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Environmental Sustainability of Fashion Product Made from Post-Consumer Waste: Impact Across the Life Cycle

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Abstract: The fashion industry has a detrimental environmental impact throughout its supply chain operations that needs immediate attention. Limited work focuses on measuring the environmental sustainability of clothing products made from post-consumer waste in the circular economy. This research aims to evaluate the environmental sustainability of fashion products made from post-consumer waste using the Higg Index tool developed by the Sustainable Apparel Coalition. Three t-shirt manufacturers—namely factory A (LEED certified), factory B (non-LEED certified), and factory C (Sub-contract) were considered as case studies. Data were collected through practice-based qualitative questions to manufacturing practitioners, which were supplemented by triangulations, and scores were obtained using the Higg Index product environmental sustainability tool. The findings highlight significant variations in most subsection analyses for product environment sustainability dimensions, scoring 369.5 (73.9%), 277.6 (55.5%), and 153.5 (30.7%) out of 500 by factories A, B, and C, respectively. Findings reveal significant differences in scores (from low to high) for the three t-shirt manufacturers. Various subsections revealed deficiencies in actual policies including product design, materials selection, manufacturing operations, and priorities regarding subcategories. Products made in a green factory and embracing the circular economy achieved the highest score, while the sub-contractor factory product obtained the lowest score. Findings highlight poor and emerging sustainable practices, identify challenges, and suggest improvement in the above-mentioned categories. The research urges stakeholders to embrace sustainable practices for fashion products to reduce environmental impact through life cycle stages and benefit the industry.

Keywords: environmental sustainability; fashion product; post-consumer waste; Higg index tools; sustainability performance

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1. Introduction

The 450 billion USD valued global fashion industry is suffering from the environmental issues generated by a large volume of fashion and textile waste [1,2]. Every year, more than 100–150 billion pieces of garments are made, using 93 billion cubic meters of fabric and emitting around 1.2 billion tonnes of CO_2 and 500,000 tonnes of microplastic fibers into the oceans [3]. Furthermore, approximately 92 million tonnes of textile waste are generated in various scenarios [4] with 50% of waste occurring at the post-consumption level. Only 15–20% of waste is collected for reuse and recycling, while more than 80% of textile waste is dumped into landfills, resulting in a higher carbon footprint, energy, and raw material losses [5,6]. As a result, the fashion sector has a negative environmental impact throughout its supply chain operations, which requires immediate remedies [7,8].

The fashion industry has made numerous efforts to fulfill the need for sustainable practices. Sustainable textiles are fabrics and materials that are produced, utilized, and disposed of in ways that reduce environmental and social hazards. These textiles are intended to lower carbon footprints, conserve resources, and encourage ethical labor practices throughout their life cycle. This includes the introduction of sustainable products, a transparent supply chain for waste clothing management, environmental impact reduction, and reuse and recycling for the production of new waste-based products [9,10]. Appropriate policies for reuse and recycling can alleviate these issues and ensure the profitability of waste management through major changes in many states [11]. This also aims to maximize a product's life cycle, from origin to production, consumption to disposal, by encouraging zero-waste design, reuse, reparability, and resource-sharing activities [12]. Specific legislations are required to implement effective waste disposal since it harms landfills, emits methane, and pollutes groundwater with hazardous leachate [13].

Today, research into fashion and textile waste reuse and recycling is critical for a variety of reasons. The most important goal is to reduce environmental degradation, promote sustainable economic growth, and cultivate a more conscious and responsible society. Because approximately 50% of clothing waste occurs during the consumption period, a good recycling program can significantly reduce waste's negative impact on society and the environment [14]. Promoting ethical consumption and production may integrate the circular economy, which is linked to sustainability. Aside from that, this research has the potential to produce jobs in the recycling and upcycling industries, which would assist local economies [15].

Despite significant research gaps, post-consumer waste (PCW)-based products are identified including waste collection and distribution, manufacturing, technological advancements and automation within insufficient infrastructures. Investigating circular fashion models and their effectiveness in minimizing clothing waste remained a significant research priority. There have been very few investigations into the environmental sustainability of clothes made from post-consumer fashion waste in the circular economy [7]. Understanding product sustainability is essential for developing strategic plans that benefit all stakeholders in the circular economy.

Therefore, this research aims to evaluate the environmental sustainability of clothing products made from post-consumer fashion waste to benefit wider stakeholders. To measure this, a case study was developed based on recycled garments made from three factories in Bangladesh: namely, factory A, factory B, and factory C. The case factory was segregated based on certification, types of raw materials, reuse, and recycling potentials. The Higg Index: Environmental Product Sustainability tool and a qualitative method were implemented to identify the sustainability practices among the case factories. The novelty of this research is to contrast and compare the sustainability performance in terms of materials sustainability, manufacturing sustainability, packaging and sundries, product care and repair service, and end of use based on the Higg product environmental sustainability tool. Driven by key literature insights, we formulate the following **research question:**

To what extent the fashion product made from post-consumer waste is environmentally sustainable? Three specific objectives were developed including-

1. To understand sustainable practices associated with fashion made from post-consumer waste;
2. To compare the sustainability attributes score achieved by the products made from post-consumer waste; and

3. To identify emerging sustainable practices, poor practices areas and suggest improvement linked to product circularity.

The rest of the manuscript is structured as follows: key literature analysis, research methods, results and discussion, theoretical and practical implications, and finally conclusions with recommendations for more study.

2. Literature Review

2.1. Sustainability Issues in the Fashion and Textiles Industry

Sustainability is becoming increasingly crucial in the fashion and textile industries, which confront enormous environmental and social challenges. Key environmental issues include the water-intensive nature of conventional cotton cultivation, greenhouse gas emissions from fossil-fuel-based polyester production, and the rise of fast fashion, which encourages rapid garment disposal [16]. Unsafe working conditions and opaque supply chains demonstrate that ethical quandaries persist, despite initiatives such as Fair Trade certifications and efforts to boost living wages. The industry is responding with sustainable design innovations, emphasizing long-lasting, eco-friendly materials and circular economy concepts that prioritize reuse and recycling [17]. Blockchain technology improves supply chain transparency, while consumer demand for ethically created goods and regulatory pressures promote industry-wide shifts toward accountability and responsible consumption [18]. However, structural barriers remain, such as economic incentives for fast fashion, the breadth and complexity of global supply chains, and the need for comprehensive regulatory frameworks to fully enforce sustainability standards [7]. To create a resilient and environmentally responsible global fashion ecosystem [19,20], all industry players should collaborate, innovate, and commit. To address these issues, stakeholders across all phases of the supply chain, from raw material manufacturing to end-of-life disposal, should work together [21].

To reduce the environmental and social effects, the fashion industry is emphasizing innovation and sustainable practices. Sustainable design focuses on creating longer-lasting products, employing environmentally friendly materials, and reducing waste through recycling and upcycling. Textile manufacturing innovations include biodegradable fibers, closed-loop production techniques, and dyeing procedures that save water and chemicals [22]. The circular economy concept is gaining popularity, emphasizing the reuse, repair, and recycling of apparel to extend its life cycle. Brands are looking into rental and resale methods to help people move to more sustainable consumption habits. Blockchain technology is also being studied to increase supply chain transparency and traceability, ensuring ethical sourcing and lowering the risk of counterfeiting [23].

2.2. Environmental Impact of Waste Generation in the Fashion Industry

From fibers to clothes, materials pass through a variety of manufacturing processes, resulting in more than 47% of total fiber waste in the fashion value chain [24]. Global apparel consumption is anticipated to increase even more, rising from 62 million tonnes in 2015 to 102 million tonnes by 2030. In 2018, more than 350,000 tonnes of clothing were disposed of. By 2030, the textile and clothing industries are estimated to produce 148 million tonnes of waste each year [25]. Clothing, textiles, curtains, blankets, plush animals, and other cloth products produce an enormous amount of waste. According to a recent survey in Connecticut, Canada, textile waste accounts for approximately 4% (96,500 tonnes) of Connecticut's waste stream; 74% (71,800 tonnes) of total disposed textiles come from residential sources, while 26% (24,700 tonnes) come from non-residential sources such as universities, state agencies, and businesses. This scenario depicts the pattern of textile waste production in Europe and North America [26].

This waste has serious environmental consequences, including greenhouse gas emissions from decomposing textiles in landfills and the release of toxic chemicals used in textile manufacture into soil and water systems. Efforts to address this issue are still ongoing with projects encouraging textile recycling, upcycling, and circular economy models gaining traction [27]. To successfully mitigate the environmental impact of fashion waste, structural reforms in the fashion industry are required to reduce waste generation at the source, improve recycling infrastructure, and educate consumers about sustainable consumption patterns [28,29].

2.3. Fashion Product's Sustainability Impact Across the Life Cycle Stages

Fashion goods' environmental and social impacts vary throughout their life cycle [30]. Beginning with raw material extraction, traditional methods such as cotton farming require substantial amounts of water and chemicals, resulting in water scarcity and pollution. Polyester, which is derived from fossil fuels, emits significant volumes of greenhouse gases during production. Manufacturing operations consume a significant amount of energy and generate waste and pollutants, all of which contribute to air and water pollution. The distribution phase contributes to the carbon footprint through transportation and packing. Water and energy consumption for garment maintenance and laundering, as well as the danger of microfiber pollution from synthetic fibers, are all factors to consider throughout the consumer usage phase [31]. Disposal of the product at the end of its life cycle presents challenges: whereas natural fibers can biodegrade, synthetic fibers remain in the environment. Addressing these issues requires wide techniques such as sustainable materials, eco-efficient production methods, extended product lifespans through strong design and quality, responsible consumption, care and disposal behaviors, and recycling and circular economy frameworks. Integrating these concepts into the garment sector is crucial for lowering the environmental impact and achieving a more sustainable future [5]. To assess a product's sustainability performance, relevant operations should be taken into considerations, including materials sustainability, manufacturing sustainability, product care, packaging, and end of use. All of this is part of a product's life cycle review to ensure its sustainability [32].

2.3.1. Material Sustainability

The sustainability impact of fashion products begins with the materials used in their production, influencing environmental and social outcomes throughout their life cycle [33]. Conventional materials like cotton and polyester pose significant challenges: cotton farming demands vast amounts of water and pesticides, contributing to water scarcity and chemical pollution. Polyester, derived from fossil fuels, emits greenhouse gases during production and does not biodegrade easily at the end of life. Sustainable alternatives, such as organic cotton and recycled polyester, mitigate these impacts by reducing chemical use, conserving resources, and decreasing waste. Innovations in materials like bamboo fiber and hemp fiber offer renewable options with lower environmental footprints. Ensuring material sustainability involves evaluating sourcing practices, promoting transparency in supply chains, and adopting certifications like GOTS (Global Organic Textile Standard) and Bluesign to verify sustainable practices [34]. Ultimately, prioritizing material sustainability in fashion production can drive industry-wide improvements, aligning with global sustainability goals and consumer expectations for environmentally responsible products [35].

In addition to material choices, sustainable fashion prioritizes waste reduction and product durability through strong product design and craftsmanship. Designing for longevity means selecting materials that can survive wear and tear, simplifying repair and maintenance, and considering end-of-life choices like recyclability or biodegradability. The circular economy advocates for closing the material flow loop through activities such as textile reuse, recycling, and upcycling. Clothing rental programs, resale platforms, and take-back schemes allow consumers to extend the life of their garments while reducing overall textile waste. Consumer education and awareness are critical in driving demand for sustainable fashion solutions and influencing industry behavior [36]. Consumers are increasingly demanding transparency in supply chains, questioning material sources, manufacturing techniques, and labor conditions. Furthermore, both government regulations and industry actions are vital in promoting material sustainability in fashion. Regulatory frameworks may include limits on hazardous chemicals in textile manufacture, waste management standards, and incentives for employing sustainable materials and practices. Collaboration among stakeholders, including brands, manufacturers, suppliers, and non-governmental organizations, is essential for promoting sustainability goals in the fashion industry [30,37].

2.3.2. Manufacturing Sustainability

Sustainability in the fashion industry extends beyond material selection to production techniques, which have a significant impact on environment, resource consumption, and social responsibility throughout the product's lifespan. Fashion manufacturing includes spinning fibers, weaving fabrics, dyeing, printing, and garment assembly. These processes usually need a substantial quantity of energy, water, and chemicals, which contribute to environmental degradation. Energy-intensive operations, which frequently employ non-renewable fuels, contribute to greenhouse gas emissions and climate change [16]. Another important concern is water consumption, particularly in the dyeing and finishing of textiles, when large amounts of water are used and frequently thrown back into untreated water systems, causing pollution and ecosystem degradation. Furthermore, chemicals utilized in textile processing, including dyes, and finishing agents, can be harmful to human beings and the environment when not handled correctly [38].

Efforts to reduce such environmental implications are centered on implementing environmentally friendly production methods that prioritize resource conservation, eliminating pollution, and the use of safer chemicals. Sustainable dyeing and finishing procedures, like as waterless dyeing and low-impact dyes, save water and prevent chemical discharge into rivers. Certification methods such as 'OEKO-TEX Standard 100' have been evaluated for dangerous compounds and guarantee compliance with environmental and social standards. The Bluesign system assesses the environmental effects of textile manufacturing based on resource efficiency, consumer safety, water emissions, and air emissions, encouraging the use of environmentally friendly inputs and processes. LEED (Leadership in Energy and Environmental Design) accreditation for manufacturing facilities supports the use of green building practices and sustainable operations, which contributes to the fashion industry's sustainability initiatives [39,40].

Collaboration among stakeholders, such as brands, manufacturers, suppliers, non-governmental organizations (NGOs), and industrial organizations, is essential for improving sustainable manufacturing methods. Industry initiatives such as the Sustainable Apparel Coalition (SAC) and the Zero Discharge of Hazardous Chemicals (ZDHC) program bring together business leaders to develop common frameworks, tools, and guidelines for improving environmental and social performance throughout the fashion supply chain [30,37].

2.3.3. Packaging and Sundries

Packaging and sundries are important in decreasing environmental impact and promoting ethical consumption practices throughout the life cycle of fashion products. The extensive use of packaging materials such as plastic bags, polyethylene wraps, and cardboard boxes has a significant environmental impact. Plastic packaging, in particular, presents a hazard due to its persistence in the environment and the likelihood of marine pollution. The fashion industry's reliance on single-use packaging exacerbates the issue, resulting in increased waste generation and resource depletion [41,42]. To address these issues, eco-friendly packaging approaches are gaining traction in the fashion industry. Brands are increasingly turning to environmentally friendly alternatives such as recyclable plastics, recycled cardboard, and paper-based packaging materials sourced from sustainably managed forests. Bioplastics derived from renewable resources offer a potential alternative to conventional plastics. Designing packaging for recyclability and reuse is an alternative way to improve sustainability. Choosing widely recyclable materials that work with existing recycling infrastructure facilitates recovery and promotes a circular economy approach to packaging [43].

2.3.4. Product Care, Use, and Repair Service

Product maintenance, use, and repair services are critical to the long-term sustainability of fashionable products, as they influence their environmental impact and durability throughout their life cycle. These stages describe how consumers interact with clothing after they have been purchased, which affects resource consumption, waste generation, and the product's total longevity. Customer education on garment care standards promotes actions that extend the life of clothing products [44]. When compared to standard laundry methods, simple acts such as washing clothes at a lower temperature, using eco-friendly laundry detergent, and air-drying garments can save a significant amount of energy and water [45].

To extend the usefulness of apparel, designers and retailers are increasingly offering repair services such as repairs, modifications, and restorations. These solutions not only increase the longevity and value of clothing items, but they also promote a circular economy model by allowing products to stay in circulation for longer periods. Some firms even provide DIY repair supplies and online guidelines, encouraging customers to restore their clothing and cultivating a sustainable culture. All of these actions encourage users to maintain their items sustainably. Transparency about product durability and maintenance requirements enables consumers to make better-informed purchasing decisions and extend the life of their garments [40,46].

2.3.5. End of Use (EOU)

End-of-use sustainability in the fashion industry is crucial for decreasing environmental impact and increasing circularity since it addresses recycling, waste management, and ethical clothing disposal. Textile waste is a major challenge in the fashion business with millions of tonnes of clothing ending up in landfills or incinerators throughout the world each year. The fashion industry's linear 'take–make–dispose' cycle exacerbates these challenges, resulting in resource depletion, pollution, and greenhouse gas emissions from decaying fabrics [47,48]. End-of-use sustainability is aligned with the circular economy's concepts of reducing waste and resource consumption through product reuse, repair, and recycling. Textile recycling is the process of transforming old clothing into fibers or yarns that can be used to create new fabrics or products [49]. Advanced recycling methods, such as mechanical and chemical recycling, offer promising solutions for transforming textile waste into new raw materials while maintaining quality [50]. Circular business models aim to maintain products in circulation for as long as possible [51,52].

3. Material and Method

This research adopts a multiple-case study approach. Three case knit factories were considered from different locations in Bangladesh: namely, factory A (LEED certified), factory B (non-LEED certified), and factory C (sub-contract) were selected based on their product styles, green certification, and recycled or upcycled potentials. As per the Higg Index Product Environmental Module tool (version 2.0), multiple module-based questionnaires were developed to collect empirical data regarding product sustainability: for example, (i) material sustainability, (ii) manufacturing sustainability, (iii) packaging sustainability, (iv) product care sustainability, and (v) end-of-use (EOU) sustainability. Two other subcategories such as (i) general product sustainability and (ii) transportation sustainability were excluded while conducting this research due to limitations and inadequate data. This tool measures the cradle-to-grave impacts of a product, from raw material selection to end of life [53–55]. Figure 1 presents the scoping and parameters, underpinning the research boundary, and the details of the case factory profile are presented in Table 1.

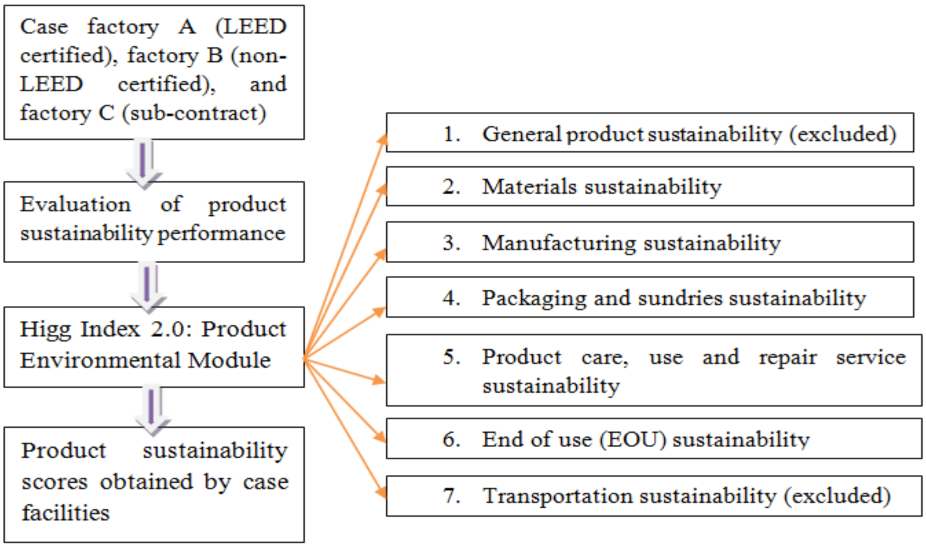

Figure 1. Research conceptual framework.

Table 1. Case study factory for product sustainability analysis.

Factory Name	Factory Operations	Year of Establishment	Product Styles	Green Chemistry Third Party Verification	Does It Use Recycled Materials	No. of Respondent	Document Analyzed
Factory A (LEED)	Knitting, dyeing, washing, printing, garment, finishing	2000	Knit items	Yes, OEKO Tex standard 100, LEED certification	Yes	17	Company website, annual report, factory operations document, recycling details
Factory B (non-LEED)	Knitting Dyeing, washing, printing, garment, finishing	2005	Knit items	Yes, OEKO Tex standard 100	Yes	16	Company website, annual report, factory operations document, recycling details
Factory C (sub-contract)	Sub-contract Garment, finishing	2015	Knit items	No	No	13	Company website, annual report, factory operations document, recycling details

A series of practice-based qualitative questions (Appendix A) were asked to multiple levels of working people of the case factories. A total number of 17 respondents from case factory A, 16 from case factory B, and 12 from case factory C participated in this study. In addition, public documents such as website information and sustainability reports related to product sustainability issues were analyzed from all the case factories for triangulation. The profiles of the respondents of interviews are shown in Table 2.

Table 2. Factory respondents and their profiles case factory (A, B, and C).

Respondent Position	Experience (Years)	Responsibilities	Case Factory
Factory Owner	40	Responsible for safe and healthy working environment, safety equipment, training, and fair pay	A, B, C
Managing Director	30–35	Look after labor laws and regulations, workers safety, appropriate training, gender equity, payment, etc.	A, B, C
Executive Director	20–25	Factory labor and workplace compliance, safety and healthy environment, community support, avoidance of fraud, corruption, and bribery	A, B, C
Production Director	20–25	Schedule plans and organize factory production policies, safety equipment, and maintenance control	A, B, C
Factory Manager	15–20	Responsible for overall production, maintenance, workers safety, and compliance	A, B, C
Product Designer and Developer	10–12	Made decisions on eco-friendly materials, reduced waste and implemented sustainability practices	A, B, C
Manufacturers and Suppliers	9–10	Responsible for adopting sustainable production method	A, B, C
Sustainability Manager/Officer	12–15	Oversee sustainability initiatives and ensure sustainability standards	A, B
Production Manager	12–15	Ensure efficient and eco-friendly manufacturing operations, take care of waste reduction and consumption	A, B, C
Quality Control Manager	8–10	Responsible for quality requirements and ensures sustainability guidelines	A, B, C
Supply Chain Manager	8–10	Responsible for supplying sustainable and eco-friendly materials	A, B, C
Environmental Health and Safety (EHS) Officer	10–12	Responsible for health, safety, and environmental impact during factory operation	A, B
HR Manager	10–12	Responsible for ethical labor practices and sustainable workplace culture	A, B, C
R&D Team	5–8	Designs and develops new sustainable materials and processes	A, B
Maintenance Manager	5–8	Ensures efficient energy consumption and reduced emissions	A, C
Operations Manager	12–16	Integrates sustainable practices in overall factory operations	A, B, C
Waste Management Coordinator	8–10	Implements waste reduction strategies such as reuse, recycling, and materials disposal and minimizes environmental impact	A, B

By using the product sustainability tools of Higg Index 2.0, the sustainability performance scores were measured by each factory. These data enable the classification and evaluation of the level of sustainability performance. To identify unsustainable practices, several variables were thoroughly evaluated and analyzed before assigning rankings.

4. Results

4.1. Materials Sustainability Evaluation

To measure the performance scores, several questions related to the chemical responsibility program, materials program, procedures for material approval and selection, and chemical impact reduction management were used in the interviews. The scores for each category are added together to obtain the total material sustainability performance. Table 3 displays the performance ratings that each factory in the module obtained.

Table 3. Materials sustainability evaluation of fashion products.

Materials	**Factory A (LEED Certified)**	**Factory B (Non-LEED)**	**Factory C (Sub-Contract)**
Materials Program/35	22.5	18.6	12.5
Chemical Responsibility: Content and Transparency/10	8	5	4
Chemical Responsibility: Verification/Certification/15	12	10	8
Chemical Impact Reduction Management/25	16	12	9
Materials Selection and Approval Procedures/15	9	6	5
Total Score (out of 100)	67.5	51.6	38.5

Factory A scored higher (67.5) than factories B (51.6) and C (38.5) (see Table 3). Factory A performed satisfactorily with materials sustainability practices highlighted in the preceding part; nonetheless, the lowest performance was recorded in the Chemical Impact Reduction Management, Materials Selection and Approval Procedures categories. Factory B managed to attain 50%, exhibiting moderate dedication in chemical responsibility and effect minimization whereas Factory C received poor score (38.5), indicating low participation in sustainability activities by the sub-contract factory. This means that sustainability programs received insufficient investment across all dimensions. The overview highlighted credentials on extensive and effective sustainability measures by certified factory A, whereas non-certified factory B and sub-contract factory C failed in implementing sustainable practices effectively.

4.2. Manufacturing Sustainability Evaluation

To evaluate the performance of factories in this domain, questionnaires were prepared across six key parameters: Manufacturing Program, Environmental Guidelines for Manufacturing Suppliers, Water Use/Conservation, Manufacturing Efficiency (Seconds/Reject Rate Reporting), Continuous Improvement Programs, and Sampling Program. Each criterion contributes to a final score out of 100. Table 4 displays the performance scores as follows.

Factory A excelled in the manufacturing sustainability area (score 75), whereas factory B performed admirably (65) and factory C performed poorly (41). Factory A and factory B performed similarly in manufacturing programs, waste use/conservation, manufacturing efficiency, continuous improvement programs, and sampling, resulting in a more similar performance. However, factory C's assessment reveals significant gaps in its sustainability criteria across all subcategories, showing a lack of accountability and unexpected performance in the sampling program. Overall, factories A and B have chances to improve their sustainable practices in this area, particularly their water use/conservation programs and continuous improvement programs in manufacturing. On the other hand, factory C need to implement stringent sustainable practices and make significant improvements in sustainability measures.

Table 4. Manufacturing sustainability evaluation of fashion products.

Manufacturing	Factory A (LEED)	Factory B (Non-LEED)	Factory C (Sub-Contract)
Manufacturing Program/35	23	20	15
Environmental Guidelines for Manufacturing Suppliers/20	15	10	6
Water Use/Conservation/20	15	15	10
Manufacturing Efficiency: Seconds/Reject Rate Reporting/5	5	5	5
Continuous Improvement Programs with Manufacturing/15	12	10	5
Sampling Program/5	5	5	0
Total Score (out of 100)	75	65	41

4.3. Packaging and Sundries Evaluation

The packaging and sundries sustainability of recycled-based products were measured in two categories. The key focus area of investigation was the present packaging scenario and program approach whether they are using sustainable design for products and transportation packages. This module also evaluates out of 100 points (Table 5).

Table 5. Packaging and sundries sustainability evaluation of fashion products.

Packaging and Sundries	Factory A (LEED Certified)	Factory B (Non-LEED)	Factory C (Sub-Contract)
Packaging Program/80	30	20	0
Packaging Restricted Substance List/20	16	16	7
Total Score (out of 100)	46	36	7

Table 5 shows that each plant performed the worst in the sustainability sector of packaging and sundries. Factory A received just 46% of the points, while factory B and factory C received 36% and 7%, respectively. Factories A, B, and C performed the worst in the packaging program subcategory, scoring 30, 20, and 0 out of 80, respectively. In this subcategory, factory A demonstrated minimum efforts and modest levels of sustainable initiatives. Interestingly, both factories A and B outperform in the Packaging Restricted Substance List, scoring 16 out of 20, suggesting good regulatory compliance and a commitment to reducing hazardous compounds in packaging materials. Factory C received a score of 7, indicating only a minimum adherence to sustainable packaging principles and recommending systematic work toward sustainable packaging. Overall, the study underscored the need for comprehensive packaging activities to achieve higher levels of sustainability; even the best-performing factories should enhance their packaging processes.

4.4. Product Care, and Use

To measure the scores in product care, use, and repair service sustainability, five categories were used. They are product care and repair service programs, repairability design standards, design for durability and longevity, product care communication to consumers, and repair service communication to consumers. Each criterion contributes to a total score out of 100, providing a detailed view of the factories' sustainability practices shown in Table 6.

Table 6. Product care, and use sustainability evaluation of fashion products.

Product Care	Factory A (LEED Certified)	Factory B (Non-LEED)	Factory C (Sub-Contract)
Product Care and Repair Service Program/40	40	40	20
Repairability Design Standards/18	18	6	3
Design for Durability and Longevity (QA feedback mechanism)/18	12	10	4
"Product Care" Communication to Consumers/12	12	6	0
"Repair Service" Communication to Consumers/12	12	10	0
Total Score (out of 100)	94	72	27

Factory A performed admirably (94 out of 100), while factory B scored 72 and factory C scored 27 (see Table 6). Factory A has demonstrated entire phase commitment in all criteria, including a thorough and robust attitude to product maintenance and repair services. Although Factory B performed well in the Product Care and Repair Service Program (40/40) and "Repair Service" Communication to Consumers (10/12), other subcategories require significant improvement. However, factory C's performance in all subcategories of this domain demonstrates significant deficiencies in its sustainability protocols. Overall, factory A sets a high level for product maintenance and the long-term viability of repair services, demonstrating a thorough and successful plan across all sectors. Although factory B follows good practices, it needs to increase consumer outreach and design criteria for durability and repairability. The low results at factory C highlight the urgent need for effective consumer engagement initiatives and solid sustainability policies.

4.5. End of Use (EOU) Evaluation Score

To measure the scores of product end of use/life (EOU/EOL), five categories were analyzed based on Higg tools: namely, end-of-use program, design policies for end-of-use streams, end-of-use collection/processing infrastructure and end-of-use communication to consumers. Each criterion contributes to a total score out of 100, providing a detailed view of the factories' sustainability practices shown in Table 7.

Table 7. End-of-use sustainability evaluation of fashion products.

End of Use	Factory A (LEED Certified)	Factory B (Non-LEED)	Factory C (Sub-Contract)
End-of-Use (EOU) Program/38	35	20	15
Design Policies for End of Use (EOU) Streams/30	25	15	10
End-of-Use (EOU) Collection/Processing Infrastructure/20	15	10	10
End-of-Use (EOU) Communication to Consumers/12	12	8	5
Total Score (out of 100)	87	53	40

In this sector, factory A demonstrated the greatest potential, scoring 87 out of 100, whereas factory B scored 53 and factory C scored 40 (Table 8). Factory A had a well-developed and successful EOU strategy, factory B had moderate but incomplete EOU practices, and factory C had major deficiencies in EOU procedures. Factory A provides almost explicit instructions for ensuring effective and sustainable processing of products after use, exhibiting a strong and comprehensive approach to product lifetime management. It also displays a solid ability to collect and process end-of-life products as well as a commitment to engaging and educating customers about sustainability and responsible disposal. Factory B presented a small but functional program for controlling product end-of-life, although there was still room for improvement. Factory C had established an immature technique of dealing with end-of-life items, necessitating a considerable upgrade to solid end-of-life management standards.

Table 8. Key summary of the findings.

Sustainability Component	Factory A (LEED Certified)	Factory B (Non-LEED)	Factory C (Sub-Contract)	Recommendations
Materials/100	67.5	51.6	38.5	Extensive and effective sustainability measures need to be implemented
Manufacturing/100	75	65	41	Waste management policies and technological advances should be incorporated
Packaging/100	46	36	7	Need to cut down packaging waste and use eco-friendly materials
Product care and repair service/100	94	72	27	Increase consumer outreach and design criteria for durability and repairability
End of Use (EOU)/100	87	53	40	Eco-friendly materials can improve lifespan of the product
Total Score/500	369.5	277.6	153.5	

4.6. Summary of Key Findings and Discussion

The findings highlights significant variations in most subsection analyses for product environment sustainability dimensions, scoring 375.5 (75.1%), 277.6 (55.5%) and 153.5 (30.7%) out of 500 by factories A, B, and C, respectively (Table 8). Various subsections revealed deficiencies in actual policies and priorities regarding materials, manufacturing, packaging, product care, repair service, and end-of-use subcategories. In all the subcategories, factory A performs better than the others.

Factory A has shown excellent performance in product care and repair service (94/100) and end-of-use (87/100) subcategories with moderate performance in the manufacturing (75/100) and materials section (67.5/100), and worst performance in the packaging section (46/100). An established materials program emphasizes chemical responsibility, sustainable sourcing, and impact reduction management. A robust manufacturing program reflects effective water use and conservation methods' adherence to environmental requirements. The weakest performance was recorded in packaging sustainability and urges for rigorous improvement, especially while using more sustainable packaging materials and cutting waste. The flawless performance was noted for product care and repair service sustainability encompassing durability and lifespan concerns, repairability design criteria, and efficient consumer communication with the services. Factory A is equipped with efficient infrastructure for collection and processing, design policies for end-of-use streams, and well-defined EOU programs.

Factory B had a moderate level of sustainability performance including materials (51.6/100), manufacturing (65/100), packaging (36/100), product care and repair service (72/100), and end of use (53/100). Sustainable practices in the Materials section identified restricted materials programs, whereas continuous improvement programs were highlighted by the manufacturing sustainability, which is good but not remarkable. Performance in packaging components showed insufficient sustainability practices, especially in using sustainable materials for manufacturing and cutting down packaging waste. Factory B has shown the highest potential in product care and repair service components, especially design standards and user communication, though it lagged behind the performance of factory A. Significant gaps were also identified in the EOU component, highlighting robust requirements in design policies and consumer communication.

Factory C had the lowest sustainability performance in all the categories including materials (38.6/100), manufacturing (41/100), packaging (7/100), products care and repair service (27/100), and end of use (40/100). The materials program by factory C is devoid of strong chemical responsibility and effect reduction management sustainable approaches. The manufacturing category recognized the need for major improvements in water consumption, environmental regulations, and plans for continual development. Its inefficiency in production is further diminished by the absence of a sampling program. The worst performance seen in the packaging component is the need to create and implement a sustainable packaging program, cutting waste, and using more eco-friendly materials. Performance in product care and repair service indicated the need for strong repairability design criteria, improved durability considerations, and improved consumer communication. The EOU program suggested comprehensive design policies for end-of-use streams and improved consumer communication.

Overall, factory A has proven to be a leader in sustainability, exhibiting excellent practices in every area. Still, there remains potential for development, especially in the area of sustainable packaging. Although factory B's performance was mediocre, there is still room for improvement in terms of materials, packaging, and end-of-life care. Factory C was far behind with serious deficiencies in every aspect of sustainability. Factory C needs to improve by creating strong materials programs, improving production procedures, launching sustainable packaging projects, and bolstering end-of-life management, product care, and repair services. Factory C may greatly improve its sustainability performance and lessen its environmental effect by addressing these areas, though this may be challenging, since they do orders according to subcontract basis. By identifying areas of strength and room for improvement, the Higg Product Sustainability Tools offer useful insights and strategic steps for evaluating and enhancing sustainability practices throughout these factories.

5. Theoretical and Practical Implications

This study has substantial theoretical implications for developing environmental sustainability strategies throughout the fashion product life cycle. To begin, this study led to a better understanding of the use of sustainability practice assessment in a major fashion manufacturing country that used industry-leading sustainability measurement techniques. Their analyses and measurements aid in understanding the product's factory-level sustainability practices. Initially, this study broadens our understanding of product environmental accountability across the life cycle stages. Previous research has repeatedly held merchants and first-tier suppliers, particularly those from wealthy countries, liable for the organization's ethical labor standards and sustainability challenges [56,57]. This study broadens the scope beyond the first tier of the supply chain to include second-tier dyeing, washing, and printing operations from environmental perspectives. Second, although brands bear primary responsibility for product performance as they design the products, this study aims to assess the extent to which manufacturers are addressing the sustainability characteristics of these items. Third, the study emphasizes the importance of a multi-stakeholder strategy, including multinational brands and retailers, in improving product sustainability in waste-to-fashion. This realization means that because manufacturing requirements vary widely by geography, any strategic decisions for understanding sustainability in the fashion business especially from upstream suppliers' perspectives must take the manufacturer's limitations into account. Fourth, the study emphasizes the importance of contextualizing sustainability concepts with specific post-consumer waste products. Higg Index tools provide valuable frameworks for evaluating product sustainability based on standards and guidelines [53,54]. However, the tool has some limitations in standard data quality and sustainability evaluation metrics. This study recommends creating more relevant and practical sustainability initiatives that are adaptive and actionable for future implications that consider the product life cycle [58,59] and manufactures perspectives.

In terms of managerial implications, this study looks into a variety of issues, including obstacles at various stages of the product life cycle. Despite poor performance ratings, manufacturers are making strides toward sustainability, particularly in the environmental aspects. The findings have the potential to influence decision-makers, supply chain managers, notably industry practitioners and policymakers, to reconsider the performance of the products they produce. We suggest manufacturers to routinely assess their product sustainability performance in light of the primary product criteria and life cycles. These recommendations would benefit manufacturers, brands, and retailers by increasing sustainability performance, working with the government, factory management, and other stakeholders to reformulate regulations that promote product sustainability and benefit packages, and involving managerial decisions. Creating a strategy plan to comprehensively reinforce product sustainability would encourage sustainability throughout the product's life cycle. However, repeated low performance across domains implies that maintaining a sustainability practice is dependent on the financial and technological capacity of the key stakeholders. To overcome these problems, key stakeholders need to work together, including governmental agencies, non-governmental organizations, trade unions, and international brands, to develop compliance rules and provide the necessary technical and financial support.

6. Conclusions

This study provides an effective mapping of sustainable practices and performance within the fashion product sustainability components made-from-post-consumer waste. The key novelty of this study is the revelation of the sustainable practices and poor practice areas for fashion product manufactured in the upstream supply chain in developing country, which are often unclear, opaque, and inaccessible to broader stakeholders. The results show a range of performances metrics of product from environmental perspectives. For example, products created in LEEDs-certified/green factories have the greatest environmental performance score (69), while ordinary (52) and sub-contractor facilities have the lowest. Despite using the same sustainable raw material (organic cotton), the total sustainability score differs greatly between the case study products generated from post-consumer waste. The use of eco-friendly chemicals, methods, and green chemistry will considerably increase product sustainability performance in the material phase. A careful study of material efficiency, low-impact garment finish, printing, and ornamentation would significantly increase the product's manufacturing score. Packaging/trims/accessories is a huge topic that has received insufficient attention and requires careful thought. Useful care instruction labels, use, care, and repair, with a focus on reducing water, energy, and detergent consumption to benefit the environment/stakeholders. In a circular fashion system, fashion design stages must include product end of life, focusing on materials selection, separations, disassembly, reuse, and recyclability with existing infrastructure, process and technology. Brands and retailers should effectively communicate instructions to stakeholders (e.g., customers) and prioritize donation, reuse, repair, repurpose, swapping, second-hand businesses. The technical product package, e.g., tech-pack, should be carefully prepared for stakeholders (e.g., suppliers, manufacturers, consumers) to provide more comprehensive information that links fashion circularity aspects from design to disposal. The study also identifies mismanagement in environmental sustainability decision making by the upstream fashion product manufacturers. However, successful strategies involve multi-level employees in decision-making processes and ensure that sustainable practices are followed throughout the life cycle. This study proposes that firms can profit from incorporating environmental sustainability into the core fashion product life cycle by demonstrating how these practices benefit other stakeholders.

7. Limitations and Future Research

This study aimed to assess the environmental sustainability of fashion products generated from post-consumer waste. Economic and societal elements should be included in a more thorough analysis. Furthermore, the study was limited to a single product typology, and the possibilities for other facilities may be similar. To achieve more generalized outcomes, we recommend broadening the application to include a wider range of products and facilities that address various social and economic issues. Furthermore, researchers and academics could use the Higg Index tool in more general applications to highlight areas of concern and viable solutions for the industry's change. These findings open up new opportunities for future research in both theory and practice, considering many aspects of policy and regulatory framework viability. Collaboration is vital for achieving larger and more inclusive sustainability goals relevant to product centric. The cooperation of different stakeholders, including the government, buyers, and non-governmental organizations (NGOs), is critical in improving present environmental circumstances and taking required actions to rectify any difficulties, all while guaranteeing a more comprehensive and holistic approach to fashion sector sustainability.

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Appendix A

Sl. No	Questionnaires	Factory Response		
		Factory A (LEED)	Factory B (Non-LEED)	Factory C (Sub-Contract)
Section 1: Materials sustainability evaluation				
1	Materials name	Organic cotton	Organic cotton	Organic cotton
2	Recycled content %	20%	20%	20%
3	Virgin, certified organic content %	80%	80%	80%
4	Other source certification or verified chain of custody for Eco-Index	Yes, GOTS, BCI Certified, improved traceability	Yes, Only GOTS certified	No
5	Coating/laminate finish? (If yes, specify type)	No	No	No

Sl. No	Questionnaires	Factory Response		
		Factory A (LEED)	Factory B (Non-LEED)	Factory C (Sub-Contract)
6	Dyeing/coloring? (If yes, specify reduced water process/technology)	Yes, eco-friendly dyes and chemicals, enzymatic scouring used	Eco-friendly chemicals, enzymatic scouring used	No, traditional dyeing process/technology used
7	Chemical impact/toxic substance reduction strategies ("green chemistry")	Yes (documented reductions)	Yes (Partially documented)	No
8	Green chemistry third-party verification	Yes, ZDHC OEKO Tex-100	No	No
Section 2: Manufacturing sustainability evaluation				
9	Marker/Materials efficiency	91%	85%	78%
10	Garment finish (no garment finish/low/medium/high impact finish)	B: Best in class (process combination enzyme wash, high-efficiency dyes, wastewater reuse	C: Low-impact finishes, basic rinse/softener	E: High-impact finish: traditional bleach/acid/dye, PP spray
11	Applied graphics and logo (embellishment/appliques/embroidery)	10 cm^2 or less	10 cm^2 or less	10.5–100 cm^2
12	Screen printing size	10.5 to 100 cm^2	10.5–100 cm^2	10.5–100 cm^2
13	Screen printing color	Two colors	Three colors	Three colors
Section 3: Packaging and sundries				
14	Product use packaging (hanger, hangtag, polybag, box, tape, pin, paper board, tissue)	Yes, product packaging is used	Yes, product packaging is used	Yes, product packaging is used
15	Packaging scenario: benchmarking reductions	Yes, benchmarking reflecting 16–20% reduced consumption	Yes, benchmarking reflects 11–15% reduced consumption,	Yes, benchmarking reflecting 11–15% reduced consumption.
16	Packaging are designed for reuse/recycling using existing processes/setup/technologies	Materials are recyclable and materials used in packaging are recyclable	Materials are recyclable, and at least one component is reused	No component is reused or recycled
Section 4: Product care, use and repair service sustainability evaluation				
17	Does the product use packaging (hanger, hangtag, polybag, box, tape, pin, paper board, tissue)	Yes, product packaging is used	Yes, product packaging is used	Yes, product packaging is used
18	Packaging scenario: benchmarking reductions,	Yes, benchmarking reflecting 16–20% reduced consumption	Yes, benchmarking reflects 11–15% reduced consumption	Yes, benchmarking reflecting 11–15% reduced consumption

Sl. No	Questionnaires	Factory Response		
		Factory A (LEED)	Factory B (Non-LEED)	Factory C (Sub-Contract)
19	Recyclability, products and transport packaging are designed for reuse/recycling	Materials are recyclable, reusable, and repurposed	Materials are recyclable, and at least one component is reused	No component is reused or recycled
		Section 5: End of Life (EOL) evaluation		
20	Product designed for closed-loop recycling: individual materials be identified by the EOL, and products made of single materials can be disassembled into individual materials easily, individual material types can be recycled. Materials can be used in closed-loop recycling	Yes, but materials can be used in closed-loop recycling processes	Yes, but materials cannot be recycled via existing setup in a closed loop system	Yes, but materials cannot be used in closed-loop recycling via infrastructure or processes
21	Product quality brands for the EOL program and communicate instructions to the consumers via on-product labels	Yes, the product has on-product label instructions for reuse, repurposing, recycling	Yes, product has on-product label instructions for reuse, repurposing, recycling	No
22	Product label instructions do prioritize donation/re-use steps for customers	Yes	No	No Instructions regarding priorities donation/reuse step for consumer

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