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Research on Apparel Design Innovation based on Sustainable Fashion – Taking the Transformation of Fast Fashion Brands as an Example

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Abstract: ***This paper focuses on the design innovation path of fast fashion brands in the context of sustainable fashion transformation, constructs an analysis framework based on sustainable fashion theory, and adopts a multi-case study method to systematically analyze three representative international fast fashion enterprises, namely SHEIN, H&M, and C&A. The study finds that the three companies have carried out multi-dimensional practical exploration in digital-driven material reuse, life-cycle oriented recycling design and green control of the whole chain, presenting systematic optimization features from raw material selection, structural design to production management and consumption guidance, while SHEIN relies on flexible supply chain and big data algorithms to implement 'on-demand production', H&M builds a sustainable fashion system, and C&A builds an 'on-demand production' system. SHEIN implements 'on-demand production' based on a flexible supply chain and big data algorithm, H&M builds a recycling consumption network, and C&A guarantees the sustainability of the whole process through raw material certification and green technology. On this basis, this paper further proposes four optimization paths for design innovation in fast fashion: firstly, to establish a sustainable design standard system and promote the standardization of the design process; secondly, to build a cross-sectoral synergy mechanism and enhance the effectiveness of organizational linkage; thirdly, to strengthen the consumer education and co-creative mechanism, and to enhance the participation in green consumption; and fourthly, to promote the industry's synergistic policy linkage, and to create a benign ecological environment. The study aims to provide operational green transformation strategies for the fast fashion industry and promote the construction of a responsibility-oriented sustainable fashion system.***

Keywords: Continuous fashion; Fast fashion; Apparel design; Design innovation; Brand transformation.

1. INTRODUCTION

In the midst of the global ecological crisis and growing awareness of social responsibility, the fashion industry, especially the fast fashion sector, is facing unprecedented pressure of transformation and development challenges. Fast fashion has reshaped the global apparel consumption structure over the past two decades and has become a dominant market model due to its high frequency of updates, low prices, and high market responsiveness. However, the over-consumption of resources, environmental pollution, and labor issues behind fast fashion have been increasingly exposed, leading to widespread public questioning of the ethics and sustainability of fast fashion. Against this backdrop, Sustainable Fashion has emerged as an important concept and strategic direction to guide the transformation of the industry. As a systematic fashion development path integrating eco-design, resource recycling, and social responsibility, sustainable fashion is not only a technological innovation but also a reconstruction of values and industrial logic. The theory of sustainable fashion is rooted in the extension of the sustainable development strategy in the field of industrial design and manufacturing at the end of the 20th century, and its core lies in the synergistic optimization of design, production, and consumption to achieve resource-saving and environmentally friendly apparel in the whole life cycle. At the apparel design level, the theory emphasizes 'management from the source', advocating the incorporation of key elements such as material renewability, biodegradability, and energy efficiency at the early stage of design, and extending the service life of apparel through modularisation and repairable structures to reduce the generation of waste. At the production stage, systematic energy saving and emission reduction are achieved through green technology, low carbon technology, supply chain management, and a fair labor system. In the consumption and reuse stage, sustainable fashion actively advocates the circular economy model, promotes diversified use paths such as apparel leasing, recycling of used clothes, and re-design, and guides the formation of consumers' green awareness and change of consumption behavior through information transparency. For fast fashion brands, the transition to sustainable fashion is not only a reflection of the industry's responsibility but also an inevitable choice to respond to new market demands and build long-term competitiveness. Especially in the context of the global 'dual-carbon'

strategy and the growing greening of consumption concepts, fast fashion brands can no longer rely on cost control and market speed to gain an advantage but need to reshape their brand image and value proposition through systematic design innovation and ecological value leadership. Design, as the source and core of fashion products, plays an irreplaceable role in sustainable transformation. Therefore, it is of great theoretical value and practical significance to explore the path choice and innovation mechanism of fast fashion brands in sustainable design practice.

Based on this understanding, this paper is based on the theory of sustainable fashion and adopts a multi-case study method to systematically analyze the sustainable design practices of three internationally influential fast fashion brands: SHEIN, H&M, and C&A. SHEIN, as a digitally-driven emerging brand, optimize its supply chain and resource allocation through data algorithms, and optimizes its supply chain in the recycling of waste materials and the allocation of resources. SHEIN, as a digitally-driven emerging brand, optimizes supply chain resource allocation with data algorithms and actively explores the reuse of waste materials and on-demand production; H&M builds a closed-loop system covering materials, design, and post-consumer recycling through its 'Conscious' series, which reflects the in-depth application of the concept of life-cycle management; and C&A demonstrates systematization and standardization of sustainable design practices through its stringent raw material certification mechanism and full-chain green management system. C&A, on the other hand, with its strict raw material certification mechanism and whole-chain green management system, has demonstrated a systematic and standardized path of ecological governance. The three brands represent diversified attempts at sustainable design by fast fashion brands at different stages of development and with different technological capabilities.

Through an in-depth comparison and analysis of these three brands, this paper aims to sort out the core strategies, path logic, and stage-by-stage results of sustainable design practices in the fast fashion industry, and to reveal their innovative features and effectiveness mechanisms in material selection, structural design, application of technological tools and life cycle management. On this basis, we further explore the construction of a sustainable design standard system, organizational synergy mechanism, consumer co-creation mode, and policy support system, so as to provide fast fashion brands with replicable and scalable green design transformation path suggestions. Through the dual perspective of theory and practice, this paper hopes to provide theoretical support and practical inspiration for the fast fashion industry to get out of the traditional dilemma of 'high consumption and high waste', and to move towards a responsible and recyclable form of future development.

2. THEORETICAL FOUNDATION AND RESEARCH METHODOLOGY

2.1 Theory of Sustainable Fashion

Sustainable Fashion is a concept of apparel design and production with ecological ethics, resource conservation, and social responsibility as its core orientation, the essence of which is to minimize the negative impacts on the environment and society while satisfying consumer needs. The theory originated from the expansion of sustainable development theory in the industrial field at the end of the 20th century, and its embodiment in the apparel industry is not only related to the selection of materials and product life cycle management but also covers the systematic optimization of the supply chain structure to the guidance of consumer behavior.

At the level of apparel design, sustainable fashion emphasizes the strategy of 'management from the source', advocating that designers should consider the renewability, biodegradability, and energy consumption level of materials at the early stage of creation, and incorporate the idea of extending the life cycle of apparel by integrating the ideas of repairability and modularity in the design. Common practices include the use of environmentally friendly fabrics such as organic cotton, recycled polyester, and Tencel, the introduction of low-emission processes such as seamless weaving and digital printing and dyeing, and the use of digital tools such as 3D sampling and virtual prototyping to improve the accuracy of the design and reduce the waste of sampling. Sustainability at the production stage is reflected in a number of dimensions, including low carbon emissions, energy saving, and fair labor practices. Some advanced brands have introduced green factory assessment systems to quantitatively manage indicators such as water usage, waste recycling rates, and carbon footprints, and to promote cleaner production and process optimization. In the consumption and reuse phase, sustainable fashion encourages the development of circular economy models, such as apparel recycling programs, refurbishment of old clothes, clothing rental, clothing swap, and other new forms of consumption. At the same time, the visualization of information (e.g. labels indicating the origin of materials and carbon emissions) enhances consumers' awareness of the environmental impact of products and helps spread the concept of green consumption.

From a macro perspective, the theory of sustainable fashion is not only a change in design or production methods, but also a reconstruction of social values in the apparel industry, and its core objective is to realize a win-win situation for the environment, economy, and society. Especially in the context of the global 'dual-carbon' strategy, sustainable fashion has evolved from a corporate moral responsibility to a necessary path for brand survival and development.

2.2 Research Methodology

In order to explore the innovation path of apparel design embodied in the transition of fast fashion brands to sustainable fashion, this paper adopts the multi-case study method as the main research method. This method has strong explanatory and exploratory qualities, is suitable for analyzing the commonalities and differences in complex phenomena, and can effectively reveal the logic of the mechanism behind the practice and the effectiveness of transformation. In this paper, three globally representative fast fashion brands, SHEIN, H&M, and C&A, are selected as research objects. These three companies occupy an important position in the international market and have initiated a number of landmark projects in terms of sustainable transformation, which have significant exemplary and comparative value: SHEIN, as a digitally emerging brand, provides new ideas for sustainable design with its supply chain flexibility and data-driven features; H&M is the earliest large-scale fast-fashion company to deploy a sustainable strategy globally, and its 'Conscious' brand is the first fast-fashion company to deploy a sustainable strategy. H&M is the first large fast fashion company to deploy a sustainable strategy globally, and its 'Conscious' series and apparel recycling system have achieved a certain scale effect; while C&A is known for its rigorous certification of raw materials and full life cycle management mechanism, and has built a more mature green control system.

This paper focuses on secondary data, supplemented by qualitative content analysis, and the data sources include but are not limited to: official sustainability annual reports released by brands; white papers and guidelines released by industry organizations (e.g. the Ellen MacArthur Foundation, the Textile Exchange Association, etc.); empirical research results from domestic and international academic journals; and tracking and reporting on environmental actions of brands by major authoritative media outlets. The above information is systematically collated and analyzed. By systematically collating and summarising the above data, this paper analyses the path characteristics and stage-by-stage results of fast fashion brands in addressing environmental challenges and shaping green competitiveness from the perspectives of material selection, structural innovation, application of digital tools, and life-cycle management in apparel design. In order to enhance the breadth and comparability of the study, this paper follows the principle of 'heterogeneous comparison on the basis of homogeneity' in the case analysis process, i.e., in the context of fast fashion, the three companies identify the commonalities and differences of their sustainable design strategies, so as to enhance the universality and practical value of the research conclusions.

Based on the guiding framework of sustainable fashion theory, combined with multiple case studies and content analyses of typical enterprises, this paper aims to analyze how fast-fashion brands move towards sustainable development through design innovation from both theoretical and practical perspectives and to provide the industry with operable ideas and paths for transformation.

3. ANALYSIS OF SUSTAINABLE DESIGN PRACTICES OF FAST FASHION BRANDS

Against the backdrop of the growing trend of global sustainability, fast fashion brands are facing increasingly severe ecological and social responsibility challenges. In order to realize green transformation, more and more brands are trying to introduce sustainable concepts into apparel design and build a closed-loop product lifecycle management system from raw material selection, design method, and production process to post-consumer recycling. This paper takes SHEIN, H&M, and C&A, three representative fast-fashion brands, as research objects, to systematically sort out their core strategies and implementation paths in the field of sustainable design, in order to explore feasible modes of sustainable transformation in the fast-fashion industry.

3.1 Digital-driven Reuse of Surplus Materials

SHEIN, as a rapidly emerging globalized digital fast fashion platform in recent years, has gradually built up an 'on-demand production' logic that is different from that of traditional fast fashion, relying on its powerful online operation system and data algorithm capability. In terms of sustainable design, SHEIN has launched the 'SHEIN X

Rescued' series in recent years, actively exploring ways to reuse waste materials. The collection mainly uses fabric remnants and out-of-season fabrics left over from the production process, and through redesign and small batch production, the value of materials can be regenerated, avoiding the waste of resources due to backlog. In addition, the collection applies environmentally friendly digital printing and dyeing technology, which significantly reduces water consumption and chemical emissions compared to traditional dyeing and finishing processes. Shein introduces a high-precision digital forecasting system and a flexible supply chain management model, which makes use of big data such as users' browsing behaviors and social media trends to build a forecasting model, effectively reducing the proportion of blind production. Its 'small batch, quick test marketing, data feedback, re-batch' model not only improves inventory turnover but also fundamentally reduces the waste of resources due to inventory backlogs, which has become an important support mechanism for its sustainable design.

Although SHEIN still faces questions about the lack of supply chain transparency in its green transformation, its attempts to reuse materials and empower digital technology provide a reference path for emerging fast fashion brands to explore sustainable design.

3.2 'Conscious' Series and Circular Design System

As one of the earliest international fast fashion giants to initiate sustainable transformation, H&M's sustainable design strategy is systematic and forward-looking. Since the launch of the 'Conscious' series in 2011, H&M has been expanding its depth and breadth in environmentally friendly materials, green design, and recycling mechanisms. The collection uses organic cotton, recycled polyester, Tencel, and other low environmental impact materials on a large scale, and strictly adheres to third-party certification systems (e.g. GOTS, GRS, etc.) to ensure the traceability and ecological safety of material sources.

In terms of product design, H&M takes 'life cycle thinking' as its guiding principle, and optimizes the durability, repairability, and recyclability of clothing. The designers give full consideration to the simplicity of the clothing structure and the replaceability of functional modules during the creation process, trying to extend the life cycle of the products through design means and reduce the possibility of premature disposal. At the back end, H&M has set up a comprehensive recycling network. Most shops worldwide have used-clothes recycling bins, accepting used clothes of any brand and promoting consumer participation in clothing recycling. After sorting, some of the recycled clothes are re-designed and processed into new products, while the rest go into the raw material recycling or energy conversion process, building a more complete 'recycling - remanufacturing - re-selling' closed-loop model. Through the combination of technological innovation and institutional design, H&M has effectively realized the structural transformation from linear consumption to circular consumption.

3.3 Full-chain Green Control and Raw Material Certification Mechanism

As a traditional European apparel brand, C&A shows a high degree of systematicity and responsibility in sustainable development, and its green design strategy runs through the whole life cycle of its products and penetrates into all nodes of the supply chain. In material selection, C&A sets strict procurement standards, all man-made cellulose raw materials must be sourced from FSC or PEFC-certified sustainable forestry systems, and prohibits the use of animal raw materials from unknown sources or obtained through unethical means, such as wool and down that have not been humanely farmed.

At the design stage, C&A has developed technical specifications covering material safety, environmental impact, recyclability, and life cycle assessment. C&A also strengthens the training of partner factories in sustainable design, promotes green processes and eco-dyeing and finishing technologies, and raises the environmental standards of the whole industrial chain. C&A also strengthens the training of partner factories in sustainable design capabilities, promotes green technology and eco-dyeing and finishing technology, and raises the environmental standards of the whole industrial chain. This whole-chain green governance approach from producers to consumers effectively enhances the integrity and credibility of its sustainable design system.

Although the three brands differ in their development paths, market positioning, and technical capabilities, they have all carried out multi-dimensional exploration in the field of sustainable design: Shein relies on digital advantages to build a resource optimization model, H&M emphasizes environmental protection of materials and life-cycle management, and C&A guarantees the green transformation with systematic standards and controls. The above practices show that fast fashion brands collaborate to promote sustainable design strategy through technological innovation, institutional design, and consumer interaction, gradually breaking the traditional label of

'fast fashion is wasteful', and providing a replicable and promotable path reference for the green transformation of the apparel industry.

4. DISCUSSION ON THE OPTIMISATION PATH OF FAST FASHION DESIGN INNOVATION

Driven by the 'dual-carbon' strategy, green transformation, and changes in global consumption concepts, fast fashion brands need to start from the design source, systematically build a sustainable design capability system, and realize the strategic leap from 'speed priority' to 'responsibility orientation'. to achieve a strategic leap from 'speed-first' to 'responsibility-orientation'. At present, most fast fashion enterprises still have problems such as fragmentation of the promotion mechanism, lack of technical standards, insufficient internal synergy, and weak motivation on the consumer side in the process of promoting sustainable design. Therefore, this paper proposes four optimization paths in order to provide operational suggestions and theoretical support for the fast fashion industry to achieve sustainable design innovation.

4.1 Establish a Sustainable Design Standard System

Currently, most fast fashion enterprises focus on a specific series of products or a single project to promote sustainable design, which lacks systematicity and standardization. This 'project-driven' mode can promote brand image construction in the short term, but it is difficult to form a long-term stable sustainable innovation mechanism. For this reason, enterprises need to establish a set of sustainable design standards covering material selection, structural design, process control, life cycle assessment, and other multi-dimensional elements, to ensure that the whole process of design activities is in line with the goal of environmental protection and resource optimization. On the one hand, introduce international mature eco-design tools and standards, such as ISO 14006 'Environmental Management System - Eco-design Guidelines', to incorporate environmental factors into the design process management, and help enterprises establish a standardized and quantifiable green design process; on the other hand, formulate the brand's own internal technical specifications for sustainable design, and clarify the material renewability rate, carbon footprint limit, garment structural durability assessment, and the environmental impact of the design process on the environment and resources. Limits, garment structural durability assessment indexes, and other core parameters guide designers to make conscious eco-decisions in the creative process. In order to effectively implement the standard system, enterprises should also combine the product life cycle assessment (LCA) methodology to systematically assess the resource consumption and environmental impact of garments from raw material extraction, production and processing, transportation, and sales to the use and disposal phases, and then feed back into the design process to optimize the material combination, simplify the structure, enhance the dismantling, and realize closed-loop improvement.

4.2 Construct a Cross-departmental Coordination Mechanism

Sustainable design is not an 'isolated behavior' of the design department, but a systematic project spanning the upstream and downstream of the supply chain and covering all functional modules of the enterprise. Currently, many enterprises face the problem that each department has a different understanding of sustainable goals, and poor synergy, resulting in the green design concept being difficult to effectively conduct in procurement, manufacturing, sales, and other links, which in turn affects the overall effect of the landing. Therefore, enterprises should establish a cross-functional sustainable design collaboration mechanism, and set up a working team covering design, procurement, quality, supply chain management, marketing, and other departments, so as to promote the green concept to achieve consistent awareness and efficient linkage within the enterprise. In terms of organizational structure, a 'sustainable development office' or a dedicated green design position can be set up, specifically responsible for promoting the development of standards, project coordination, and external cooperation, and enhancing the professionalism and execution of the project. Introduce green performance indicators into the performance evaluation system, such as the proportion of environmentally friendly materials used, the level of carbon emission control, and the number of recyclable structural designs, etc., so that each department can embed sustainable goals into the logic of business operations. In addition, internal training, creative competitions, and green design workshops not only enhance employees' environmental awareness and professional skills but also help build a green innovation culture within the company.

4.3 Strengthen Consumer Education and Co-Creation Mechanisms

Consumers, as the end-users of fashion products, have a direct impact on the market effectiveness of sustainable

brand design in terms of their environmental awareness and consumption choices. However, the research shows that some consumers have a vague perception of 'sustainable clothing' and easily equate it with stereotypes such as 'high price', "impractical" and 'single design'. Some consumers have a vague perception of 'sustainable clothing' and easily equate it with stereotypes such as 'high price', "impractical" and 'single design', which to a certain extent restricts the market conversion rate of green products. Brands should take the initiative to take responsibility for spreading the concept of environmental protection and establish a multi-dimensional consumer education mechanism. The first is to transparently display the environmental attributes and carbon footprint information of the apparel through the product labeling system, such as the source of raw materials, environmentally friendly processes, water consumption, and emissions, etc., so as to enhance consumers' perception of the environmental value of the products; the second is to develop visual digital platforms, such as the sustainable points system and interactive LCA assessment page so that consumers can intuitively understand the meaning and effect of environmental design during the browsing and shopping process; the third is to use social media, online communities and other channels to organize the environmental education of consumers. Third, use social media, online communities, and other channels to organize green topic discussions and environmental initiatives to guide the public to form a sustainable consumption identity. Through the 'consumer co-creation mechanism' to enhance user participation, such as inviting consumers to participate in the transformation of old clothes, product naming, environmental protection packaging design, and other links, so as to make them become an active link in the green innovation chain. This mechanism not only enhances the emotional added value of the product but also helps the brand to build a deeply interactive user community and increase consumer loyalty to the sustainable brand.

4.4 Promote Industry Synergy and Policy Linkage

It is difficult for individual fast fashion brands to independently support the sustainable transformation of the whole industry, especially in the areas of upstream material development, recycling system construction, and green supply chain supervision, which need to rely on the joint promotion of the industry platform and policy environment. Therefore, building an industry synergy mechanism and policy linkage system is an important pivot point for realizing systemic change. At the industry level, we should actively promote the establishment of a unified sustainable design certification system and evaluation standards, such as a unified green raw material labeling system and the formulation of recyclable structure design guidelines, so as to provide different brands with technical specifications to follow, reduce 'green rinsing' behaviors, and enhance the overall transparency and credibility of the industry. At the same time, leading enterprises are encouraged to join hands with upstream and downstream small and medium-sized enterprises to form green industry alliances, realize resource sharing and technology co-construction, and build a green industry ecology. At the policy level, the government should promote the green transformation of enterprises through incentive mechanisms. For example, it should provide tax relief, financial subsidies, or green credit support for the import of environmentally friendly design materials, the promotion of green-certified products, and the construction of recycling facilities. In addition, the construction of an apparel recycling system should be improved, promoting the establishment of recycling points in urban business districts and communities, and cooperating with brand enterprises to establish a standardized and high-efficiency apparel reuse platform. Universities and research institutes are encouraged to carry out research and development of key technologies such as green fibers, new environmentally friendly processes, and visual assessment tools, and to form industry-university-research consortia with brands through the results-transformation mechanism, so as to speed up the transformation of green design from theory to application.

In order to achieve a truly sustainable design transformation, fast fashion brands need to make multi-dimensional efforts from standard construction, organizational synergy, and consumer interaction to industry policy linkage. By building a systematic, quantifiable, and synergistic green design system, not only can we effectively improve our own environmental competitiveness, but also provide solid support for the fast fashion industry to build a responsible and recyclable new development pattern. In future development, the only way to break the structural dilemma of 'fast fashion = high consumption' and reshape the long-term resilience and sustainability of the fashion industry ecosystem is to embed sustainable thinking in the source of design.

5. CONCLUSION

1) Fast fashion brands are building a differentiated sustainable design system through material reuse, eco-design, and digital production strategies, indicating that the fast fashion industry has the feasibility of realizing green transformation under environmental constraints.

2) The cases of SHEIN, H&M, and C&A show that technological innovation, institutional norms, and consumer

interaction constitute the core support elements of sustainable design in fast fashion, and their synergistic promotion can help to break the structural dilemma of high waste in traditional fast fashion.

3) The construction of standardized, collaborative, and visualized sustainable design paths is not only the key to the green competitiveness of enterprises, but also provides systematic experience of value for the transformation of the fast fashion industry as a whole.

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