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Artificial Intelligence in Fashion Retail: Opportunities, Challenges and Governance

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Abstract:

Artificial Intelligence (AI)'s rapid expansion has changed the process of garments design, logistics processes, and advertisements in the fashion industry worldwide. From forecasting trends and tailored advertising to machine-based stock optimisation, AI is forcing apparel businesses to make radical gains in operations efficiency and competitive success in the marketplace, while creating unprecedented potential. However, this rapid remolding of operations has brought an innumerable number of issues. As apparel businesses rely increasingly on decision-making based on AI, issues concerning fairness in implementing AI, safeguarding their information, and consumer confidence have gained worldwide attention. Infrastructure gap in AI between large and small- or medium-sized companies in the fashion industry impedes equal adoption of AI heavily and expands the distance between large companies in fashion and small- or medium-sized companies. Moreover, a failure in a governing framework of laws at the same time compels fashion companies to reach a compromise between innovation in technologies and meeting stakeholders' rising expectations for ethical accountability and governance. This research aims to explore broader ethical, technical and legal problems caused by new applications of AI which are reshaping the value chain in fashion. Based primarily on qualitative research, it reviews recent findings and reports in the industry in an attempt to map cutting-edge applications of artificial intelligence in the fashion industry. It marks an imperative for developing transparent guidelines for collaborative mechanisms in governance and thereby offers business professionals in the fashion sector a modern-day overview for balancing competitiveness versus responsible use of AI in the sector.

Keywords: Artificial intelligence; fashion industry; fashion value chain; personalised marketing; legal governance.

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1. Introduction

Global economic instability, unequal pandemic recoveries in regions, and changing consumer preferences are all jointly pushing for swift demand as well as supply transformations in the worldwide apparel sector [1]. Even though sustainable development continues to remain a shared priority for the world's societies as well as governmental regulatory institutions globally, economic recession uncertainties prompted consumers towards a shift in their user preferences towards affordability as well as aesthetic values over environmental values. As a result, those conflicting expectations further highlight a pressing imperative for innovation solutions allowing worldwide fashion businesses to cope up with societal as well as governmental pressures without negatively impacting their competitiveness. However, in this regard, a consistent change driver for those within recent years in the fashion sector remains AI, which applications now cover nearly the whole fashion industry ranging throughout design production to retailing [2].

When AI first launched in the fashion industry, its primary applications were in reducing costs as well as enhancing functional effectiveness. Within the fashion Supply Chain Management (SCM) sector, the stock keeping and sales forecast optimality capabilities of AI were revealed in [3]. Researchers were able to handle large Stock-Keeping Unit (SKU) efficiently with applications of Neural Clustering and Classification (NCC). Further research reveals that [4], based on operational effectiveness imperatives, product forecast methods have evolved further beyond simple integration of large datasets towards image-rich and information-rich methods. By matching visual characteristics of apparel with their respective sale information in an attempt for greater accuracy in demand prediction, for instance, this program maximises stock holding as well as reducing wastages of resources, it is revealed that the footprint of AI goes a lot further in enhancing not only functional effectiveness.

Yet later research also documents how in the contemporary era AI increasingly needs to fall within broader frames of ethics, society and environment. To the degree that AI in fashion increased efficiency and forecasting capability, it also made more keenly visible an ecosystem in which risk and possibility coexist [5]. Beyond sustainability within a retail ecosystem in fashion, such variables as algorithmic bias in an AI program, opacity concerning information and consumer mistrust any either directly impede brand reputation and competitive position [6]. Thus, this also demonstrates that AI possesses the capacity to enhance operational precision and potentially drive circular practices, while simultaneously increasing risks associated with governance and ethical accountability, thereby giving rise to both positive and negative implications for its long-term societal impact.

Despite current policy-orientated reports emphasising sustainability and ethical governance [7], and existing technological research frequently highlighting AI's innovative and operational advantages, the fashion industry itself still lacks systematic integration across these domains. Beyond short-term efficiency gains, the long-term implications of advanced AI remain unclear, particularly concerning unequal AI infrastructure, algorithmic fatigue, data privacy, and consumer trust.

To bridge this gap, this study examines how emerging AI technologies are reshaping the fashion industry, focusing not only on their innovative potential but also on the ethical, social and legal issues they raise. Section 2 outlines the latest applications of AI within the fashion value chain, while Section 3 analyses the potential risks posed by AI-driven systems to consumer autonomy, data privacy and governance mechanisms. Finally, Section 4 outlines future research directions and key strategic considerations for policymakers and fashion brands' operators.

2. Applications of AI in the Fashion Value Chain

2.1 Innovative AI Fashion Design

This research study proposes a framework termed the Human-AI Collaborative Generative Adversarial Network (HAC-GAN) [8], which redefines the role of AI within the fashion design process. Rather than simply automating tasks, by enabling real-time adjustments, the system assists fashion designers in accelerating creative designs, and maintains cultural sensitivity through the large volume of historical and contemporary fashion design data provided by the framework.

In this research study, researchers combined AI-driven design innovation with human evaluation. They first compiled over 50,000 streetwear and haute couture designs from 2010 to 2023 named FashionDNA-1M, which incorporates metadata detailing production techniques, materials, and socio-cultural contexts. Subsequently, a deep conditional generative adversarial network (DCGAN) trained on this dataset employed style transfer techniques to fuse elements from contemporary and early fashion eras. Secondly, they organised 30 professional designers to evaluate the visual appeal and practicality of the model's outputs across tasks such as fabric selection and pattern drafting. Furthermore, they tested an iterative optimisation feature enabling designers to provide real-time guidance and modify outputs during the AI generation process. Meanwhile, to evaluate the overall creative value, researchers developed the Fashion Creativity Index (FCI), covering cultural resonance (assessed by an expert panel

based on UNESCO guidelines), practicality (determined through wearability scores generated by 3D garment simulations), and innovation (measured by the possible spatial distance from existing designs).

The final research study revealed that in professional designer evaluations, 65% of GAN-generated outputs excelled during the initial conceptualisation phase, being rated as AI models possessing professional practical value. Furthermore, participants particularly emphasised the model's capability to rapidly generate a large number of design variants, significantly enhancing the efficiency of creative design workflows.

However, research studies indicate that designs generated by AI score lower in emotional appeal compared to human-designed solutions. It means while creativity generated by AI can introduce novelty, it is not yet endowed with depth in emotional and cultural linkage inherent in human creativity even when provided with full contextual information. FCI subsequently incorporated such research outcomes for scoring, which had an innovation score 42% higher than standard GAN tools in effect validating HAC-GAN's design capability for generating.

2.2 AI in Fashion Supply Chain

This study explores predictive Machine Learning and Artificial Intelligence clustering techniques for enhancing supply chain operations within the apparels industry [4]. The researcher incorporated historical sales along with product attributes information while at the same time taking into consideration losses of sales opportunities brought about by stockouts and losses brought about by overproduction.

They employed an AI technique for product feature extraction in product images, categorising products in C1 and C2 based on sale behaviours and visual attributes. Support Vector Machines (SVM), Random Forests (RF), Neural Networks (NN) and Naive Bayes (NB) were further trained for assignment of new products into some groups. Then for each product in each group, historical closest matches were identified using cosine similarity, while their corresponding sales history served as their predictive foundation. Finally, for complete assessment purposes, model performance for each group was also assessed using a mix of prediction and classification measures.

The result reveals that optimal classification efficiency was achieved by the NN with 0.716 AUC and 72.4% accuracy level. SVM came next with 0.621 AUC while RF had 0.526 AUC with the least performance by the model for NB. Further, compared with Cluster C1's RMSE at 0.0328 and 0.0169 MAE, Cluster C2 had an RMSE at 0.0248 with 0.0163 MAE, which means there is more predictive accuracy for C2. Moreover, most predicted weekly sales curves closely fit actual sales behaviours. Overall, these researches substantiate the fact that image forecasting technology using AI is in a position to assist the fashion industry actively prevent wastages in stock as well as overproduction, consequently pushing the supply chain towards sustainability as well as circularity.

2.3 AI-Powered Fashion Retail Transformation

This research employed a qualitative research design incorporating expert interviews for its study into how customer and inventory management in the fashion retail sector is being transformed by technologies based on AI [9]. Although its sample size was a small one made up of interviews with 20 retailing professionals, technologists, and industry commentators with close specialist knowledge about the practical uses of AI, its ultimate findings delve extensively into attributes both beneficial and concerning the use of AI in fashion retailing.

2.3.1 AI in Fashion Product Inventory Management

According to interview results, a number of participants cited the viability of retailers using AI-driven demand forecasting technology. Such technology reconciles historical sales data with external sources such as market trends in addition to seasonal shifts in an attempt to make more accurate demand forecasting, with the real-time stockkeeping unit adjustment. Data from a 2017 report by McKinsey indicate that organisations in the leading quarter for their analytic capabilities are twice as likely as their counterparts to outperform in financial performance, and making decisions five times earlier compared with organisations in the bottom quartile [10], which confirms the value of AI-driven demand prediction. Moreover, 45% of high-performance retailing organisations, including fashion retailers, operate infrastructure based on cloud analytics. Besides enhancing scalability, this technology further reduces error rates in inventory management systems [10]. These inferences all collectively substantiate that predictive and analytical AI-based methods for optimising inventories can enhance functional effectiveness while generating better financial outcomes in the retail fashion sector.

2.3.2 AI-driven personalisation

These interviews also identified another key advantage that AI is feasible to greatly enhance customer engagement with the help of AI-driven personalisation tools such as recommendation system and virtual advisors which provide custom recommendations and provide consistent support in different social media or website channels [9].

In relation to this, a recent quantitative study on AI-powered personalisation in fashion e-commerce surveyed 729 online consumers who were users of AI-powered recommendation technologies [11]. Through survey research based on Structural Equation Modelling (SEM), the study indicated consumer brand trust had a strong

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influence significantly on satisfaction (β = 0.721) and loyalty (β = 0.191), while AI-personalised recommendations substantiate such linkages by moderating between associations of trust-satisfaction-loyalty. Moreover, incorporating personalisation as a moderator increased explanatory power in the model by 5%, which is an indication of its primary role in brand loyalty improvement. In addition, higher reliability was manifested throughout constructs such that Cronbach's Alpha values were above 0.84 for personalisation and 0.92 for loyalty for high internal consistency. Overall, these findings show that not only does improvement in shopping experience emanate as a result of AI-powered personalisation but consumer confidence is enhanced while brand loyalty is cultivated within the domain of fashion e-commerce.

Furthermore, comprehensive research data from a joint study by Vogue Business and Google provides further validation for the above findings. This research surveyed nearly 3,000 luxury fashion buyers across the United States, the United Kingdom, Italy and France, revealing their positive response to AI-driven personalised services [12]. The study identified "purists", comprising 69% of respondents, as the most receptive consumer segment. Within this group, 62% indicated personalised offers would prompt purchases of fashion products, with 37% stating AI-generated product recommendations influenced their buying decisions. The research estimates such personalisation strategies could deliver up to 17% revenue growth for fashion brands, highlighting the commercial potential of AI-driven personalisation interference within the fashion retail sector.

2.4 Fashion Circularity

As the fashion industry accelerates its adoption of circular economy principles, AI is increasingly recognised as a key tool for extending garment lifespans, enhancing textile recycling rates, and optimising end-of-life disposal processes. To improve the sustainability of post-consumer textile flows, study into AI systems addressing material identification, degradation prediction, and logistics optimisation presents significant challenges. Among these, a key application of AI lies in predicting the degree of garment deterioration, which enabling consumers to make informed decisions regarding the use, maintenance, and disposal of clothing.

This study developed a deep learning-based system trained on approximately 30,000 user-submitted photographs to detect visible signs of wear such as pilling, deformation, and fading [5]. Test results demonstrate that this deep learning model achieves a 30% improvement in consistency compared to traditional feature models, alongside a 92% classification accuracy rate for garment deterioration levels. These insights not only assist consumers in optimising wardrobe management but also effectively guide efforts to reduce premature textile disposal, thereby mitigating the phenomenon of fast consumption.

Beyond consumer-facing solutions, predictive maintenance techniques are increasingly being applied to post-consumer textile management. This study highlights how failure prediction models can anticipate product deterioration and end-of-life timelines, enabling brands and logistics providers to optimise repair workflows, resale triaging, and recycling processes [13]. By identifying garments likely to fail early, companies can reduce reverse logistics costs and accelerate second-life business models, ultimately supporting more efficient circularity strategies.

3. Critical Discussion and Strategic Implications

While emerging AI technologies offer significant advantages across the fashion value chain, as discussed in section 2, these benefits also give rise to a set of complex and often conflicting challenges. These include unequal access to AI infrastructure, consumer fatigue and systematic bias with algorithmic content, and regulatory and ethical gaps in fashion AI.

3.1 Unequal Access to AI in Infrastructure

As outlined in Section 2, effective AI integration in fashion requires scalable infrastructure, machine learning pipelines, and long-term analytics maintenance. While large fashion retailers such as L'Oréal are leveraging AI at scale to automate workflows and enhance marketing performance [14], small and medium-sized enterprises (SMEs) face disproportionate challenges due to limited financial and technical resources.

A recent study involving 50 fashion SMEs collected data from 156 respondents through open-ended qualitative questions to explore the barriers hindering AI adoption [15]. Among them, 140 out of 156 participants cited high initial investment costs as the most significant barrier, reflecting widespread concern over the capital-intensive nature of AI adoption. Similarly, 95 participants cited continuing maintenance costs as a significant obstacle, and 110 respondents emphasised challenges in obtaining funding. These results point to a structural problem: fashion SMEs are particularly vulnerable to the capital-intensive nature of AI because they usually have lower margins and shorter seasonal cycles.

Furthermore, according to 119 respondents, SMEs frequently lack the internal capacity to deploy and manage AI systems efficiently due to a lack of in-house technical expertise. The gaps in digital readiness are further highlighted by other problems like insufficient infrastructure (84 mentions) and data unavailability (98 mentions). Organisational obstacles also surfaced, as 79 participants

reported a general lack of knowledge about AI's potential advantages, 92 respondents mentioned resistance to change, and 85 identified training gaps. These findings collectively demonstrate that SMEs face restrictions not only in terms of financial limits but also in terms of their ability to integrate cultural and technological capabilities.

These findings also reveal that SMEs in the fashion industry are at a severe disadvantage in unequal access to infrastructures for AI, thereby inhibiting their competitiveness in customer experience, operational efficiency, and market visibility. Moreover, SMEs lack access to funds like larger fashion businesses, which can leverage tools for AI in optimising stockkeeping, making customised recommendations, and easing promotional operations. Hence, SMEs are likely to inhibiting their control over data as well as over customer relationships. Consequently, increased reliance on AI by large fashion businesses in the fashion industry instead inhibits SMEs' capacity for distinguishing their competitive edge, generating innovation, as well as building brand equity in the long term. Additionally, since capability in AI is set to further enhance in times ahead, a performance disparity between brands founded on AI versus SMEs by limited resources may become increasingly greater, thereby further worsening competitive disparity as well as divergence in evolution paths for fashion brands.

3.2 Data Transparency and Personalisation Fatigue

Based on inferences in Section 2.3.2, AI-oriented personalised service is further complicated in its longer term influence on consumer-brand relationships. Although user engagement and purchasing intention might gain in the short term at first, there is research which demonstrates that consumers experience recommendations generated by a certain AI too repeatedly, mechanically, or unimaginatively in relation to innovation, then such an experience is very much likely to leads towards cognitive overload, lessened emotional attachment, and even reduced brand trust [16].

This study validates the relationship between AI-driven personalisation and consumer purchasing decisions [17]. Findings indicate that consumer purchasing decisions are significantly influenced by personalised marketing messages ($\beta = 0.28$, $t = 5.48$, $p < 0.001$). This demonstrates that customers respond positively only to recommendations that are genuinely relevant and meet their needs. In the absence of this perceived relevance, user engagement gradually diminishes, and the effectiveness of personalisation strategies decreases out of time.

In addition, concerns over data misuse and privacy issues further complicate the problem. A study on AI applications in the retail sector revealed that 53.2% strongly agreed that AI-driven retail systems collecting mass personal data pose significant privacy risks [18]. Consumers today demand greater control over their desire for sharing their information and demand more information about what is done with their personal information by brands. These findings indicate what is at the core of issues around privacy is less about information gathering but about a lack of further information and a lack of autonomy. Study further revealed 44% of respondents favoured retailers' AI system clearly outlining decision-making procedures with only 9.4% opposing it [18]. Hence, it once again reflects consumers' increasingly adamant demand for increased openness and accountability in AI-driven marketing. As a result, when such expectations are not fulfilled by brands, consumer confidence can quickly decrease and customer loyalty undermined even when recommendations are accurate and relevant. Such a challenge for fashion businesses in delivering effective AI-driven personalisation while ensuring customer autonomy is now key in fostering long-term consumer relationships.

3.3 Regulatory Gaps in the Filed of Fashion AI

Although there is a rapid integration of AI within the value chain in fashion, there are no formal regulatory frameworks for the fashion industry yet. Whether risk-based regimes for classification and accountability mechanisms such as the 'EU AI Act', which establishes such regimes, are directly deployable in creative sectors such as fashion is unclear [19]. As such, many fashion brands are not regulated in accountability for algorithms, in data ethics or including in respect for transparency.

Large public organisations are increasingly concerned about the exponentially rapid increase in AI in today's lack of robust financing for ensuring digital literacy and sustainable regulation. As a case in point, the European Economic and Social Committee (EESC) called for tighter regulations for securing artistic integrity and minimising the environmental costs of large computing infrastructure while cautioning about unregulated adoption in the cultural sector [7]. Thus, a deficiency in appropriate regulatory mechanisms render it even more challenging for a company in a fashion industry to develop strategies for operations. On one hand, fashion businesses are exposed to pressures towards implementing AI to stay competitive while at once they also need to satisfy stakeholder needs and increasing expectations for social responsibility and ethical disclosure. As it is today, swift innovation in AI is bound to make conventional regulation mechanisms lag further behind while spotlighting an even greater ever-increasing risk gap between public confidence and company innovation [20]. Further, fashion industries should also be careful that in a lack of such stringent measures specific for a fashion industry, people would increasingly question mass-dependent mechanisms for AI more seriously still, further pushing for open governance in attaining consum-

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er confidence [21].

4. Conclusion

Artificial Intelligence is redesigning the fashion industry by allowing unprecedented innovation in creativity, consumer customisation and improvement in productivity for operations. However, as this study demonstrates, its actual employment is far more complicated in practicality than innovation promise and gleaming futures. As great as it can enable a mass range of problems in the industry such as reduction in wastages, acceleration in design cycles, as well as accommodation for customised features in marketing, it is thus remarkable for a range of fashion companies to show considerable differences in their perceptions in regard to useability for AI. Such disparity reflects inherent incompatibilities between capabilities in technologies, pressures in society, as well as needs in marketplace.

Consumers are increasingly preferring lower price and trend-seeking aesthetics, while fashion corporates apply AI for meeting short-term demand rather than averting long-term problems posed by AI. Social and institutional demand for environmental responsibility limits fashion businesses significantly, especially mediums- and small-scales fashion businesses, which are pressed more towards balancing both extremes. Thus, insufficient mechanisms for governing AI in a proper manner, open processes, and protection in an ethical direction within the fashion industry further continues risks such as loss of information privacy, long-term AI environmental risk and algorithmic accountability substitution.

The long-term challenge for the fashion industry is implementing responsible use of AI rather than undertaking it for immediate financial returns. To this end, increased regulatory authority is required. Constructing open regimes for regulation and cooperation between brand-independent forums for regulation, legislator groups, and brands is required. On a short-term cycle, algorithmic audits or emission environment reporting training or voluntary regimes based on ethical design input by stakeholders could at once close dominant prevailing regulatory loopholes. By striking a balance between strategic benefits for innovative use of AI with longerterm ethical and societal goals, the industry can hold long term public confidence better, and with fashion companies also rewarding such retained confidence. Secondly, this shall better ensure innovation in AI in the fashion industry evolves into sustainable, enduring and ethically compliant support tools for operations.

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