes design in its broadest sense as a means of shaping the surrounding world. According to the study, designers' decisions not only define the distinctive characteristics of products but also, on a broader level, influence how human needs are addressed and how life structures are organized. Design is presented as a critical force that challenges the status quo by responding to environmental, social, and economic issues and by proposing innovative pathways to compensate for past unsustainable practices.

The study highlights the significant role of designers in educating consumers about production conditions, thereby reshaping aesthetic perceptions and contributing to social transformation. Consumer awareness is identified as a key variable influencing the willingness to purchase sustainable products. Rad (2023) emphasizes the importance of fostering ethical and environmentally conscious values among consumers, encouraging greater recognition of environmental resources and humanitarian principles. Overall, contemporary design attitudes are described as encompassing two main dimensions: the use of environmentally friendly materials and the transformation of aesthetic culture toward ethical production processes and post-consumption practices.

Jorjani et al. (2023) conducted a study entitled "Sustainable Clothing Design for Girls Using Agricultural Waste and Textile Scraps (Case Study: Faculty of Art, Semnan University)." The findings indicated that all elements of the designed coats, with the exception of body-fit attributes, were accepted by the participants. Furthermore, participants' awareness of sustainable clothing principles had a positive effect on their level of satisfaction with the designs. These results underscore the importance of education and structured planning in promoting sustainable clothing design practices.

Gorgondi et al. (2023) investigated "Sustainable Fashion in Clothing and the Use of Emerging Technologies for Environmental Preservation." The study identifies the fashion and clothing industry as the second most polluting industry globally after the oil sector. Fast fashion is highlighted as a major contributor to environmental degradation due to excessive consumption of water, fibers, chemical dyes, energy, and the generation of large volumes of waste. In response, sustainable fashion is presented as an alternative approach aimed at supporting environmental preservation. The research focuses on the role of emerging technologies in advancing sustainability, including waterless dyeing techniques, 3D design and printing technologies, and textile recycling processes. The study employed a qualitative descriptive–analytical methodology, relying on library-based resources for data collection.

Ma et al. (2024) conducted a study entitled "Sustainability in Design: Sustainable Fashion Design Practices and Environmental Impact Using Hybrid Analysis." The findings revealed significant improvements in environmental performance indicators among fashion companies that implemented sustainable design practices, demonstrating a direct relationship between such practices and reduced carbon footprints. The study identified key drivers encouraging fashion businesses to invest in innovative sustainable design solutions, particularly in response to sustainability challenges and increasing consumer demand for environmentally friendly products. Collaboration with environmentally responsible suppliers and the adoption of transparent supply chain practices were recognized as critical factors in effectively addressing sustainability challenges. Furthermore, the integration of circular economy principles, such as recycling and reuse, was emphasized as a key strategy for enhancing environmental performance within the fashion industry. By combining practical insights with theoretical reflections, the study contributes meaningfully to the discourse on sustainable fashion and provides guidance for industry stakeholders, policymakers, and researchers.

Gomes et al. (2024) presented a study titled "Empowering Eco-Friendly Choices: A Decision Support System for Evaluating the Environmental Impacts of Textiles and Apparel." The research developed a decision-support system that integrates a set of environmental performance indicators, enabling producers to assess the environmental impacts of textile and clothing production processes. Based on the evaluation results, the system assigns environmental labels that allow consumers to compare products according to their ecological performance. Overall, the study supports environmentally informed decision-making for both producers and consumers, thereby promoting sustainable practices within the textile and apparel industries. The proposed system is designed to be flexible and adaptable, allowing various companies to tailor it to their specific needs and improve overall environmental performance.

Overdijk (2024) examined "Sustainable Clothing Consumption: Integrating Behavior Change Frameworks into a Step-by-Step Design Process for Environmental Impact." The study acknowledges that prevailing clothing consumption patterns exert substantial negative impacts on the environment and argues that behavioral change among consumers is essential to mitigating these effects. To address this issue, a step-by-step design methodology was developed, drawing on established behavior change frameworks and theories. This methodology was applied to create intervention concepts aimed at reducing barriers to sustainable clothing consumption among Frisian consumers. Insights gained throughout the project were subsequently used to refine and improve the proposed design approach.

Farghaly et al. (2024) conducted a study entitled “The Impact of Fast Fashion on Sustainability and Eco-Friendly Practices in the Fashion Design World.” The study contributes to the existing body of knowledge on sustainability in textile and apparel production and consumption. It emphasizes that efforts to promote sustainability within the textile and clothing industry must prioritize the transition toward eco-friendly materials and the resolution of ethical concerns related to production processes. Nevertheless, the study highlights that prevailing business models in the fashion industry continue to rely heavily on high-volume production and accelerated sales cycles.

The research examined several design strategies currently implemented within niche markets, evaluating consumer interest in these approaches. Furthermore, it discussed the potential of these strategies to support sustainable development by generating new forms of value within the textile and clothing industry. By critically addressing the tension between fast fashion models and sustainable design practices, the study underscores both the challenges and opportunities associated with integrating eco-friendly and ethical considerations into contemporary fashion systems.

## 3. Conceptual Model and Research Methodology

### 3.1. Conceptual Model

The conceptual model for this study was developed based on components extracted from the literature review, as summarized in Table 1 and illustrated in Figure 1. These components are organized under two primary dimensions: the environmental impacts and the cultural impacts of utilizing bio-sustainable materials in clothing design.

The specific components identified through the review of existing research are detailed in Table 1 and visually represented in Figure 1, providing a structured framework for examining the multifaceted effects of bio-sustainable material adoption in the fashion and clothing industry.

**Table1:** A component extracted from the research literature

| Symbol | Next | Symbol | Component |
|---|---|---|---|
| **C1** | Environmental impacts of using bio-sustainable materials in clothing design | S11 | Positive impacts on ecosystems |
| | | S12 | Low volume of textile waste and environmental pollutants |
| | | S13 | Reducing energy and water consumption |
| | | S14 | Reducing greenhouse gas emissions |
| | | S15 | Reducing textile waste |
| | | S16 | Environmentally friendly production processes |
| | | S17 | Biodiversity loss and climate change |
| | | S18 | Reducing carbon footprint |

| Symbol | Next | Symbol | Component |
|---|---|---|---|
| **C2** | Cultural Impacts of Using Bio-Sustainable Materials in Clothing Design | S21 | Raising awareness about environmental destruction caused by the clothing industry, |
| | | S22 | Promoting the use of indigenous natural fibers |
| | | S23 | Promoting a culture of green consumption and strengthening sustainable perspectives |
| | | S24 | Positive changes in attitudes and behaviors |
| | | S25 | Sustainability refers to the ability of a system to maintain itself and meet current needs without harming future generations. |
| | | S26 | The positive impact of new products and processes on culture, customs, and traditions |

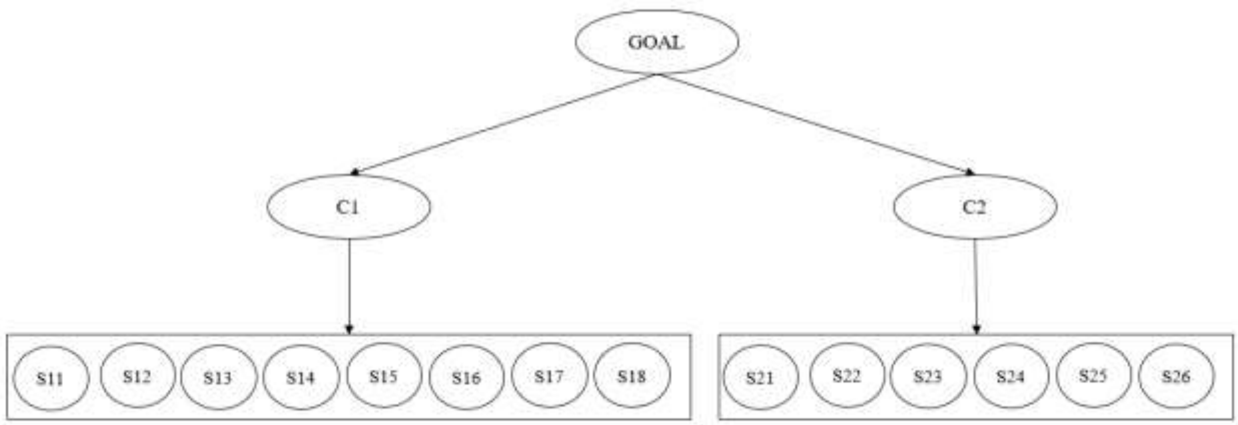


**Figure2:** Conceptual research model

## 4. Research Methodology

This study adopts an applied research approach and employs a survey-based methodology. The statistical population consists of experts and professionals working within the clothing industry in Mazandaran Province, Iran. A targeted sample of ten participants was selected using the snowball sampling technique. Data were collected through a researcher-designed questionnaire and subsequently analyzed using the Analytic Hierarchy Process (AHP) method.

### 5.1. Consistency Ratio (Reliability Measurement)

The consistency ratio (CR) of the research was calculated using the following formulas.

$$WSV = [M] \times [W] \quad [1]$$

$$L = \frac{1}{n}\left[\sum_{i=1}^{n}\left(\frac{MW_i}{W_i}\right)\right] \quad [2]$$

$$CI = \frac{\lambda_{max} - n}{n - 1} \quad [3]$$

If the CR value is equal to or less than 0.1, the comparisons are considered consistent. The formula is expressed as follows:

$$CR = CI / RI \quad [۴]$$

where CI denotes the Consistency Index and RI represents the Random Index. This evaluation ensures the reliability and consistency of expert judgments in the AHP analysis.

## 5. Findings

Respondents' demographics including gender, education, and work experience It is given in Table2.

**Table2:** Demographic statistics

| Gender | Abundance | Percentage of frequency | Cumulative abundance percentage |
|---|---|---|---|
| **Man** | 9 | 90 | 90 |
| **Woman** | 1 | 10 | 100 |
| **Total** | 10 | 100 | |
| **Education** | Abundance | Percentage of frequency | Cumulative abundance percentage |
| **Bachelor's deg.** | 3 | 30 | 30 |
| **Master's deg.** | 6 | 60 | 90 |
| **PhD** | 1 | 10 | |
| **Total** | 10 | 100 | 100 |

### 6.1. Delphi Technique

According to this technique, each member of the group was first given a questionnaire containing the desired sub-criteria. Then, experts in this field, who were selected from 10 experts and were familiar with all matters, examined each indicator according to the Delphi method. For the initial screening of the identified indicators, the assigned scores ranged from 1 to 5, and indicators with scores below 4 were eliminated. The Delphi technique continued in 3 steps.

**Table 3:** Summary of the results of the second step of the Delphi technique

| Status | Ave. | Experts | | | | | | | | | | Substandard |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Confirmation** | 4.5 | 5 | 5 | 5 | 5 | 4 | 3 | 5 | 3 | 5 | 5 | Positive impacts on ecosystems |
| **Confirmation** | 4.1 | 3 | 3 | 4 | 3 | ۵ | 3 | 5 | 5 | 5 | 5 | Low volume of textile waste and environmental pollutants |
| **Confirmation** | 4 | 4 | 3 | 4 | 4 | 5 | 5 | 3 | 5 | 3 | 4 | Reducing energy and water consumption |
| **Confirmation** | 4.1 | 4 | 4 | 5 | 4 | 3 | 5 | 3 | 5 | 3 | 5 | Reducing greenhouse gas emissions |
| **Confirmation** | 4.1 | 5 | 5 | 5 | 3 | 3 | 3 | 3 | 5 | 5 | 4 | Reducing textile waste |
| **Confirmation** | 4.1 | 5 | 5 | 3 | 4 | 4 | 3 | 5 | 5 | 4 | 3 | Environmentally friendly production processes |
| **Confirmation** | 4.2 | 5 | 3 | 5 | 4 | 4 | 4 | 4 | 3 | 5 | 5 | Biodiversity loss and climate change |
| **Confirmation** | 4.1 | 5 | 3 | 5 | 4 | 3 | 4 | 4 | 3 | 5 | 5 | Reducing carbon footprint |

**Table 3:** Summary of the results of the second step of the Delphi technique

| Status | Ave. | Experts | | | | | | | | | | Substandard |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Confirmation** | 4.2 | 5 | 5 | 3 | 5 | 5 | 4 | 5 | 3 | 4 | 3 | Raising awareness about environmental destruction caused by the clothing ,industry |
| **Confirmation** | 4 | 4 | 5 | 4 | 3 | 5 | 4 | 3 | 4 | 5 | 3 | Promoting the use of indigenous natural fibers |
| **Confirmation** | 4.1 | 5 | 3 | 5 | 3 | 5 | 3 | 3 | 5 | 4 | 5 | Promoting a culture of green consumption and strengthening sustainable perspectives |
| **Confirmation** | 3.6 | 4 | 4 | 3 | 3 | 4 | 3 | 4 | 4 | 3 | 4 | Positive changes in attitudes and behaviors |
| **Until then** | 4 | 4 | 5 | 3 | 3 | 5 | 3 | 4 | 5 | 5 | 3 | Sustainability refers to the ability of a system to maintain itself and meet .current needs without harming future generations |
| **Confirmation** | 4.1 | 4 | 5 | 5 | 3 | 5 | 3 | 4 | 4 | 3 | 5 | ,The positive impact of new products and processes on culture, customs and traditions |

Based on Table 3, all components are approved.

## 6.2AHP technique

### 6.2.1 Priority of main criteria based on objective

The pairwise comparison matrix resulting from the aggregation of experts' views is presented in Table 4.

**Table 4:** Pairwise comparison matrix of main criteria

| | **$C_1$** | **$C_2$** | **Geometric mean** | **Special vector** |
|---|---|---|---|---|
| C1 | 1 | 1.813 | 1.347 | 0.645 |
| C2 | 0.552 | 1 | 0.743 | 0.355 |

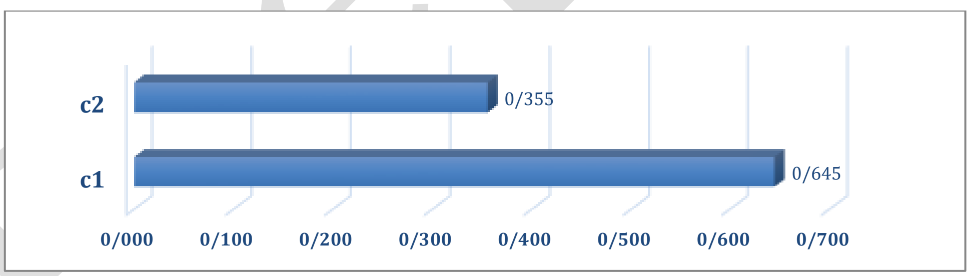


**Figure 2:** Graphical representation of the priority of the main criteria

Based on the calculated eigenvector, the prioritization of the research components is presented in Table 5.

**Table 5:** Prioritization of research components

| Criteria | Special vector | Prioritization |
|---|---|---|
| Environmental impacts of using bio-sustainable materials in clothing design | 0.645 | 1 |
| Cultural Impacts of Using Bio-Sustainable Materials in Clothing Design | 0.355 | 2 |

### 6.2.2. The following prioritization of environmental impact criteria for the use of bio-sustainable materials in clothing design:

The pairwise comparison matrix, derived from the aggregation of expert opinions, is presented in Table 6.

**Table 6:** Pairwise comparison matrix of environmental impact criteria for the use of bio-sustainable materials in clothing design

| | $S_{11}$ | $S_{12}$ | $S_{13}$ | $S_{14}$ | $S_{15}$ | $S_{16}$ | $S_{17}$ | $S_{18}$ | Geometric mean | Special vector |
|---|---|---|---|---|---|---|---|---|---|---|
| $S_{11}$ | 1 | 1.303 | 0.993 | 1.854 | 1.966 | 1.141 | 1.058 | 1.065 | 1.253 | 1.151 |
| $S_{12}$ | 0.767 | 1 | 1.097 | 1.189 | 2.364 | 1.752 | 1.909 | 1.182 | 1.322 | 0.159 |
| $S_{13}$ | 1.007 | 0.912 | 1 | 1.661 | 1.254 | 3.115 | 1.311 | 1.48 | 1.358 | 0.164 |
| $S_{14}$ | 0.539 | 0.841 | 0.602 | 1 | 2.13 | 2.085 | 1.442 | 1.805 | 1.153 | 0.139 |
| $S_{15}$ | 0.509 | 0.798 | 0.798 | 0.47 | 1 | 1.268 | 2.521 | 1.21 | 0.936 | 0.113 |
| $S_{16}$ | 0.877 | 0.571 | 0.321 | 0.486 | 0.789 | 1 | 1.265 | 1.463 | 0.762 | 0.092 |
| $S_{17}$ | 0.946 | 0.524 | 0.763 | 0.693 | 0.397 | 0.79 | 1 | 1.999 | 0.798 | 0.096 |
| $S_{18}$ | 0.939 | 0.846 | 0.554 | 0.554 | 0.827 | 0.673 | 0.5 | 1 | 0.716 | 0.086 |

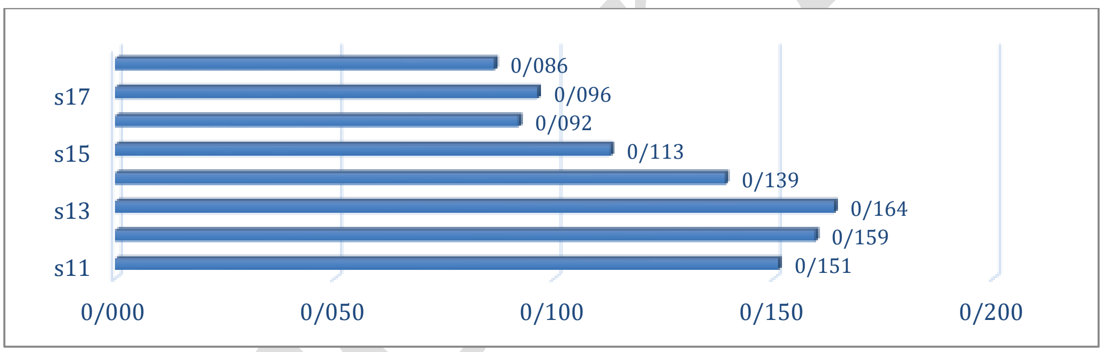


**Figure 3:** Graphical representation of environmental impact criteria of using bio-sustainable materials in clothing design

Based on the obtained eigenvector: The prioritization of research components is given in Table 7.

**Table 7:** Prioritization of research components

| Criteria | Special vector | Prioritization |
|---|---|---|
| Reducing energy and water consumption | 0.164 | 1 |
| Low volume of textile waste and environmental pollutants | 0.159 | 2 |
| Positive impacts on ecosystems | 0.151 | 3 |
| Reducing greenhouse gas emissions | 0.139 | 4 |
| Reducing textile waste | 0.113 | 5 |
| Biodiversity loss and climate change | 0.096 | 6 |

**Table 7:** Prioritization of research components

| Criteria | Special vector | Prioritization |
|---|---|---|
| Environmentally friendly production processes | 0.092 | 7 |
| Reducing carbon footprint | 0.086 | 8 |

### 6.2.3. The following prioritization of the criteria for the cultural impacts of using bio-sustainable materials in clothing design:

The pairwise comparison matrix resulting from the aggregation of the experts' views is presented in Table 8.

**Table 8:** Pairwise comparison matrix of the criteria for the cultural impacts of using bio-sustainable materials in clothing design

| Symbol | $S_{21}$ | $S_{22}$ | $S_{23}$ | $S_{24}$ | $S_{25}$ | $S_{26}$ | Geometric mean | Special vector |
|---|---|---|---|---|---|---|---|---|
| $S_{21}$ | 1 | 1.259 | 1.854 | 1.254 | 1.456 | 1.223 | 1.317 | 0.211 |
| $S_{22}$ | 0.794 | 1 | 1.101 | 1.217 | 1.542 | 2.726 | 1.284 | 0.205 |
| $S_{23}$ | 0.539 | 0.908 | 1 | 1.888 | 1.259 | 2.011 | 1.152 | 0.184 |
| $S_{24}$ | 0.797 | 0.821 | 0.53 | 1 | 1.5 | 2.825 | 1.066 | 0.171 |
| $S_{25}$ | 0.687 | 0.794 | 0.794 | 0.666 | 1 | 1.223 | 0.841 | 0.134 |
| $S_{26}$ | 0.818 | 0.367 | 0.497 | 0.354 | 0.818 | 1 | 0.592 | 0.095 |

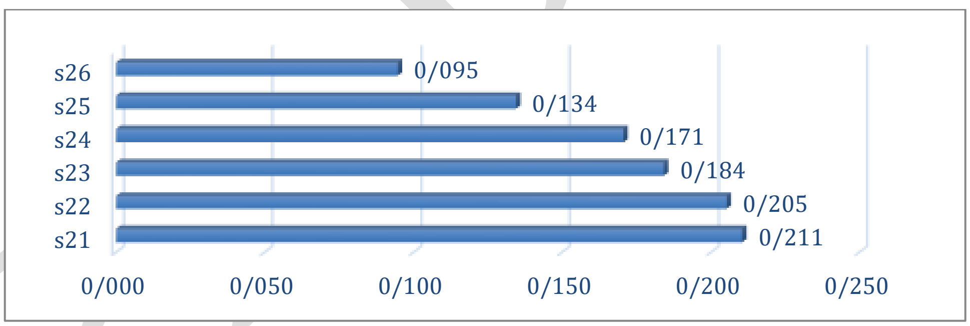


**Figure 4:** Graphical representation of the cultural impact criteria of using bio-sustainable materials in clothing design

Based on the obtained eigenvector: The prioritization of research components is given in Table 9.

**Table 9:** Prioritization of research components

| Criteria | Special vector | Prioritization |
|---|---|---|
| Raising awareness about the environmental destruction caused by the clothing industry, | 0.211 | 1 |
| Promoting the use of indigenous natural fibers | 0.205 | 2 |
| Promoting a culture of green consumption and strengthening sustainable perspectives | 0.184 | 3 |

**Table 9:** Prioritization of research components

| Criteria | Special vector | Prioritization |
|---|---|---|
| Positive changes in attitudes and behaviors | 0.171 | 4 |
| Sustainability refers to the ability of a system to maintain itself and meet current needs without harming future generations. | 0.134 | 5 |
| The positive impact of new products and processes on culture, customs, and traditions | 0.095 | 6 |

### 6.2.4 Final priority of the following criteria

The results of the calculation are given in Table 10.

**Figure 10:** Determining the final priority of the indicators using the AHP technique

| **symbol** | | Next | | | Component | Final weight |
|---|---|---|---|---|---|---|
| C1 | 0.645 | Environmental impacts of using bio-sustainable materials in clothing design | S11 | 0.151 | Positive impacts on ecosystems | 0.097 |
| | | | S 12 | 0.159 | Low volume of textile waste and environmental pollutants | 0.103 |
| | | | S 13 | 0.164 | Reducing energy and water consumption | 0.105 |
| | | | S 14 | 0.139 | Reducing greenhouse gas emissions | 0.09 |
| | | | S 15 | 0.113 | Reducing textile waste | 0.073 |
| | | | S 16 | 0.092 | Environmentally friendly production processes | 0.059 |
| | | | S 17 | 0.096 | Biodiversity loss and climate change | 0.062 |
| | | | S 18 | 0.086 | Reducing carbon footprint | 0.056 |
| C2 | 0.355 | Cultural Impacts of Using Bio-Sustainable Materials in Clothing Design | S 21 | 0.211 | Raising awareness about environmental destruction caused by the clothing industry, | 0.075 |
| | | | S 22 | 0.205 | Promoting the use of indigenous natural fibers | 0.073 |
| | | | S 23 | 0.184 | Promoting a culture of green consumption and strengthening sustainable perspectives | 0.066 |
| | | | S 24 | 0.171 | Positive changes in attitudes and behaviors | 0.061 |
| | | | S 25 | 0.134 | Sustainability refers to the ability of a system to maintain itself and meet current needs without harming future generations. | 0.048 |
| | | | S 26 | 0.095 | The positive impact of new products and processes on culture, customs, and traditions | 0.034 |

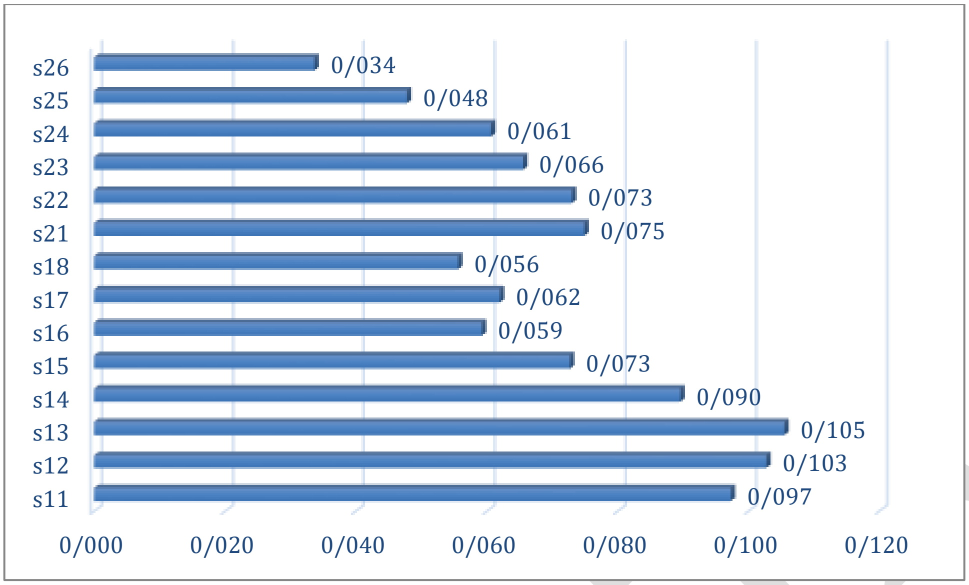

**Figure 5:** Determining the final priority of indicators using the AHP technique

**Table 11:** Final prioritization of components

| Component | Final weight | Prioritization |
|---|---|---|
| Reducing energy and water consumption | 0.105 | 1 |
| Low volume of textile waste and environmental pollutants | 0.103 | 2 |
| Positive impacts on ecosystems | 0.097 | 3 |
| Reducing greenhouse gas emissions | 0.09 | 4 |
| Raising awareness about the environmental destruction caused by the clothing industry, | 0.075 | 5 |
| Promoting the use of indigenous natural fibers | 0.073 | 6 |
| Reducing textile waste | 0.073 | 6 |
| Promoting a culture of green consumption and strengthening sustainable perspectives | 0.066 | 7 |
| Biodiversity loss and climate change | 0.062 | 8 |
| Positive changes in attitudes and behaviors | 0.061 | 9 |
| Environmentally friendly production processes | 0.059 | 10 |
| Reducing carbon footprint | 0.056 | 11 |
| Sustainability refers to the ability of a system to maintain itself and meet current needs without harming future generations. | 0.048 | 12 |
| The positive impact of new products and processes on culture, customs, and traditions | 0.034 | 13 |

## 6. Conclusion

In this study, the reduction of energy and water consumption is identified as the highest priority among the evaluated components. This finding reflects the critical role that resource efficiency plays in the sustainable transformation of the clothing and fashion industry. Reducing energy and water use in the production of bio-sustainable materials contributes significantly to environmental preservation, economic sustainability, and cultural shifts in consumer behavior.

From an environmental perspective, lower energy and water consumption directly alleviates pressure on natural resources involved in fiber and fabric production. This reduction supports ecosystem preservation, protects biodiversity, and mitigates the depletion of essential resources. Moreover, conventional garment manufacturing processes are typically associated with intensive water usage and high energy demand, resulting in substantial air and water pollution. The adoption of bio-sustainable materials, combined with energy-efficient and low-impact production methods, plays a vital role in minimizing environmental pollutants and improving overall ecological performance.

Reducing energy consumption also leads to a decrease in greenhouse gas emissions, thereby lowering the carbon footprint of the clothing industry. Given the fashion sector's substantial contribution to global emissions, this outcome is particularly important in the context of climate change mitigation and international sustainability goals. In parallel, improved resource efficiency enhances economic sustainability. Over time, lower energy and water requirements can reduce production costs, increase operational efficiency, and strengthen the long-term viability of apparel businesses, especially in competitive markets.

From a cultural and marketing perspective, sustainable production practices influence consumer awareness and purchasing behavior. Transparent communication about reduced resource consumption and environmentally responsible manufacturing processes increases consumer trust and encourages more conscious and ethical consumption patterns. In contemporary fashion markets, sustainability has become a symbolic value that shapes brand identity and cultural meaning, positioning eco-friendly clothing not only as a functional product but also as a reflection of social responsibility and lifestyle choices.

Furthermore, the constraints associated with reducing energy and water consumption stimulate innovation in clothing design. Designers and manufacturers are encouraged to rethink material selection, production techniques, and even business models, leading to the development of novel technologies and creative solutions. This innovation-driven approach supports the integration of sustainability into both aesthetic expression and functional performance in fashion design.

Overall, prioritizing the reduction of energy and water consumption in the production of bio-sustainable materials contributes to environmental protection, economic resilience, cultural transformation, and innovation within the apparel industry. Accordingly, this research suggests that sustainability-oriented design strategies should emphasize resource efficiency as a core principle, integrating environmental responsibility with market competitiveness and cultural relevance.

This research proposes three practical strategies for reducing textile waste and environmental pollutants within clothing design, emphasizing a lifecycle-oriented approach from design and production to consumption and use.

The first strategy focuses on designing for durability and longevity. Selecting high-quality raw materials is a fundamental step in this approach. The use of durable and resilient fibers and fabrics that retain their physical and aesthetic properties after repeated washing and prolonged use significantly slows garment degradation and reduces the frequency of replacement. In addition, emphasizing classic and timeless design principles—rather than short-lived fashion trends—extends the functional and symbolic lifespan of garments. Such designs remain relevant across seasons and cultural shifts, supporting sustainable consumption patterns. Furthermore, modular and multipurpose design solutions offer additional potential for waste reduction. Garments that can be reconfigured, adapted, or combined with other clothing items—for instance, jackets that can be transformed into vests through detachable components—reduce the need for purchasing new products and enhance user engagement with clothing.

The second strategy involves the application of zero-waste design principles during the pattern-making and cutting stages. Intelligent cutting techniques and optimized pattern layouts can significantly minimize fabric waste by utilizing the entire surface of the textile. Some designers employ complex geometric or algorithm-based patterns that leave little to no unused material. Even when small amounts of cutting waste are unavoidable, these remnants can be repurposed into secondary products such as accessories, decorative appliqués, or filling materials for other textile items. Additionally, designing patterns in accordance with standard fabric widths allows for more efficient material utilization, preventing unnecessary offcuts and reducing waste generation at the production stage.

The third strategy emphasizes the use of environmentally friendly dyeing and printing techniques. Natural dyeing methods, including plant- and mineral-based dyes, offer a less polluting alternative to conventional synthetic dyes. Moreover, innovative waterless or low-water dyeing technologies—such as supercritical carbon dioxide dyeing or dry dyeing systems—substantially reduce water consumption and chemical discharge. In the printing stage, digital printing presents a more sustainable alternative to traditional methods, as it eliminates the need for printing plates, reduces water and ink usage, and minimizes waste generation. Digital technologies also enable precise, small-scale production, helping to prevent overproduction. Furthermore, ensuring the use of non-toxic, heavy-metal-free dyes and pigments is essential for protecting both environmental and human health throughout the production and consumption phases.

Overall, by adopting a holistic lifecycle perspective and integrating durability-oriented design, zero-waste principles, and environmentally responsible dyeing and printing technologies, these strategies can play a significant role in reducing waste, emissions, and environmental pollutants in the apparel industry. Such approaches not only support ecological sustainability but also enhance the cultural and economic value of clothing products in contemporary fashion markets.

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