

Evaluating the Impact of Technological Advancements on Sustainable Fashion Practices

Harshal

Department of CS & IT

*Jain (deemed-to-be) University
Bengaluru, India*

Gauri Mehra

Department of School of Commerce

*Jain (deemed-to-be) University
Bengaluru, India*

Laxmi Rathod

Department of School of Commerce

*Jain (deemed-to-be) University
Bengaluru, India*

Aniket Mali

Department of CS & IT

*Jain (deemed-to-be) University
Bengaluru, India*

ABSTRACT

The fashion industry's current "take-make-waste" system is one of the biggest contributors to climate change. Even though some brands talk about being sustainable, they still make too much clothing, which leads to a lot of greenhouse gas emissions and tons of textile waste. This study looks at how new technologies like AI, blockchain, and digital fashion tools could help create a more circular fashion system. To understand this better, I did both qualitative research by looking at current media and quantitative research through a survey of 160 people to see what consumers think. The survey showed that even though people know buying from bad environmental brands isn't good, they face challenges like high prices and not trusting corporate sustainability claims. Changing consumer behavior is important, but I also created a model for a hyperspectral sorting system that can help AI identify different fiber blends, which can help reduce contaminants in recycling and improve the quality of recycled materials. I believe technology is a key part of the solution, but without proper policies and brand accountability, real change won't happen.

Keywords—Sustainable Fashion, AI-Driven Circularity, Textile Waste Management, Blockchain Transparency, Consumer Behavior, Fashion Technology, Hyperspectral Imaging.

I. Introduction

The fashion industry is one of the fastest-growing industries in the world, influencing culture, economic activity, and individual expression.

However, its rapid growth has also led to serious environmental problems. The fast fashion model encourages buying cheap, trendy clothes quickly, leading to

overconsumption and a lot of textile waste. Because of this, the fashion industry is responsible for nearly 10% of global carbon emissions and uses a lot of water and chemicals.

The move toward sustainability is no longer just about being ethical; it's a complex engineering challenge. While the "fast fashion" model relied on hidden supply chains and huge amounts of waste, new digital tools like AI, blockchain, and IoT are starting to change that.

Instead of seeing these tools as a quick fix, this research looks at them as ways to improve existing processes. For example, AI and digital design tools let brands create virtual samples, reducing the waste from physical prototypes. Blockchain and IoT help with the industry's "transparency issue" by creating a digital record for each garment, allowing real-time tracking from the start of production to the store. This makes it hard for brands to hide unethical practices or fake sustainability claims. By using predictive analytics, technology can help align production with actual customer demand, reducing overproduction that fills landfills.

AI can help brands predict what people will want, cutting down on overproduction.

Blockchain can ensure a transparent and traceable supply chain, so consumers can check if a brand is actually sustainable. Digital prototyping and 3D design tools also help by reducing the need for physical samples, lowering material use and waste.

Even though there's a lot of talk about a "digital green revolution," real progress is still slow.

For most of the industry, moving from traditional manufacturing to a tech-based sustainable system isn't just an upgrade; it's a complete overhaul that many aren't ready for.

The main problem is a triple challenge: infrastructure, money, and a lack of skilled people.

Small and medium-sized businesses, which are a big part of the garment industry, often don't have the technology needed for AI or blockchain systems, like data management tools or smart factories. Plus, the high cost of "green tech" makes it hard for smaller companies to keep up, leaving only big brands with the tools to be transparent.

Beyond the technology, there's a lack of people who understand both fashion and tech.

Designers aren't usually data scientists, and engineers may not know much about circular fashion. So, it's not enough to just list what these tools can do. We need to think about how to use them in real workflows, moving past just testing ideas to solve the industry's biggest sustainability problems.

Objectives of the Study

The present study aims to achieve the following goals:

- To look at how technological progress helps promote sustainable practices in the fashion industry
- To check how aware consumers are and what their feelings are about sustainable fashion
- To find out the difference between new technologies and how they are actually used in the fashion industry's sustainable systems
- To see how new technologies like Artificial Intelligence, blockchain, and IoT can help reduce environmental harm
- To create a model that can improve textile recycling and make processes more efficient using AI-based systems and ideas

Hypothesis

The study is based on the following ideas:

1. H0 (Null Hypothesis): Technological progress does not greatly affect sustainable fashion practices.
2. H1 (Alternative Hypothesis): Technological progress has a big positive effect on sustainable fashion practices.

Literature Review

Most existing research on sustainable fashion focuses on reducing environmental harm through circular economy models, recycling efforts, and fair sourcing methods.

Many studies have shown the importance of cutting down on textile waste, lowering carbon emissions, and encouraging people to buy more responsibly.

The current academic world is divided between two main groups: the "Slow Fashion" supporters and the "Techno-Optimists."

Scholars like Jung and Jin have long supported the slow fashion movement, pushing for a major change in how fashion is made and bought to lower the industry's environmental impact. This is also supported by Kim and Damhorst, who have studied consumer behavior and found that buying sustainably is often driven by personal beliefs rather than just what is available in the market. While these studies give a strong ethical direction for the industry, they

often fail to explain how these ideas can be put into practice on a large scale.

At the same time, there has been a rise in fashion technology research.

Studies have tested AI in design, blockchain for tracking products, and automated sorting systems to improve how businesses work. However, a big gap still exists. Right now, environmental sustainability research often doesn't go into the details of how these technologies are actually used, while technology-focused papers usually focus only on how efficient they are without looking at their real environmental benefits.

This split has left a big gap in the field.

Most existing frameworks are still just ideas on paper, offering big-picture views of a circular economy without the practical steps needed to use these tools in the complex real-world supply chains of the global fashion industry. There is a clear need for a combined approach—one that brings together the ethical goals of slow fashion with the precise tools of digital innovation.

I. Methodology

A. Research Approach

This study adopts a mixed-methods framework to examine both technological developments and consumer readiness within the fashion industry. The intention is to balance theoretical insights from existing research with practical observations of consumer behavior, ensuring that technological possibilities are evaluated alongside real-world adoption challenges.

The first stage involved an extensive review of academic and industry literature. Rather than simply summarizing prior work, this review was used to identify gaps between advancements in sustainable fashion technologies and their actual implementation within fast-fashion systems. Particular attention was given to innovations such as AI-based sorting systems and the reasons they have yet to achieve widespread integration in global supply chains.

To complement these findings, a primary data collection phase was conducted through a survey focused on consumer perspectives. Due to time limitations, a convenience sampling method was applied, resulting in a sample of 160 young participants. Although relatively small, this group provides an initial snapshot of how emerging consumers perceive sustainability, transparency, and technology-driven solutions in fashion.

The survey instrument was developed using concepts drawn from established studies on sustainable consumer behavior. To improve clarity and usability, a pilot test was carried out with a small group of respondents. Feedback from this phase was used to refine the questions, ensuring they were easy to understand and capable of capturing genuine responses.

B. Literature Review Process

A systematic literature review was conducted to establish the theoretical foundation of the study. Sources published between 2012 and 2025 were selected to reflect the transition from early sustainability discussions in fashion to the current emphasis on technology-driven solutions. Key databases such as Google Scholar, JSTOR, and ResearchGate were used to gather relevant materials. Approximately twenty core studies were analyzed.

The review focused on five main areas:

1. Circular Systems – the movement from linear production models toward closed-loop manufacturing.
2. Consumer Behavior Barriers – the mismatch between sustainable intentions and actual purchasing decisions.
3. AI-Based Sorting Technologies – the development and scalability of automated textile classification systems.
4. Blockchain Applications – the potential of distributed ledger systems to improve supply chain transparency.
5. Digital Design Tools – the role of 3D prototyping in reducing waste before production begins.

This process not only provided an overview of current advancements but also highlighted key technological and practical limitations that this study aims to address.

Survey Design

3.2.1 Survey Instrument and Structure

To convert consumer attitudes into measurable data, a structured questionnaire consisting of fifteen items was created using Google Forms. The survey included a combination of multiple-choice questions and five-point Likert scales to capture both categorical responses and degrees of opinion. This approach enabled a more detailed analysis of consumer priorities and behavior.

The questionnaire was organized into five thematic areas:

- Awareness vs. Understanding – evaluating whether participants possess genuine knowledge of sustainability concepts or only recognize common terms.
- Purchase Motivations – examining the relative importance of cost, ethics, and other factors in buying decisions.
- Trust and Skepticism – assessing confidence in sustainability claims and emerging technologies such as blockchain.
- Disposal Practices – understanding how consumers manage clothing at the end of its lifecycle.
- Willingness to Pay – determining how much extra consumers are prepared to spend on sustainable products.

This thematic grouping enabled comparisons across different dimensions, such as identifying whether higher awareness corresponds to greater willingness to pay.

Sampling and Participants

The study used a convenience sampling method targeting digitally active individuals. The survey was distributed through platforms such as Instagram and LinkedIn, resulting in 160 valid responses from participants aged 16 to 35.

This age group was selected intentionally, as it represents both a major segment of fast-fashion consumers and a population highly familiar with digital technologies. By focusing on this demographic, the study aims to capture insights from individuals most likely to engage with innovations such as AI-driven systems and blockchain-based transparency tools. Their responses provide an early indication of how such technologies may be received in the broader market.

E. Data Analysis

After the survey was completed, the collected responses were transferred to Microsoft Excel for detailed quantitative analysis. Instead of limiting the analysis to simple totals, emphasis was placed on identifying patterns, frequency distributions, and trends that reflect underlying consumer attitudes toward fashion consumption. Converting the data into percentages enabled a clearer and more structured interpretation, allowing the findings to move beyond general observations and provide a measurable representation of consumer sentiment.

In the final stage, the results from the survey were compared with the broader technological insights identified during the literature review. This comparison made it possible to identify gaps between emerging innovations—such as blockchain-based transparency and AI-enabled sorting systems—and actual consumer behavior, particularly in terms of trust and willingness to spend. By combining primary data with secondary research, the study ensures that its conclusions are both theoretically informed and practically relevant to current market conditions.

Awareness of Sustainable Fashion

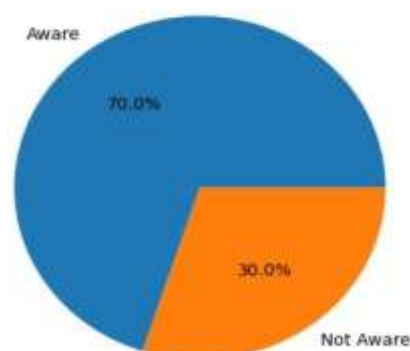


Figure 1: Awareness of Sustainable Fashion among Respondents

The chart shows that a majority of respondents are aware of sustainable fashion, indicating growing environmental consciousness among consumers.

I. RESEARCH GAP

Despite sustainability becoming a central theme in contemporary fashion discussions, there remains a significant gap between theoretical awareness and practical implementation. Much of the existing research tends to move in two separate directions that rarely intersect in a meaningful way.

On one side, a large body of socio-environmental literature highlights the severe consequences of the fashion industry—ranging from textile waste and pollution to unethical labor practices. While these studies provide strong arguments about why change is necessary, they often stop short of exploring how such transformation can be achieved through concrete technological solutions.

On the other side, research focused on technological innovation within fashion tends to prioritize efficiency, productivity, and scalability. Metrics such as speed, automation, and cost reduction dominate this space, while environmental considerations are frequently secondary. Sustainability, in such cases, appears as a by-product of efficiency rather than a core objective guiding system design.

This disconnect has created a fragmented knowledge landscape, where critical questions remain unresolved. The lack of integration between sustainability goals and technological capabilities leaves the industry without a clear, actionable pathway forward. In response, this study focuses on addressing several key gaps:

1. Effectiveness of Technology – Which technological solutions genuinely contribute to reducing environmental impact, beyond theoretical promise or industry hype?
2. Scalability and Access – How can advanced innovations be made accessible to smaller businesses, rather than remaining limited to large corporations?
3. Consumer Trust – In a market increasingly affected by greenwashing, how can transparent systems such as blockchain help rebuild credibility?
4. Operational Integration – What would a fully functional, technology-driven circular model look like within a fast-paced retail environment?

By bringing together insights from both sustainability research and technological development, this study moves beyond isolated perspectives. It aims to develop a practical framework that connects digital innovation directly with the environmental challenges faced by the fashion industry today.

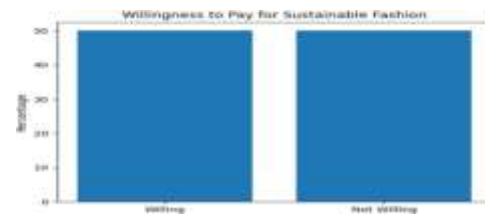


Figure 2: Willingness to Pay for Sustainable Fashion Products

The chart indicates that consumers are divided in their willingness to pay a premium, highlighting price as a key barrier.

Results and Discussion

Unpacking the "Sustainability Paradox"

The responses gathered from the 160 participants offer an insightful, though somewhat concerning, perspective on the current state of sustainable fashion. Although sustainability is widely promoted within the industry, the findings indicate that it has not yet translated into consistent consumer behavior. For many young consumers, it remains more of an ideal than a routine practice.

The Intention–Action Divide

One of the most notable observations is the gap between awareness and actual purchasing behavior. A majority of respondents (approximately 65–70%) demonstrated a reasonable understanding of sustainable fashion concepts. However, this awareness does not appear to influence buying decisions to the same extent, as only about 30–35% reported purchasing environmentally friendly clothing. This highlights a clear disconnect between what consumers know and what they are willing to act upon, suggesting that awareness alone is insufficient to drive market change.

Economic Constraints and Lack of Trust

Two major factors appear to limit wider adoption: cost sensitivity and skepticism toward brand claims.

- Price Sensitivity: A significant proportion of respondents showed reluctance to pay higher prices for sustainable products. This suggests that, particularly in uncertain economic conditions, ethical considerations are often secondary to affordability.
- Trust Issues: More than 60% of participants expressed doubt regarding the authenticity of sustainability claims made by fashion brands. This indicates a broader credibility problem within the industry, where repeated exposure to vague or misleading claims has reduced consumer confidence.

Limited Awareness of Technological Solutions

While respondents showed willingness to engage in basic sustainable practices—such as reusing or donating clothing—there was limited awareness of advanced

technological solutions. Concepts such as AI-based textile sorting or blockchain-enabled supply chain tracking were largely unfamiliar to participants. This suggests a communication gap, where the industry has not effectively demonstrated how technology can address the very concerns consumers express, particularly around transparency and accountability.

Integrated Interpretation: The Role of Technology

When viewed collectively, these findings reinforce a key insight: the primary challenge is no longer awareness, but implementation. The data indicates that technology has the potential to play a crucial role in bridging the gap between intention and action.

- Blockchain-based systems can enhance transparency by providing verifiable information about product origins, thereby addressing trust concerns.
- AI-driven sorting technologies can improve recycling efficiency, potentially reducing costs and making sustainable products more affordable.
- Digital design tools can minimize waste during early production stages, preventing inefficiencies before they reach the consumer level.

Overall, the results suggest that technological innovation should not be viewed solely as a tool for operational improvement, but also as a means of rebuilding consumer trust. Strengthening this relationship between brands and consumers may be essential for achieving meaningful progress in sustainable fashion.

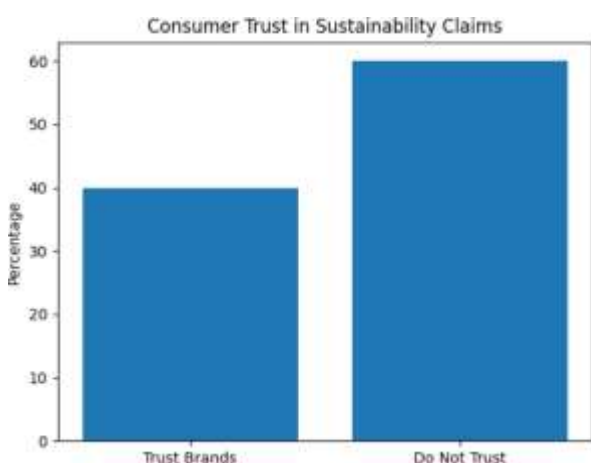


Figure 3: Consumer Trust in Sustainability Claims

A significant portion of respondents do not trust brand claims, reflecting the need for transparency through technologies like blockchain.

II. CONCEPTUAL IMPLEMENTATION: AI-BASED TEXTILE SORTING

To demonstrate how technological solutions can be applied in practice, this study introduces a conceptual model centered on AI-enabled hyperspectral textile sorting systems. The

purpose of this model is to show how advanced analytics can be integrated into waste management processes within the fashion industry.

Hyperspectral imaging operates by capturing detailed spectral information from textile materials across a wide range of wavelengths. Each fabric type produces a distinct spectral signature, which can then be analyzed using machine learning algorithms. By processing these signatures, the system can accurately classify materials such as cotton, polyester, nylon, as well as blended fabrics. This level of precision enables more efficient sorting, which is essential for improving recycling outcomes and supporting circular production systems.

Flowchart Representation

1. Operational Assessment ↓
2. System Design ↓
3. AI Model Training ↓
4. Real-Time Classification ↓
5. Automated Sorting ↓
6. Performance Monitoring ↓
7. Sustainability Evaluation

The proposed system follows a structured, multi-stage implementation process designed to integrate advanced technology into textile waste management:

1. Operational Analysis – The process begins with identifying inefficiencies and limitations in existing textile waste handling and sorting systems.
2. System Development – A hyperspectral imaging setup is designed and integrated with conveyor-based sorting infrastructure to enable continuous processing.
3. Model Training – Machine learning algorithms are trained using spectral datasets representing a wide range of textile materials.
4. Real-Time Identification – The system captures spectral data during operation and applies trained models to classify fabrics instantly.
5. Automated Separation – Based on classification outputs, mechanisms such as robotic arms or air-jet systems sort textiles into appropriate categories.
6. Performance Evaluation – The system's accuracy, speed, and operational efficiency are continuously monitored and assessed.
7. Sustainability Assessment – The final stage involves measuring environmental impact, including reductions in landfill waste and improvements in recycling rates.

This framework highlights how a technology-driven approach can significantly enhance the efficiency and effectiveness of textile waste management, supporting the transition toward circular systems.

Case Studies in Sustainable Fashion Technology

A number of global fashion brands have already begun incorporating technological solutions to address sustainability challenges:

- H&M has introduced garment collection initiatives and applies data analytics to streamline production processes and reduce surplus inventory.
- Zara utilizes AI-based demand forecasting to better align production with consumer demand, thereby limiting overproduction.
- Patagonia is widely recognized for its sustainability-focused practices, including repair programs and digital transparency initiatives that encourage product longevity and responsible consumption.

These examples demonstrate that when effectively implemented, technological innovations can play a meaningful role in advancing sustainability within the fashion industry.

III. Limitations of the study

While this study provides valuable insights, several constraints should be acknowledged.

- The sample size was limited to 160 participants, which may reduce the extent to which the findings can be generalized to a broader population.
- The research primarily targeted individuals aged 16–35, meaning perspectives from older or less digitally engaged demographics are not fully represented.
- Data collection relied on self-reported responses, which can introduce biases such as overreporting socially desirable behavior.
- The proposed AI-based textile sorting system remains conceptual and has not yet been validated through real-world industrial implementation.
- Restricted access to industry-specific datasets limited the scope for deeper empirical investigation and validation.

IV. CONCLUSION

This study underscores the considerable potential of emerging technologies to enhance sustainability within the fashion industry. Innovations such as artificial intelligence, blockchain systems, and digital design tools present viable pathways for addressing issues like waste, inefficiency, and lack of transparency. However, their adoption in practical settings remains uneven and limited.

A key finding of this research is the disconnect between sustainability-focused discourse and

technology-driven development. Addressing this divide will require coordinated efforts across multiple domains, including academic research, industry practice, and policy frameworks.

The conceptual model of AI-based textile sorting presented in this study illustrates how targeted technological solutions can contribute directly to improved waste management and the advancement of circular fashion systems.

Future research should prioritize real-world testing through pilot implementations, along with detailed assessments of economic feasibility and scalability. Such efforts are essential to determine whether these technologies can be effectively integrated into existing fashion supply chains and deliver meaningful environmental benefits.

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