AI-Driven Capsule Wardrobes: Optimizing Fashion Choices for Sustainability and Versatility

Reimagining Fashion: AI's Role in Promoting Sustainable Consumer Identity

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On my honor as a University student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments.

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Introduction

The fashion industry has become a leading contributor to environmental waste, largely driven by the demands of fast fashion, which promotes rapid consumption cycles and disposable clothing. This overconsumption stems from the pressure on consumers to constantly update their wardrobes to stay in line with rapidly changing trends, leading to high volumes of discarded clothing. The emergence of social media and apps like TikTok further exacerbates this issue. As the United Nations Sustainable Development Goals (SDGs) emphasize, addressing this environmental crisis within the fashion industry is crucial, particularly as climate change accelerates (United Nations, 2015). Achieving this requires innovative approaches that challenge traditional methods of production and consumption.

One potential solution lies in the use of artificial intelligence (AI) and machine learning which can forecast fashion trends, optimize wardrobes, and ultimately encourage more sustainable consumer behavior.These predictive capabilities could also aid in promoting capsule wardrobes, which are a collection of thoughtfully curated, easily interchangeable items that are designed to maximize the number of outfits one can create. Capsule wardrobes prioritize quality and versatility and align consumer habits with sustainable practices (Bang & DeLong, 2022).

Implementing AI models in the fashion industry presents significant challenges, including data biases, limited inclusivity, and a lack of transparency in algorithmic processes. Biases often arise from limited dataset diversity, leading to models that may not reflect the needs and preferences of diverse demographic groups (Ferrara, 2023). Scaling AI across industries can be hindered by outdated infrastructure, inadequate data, and resistance to adopting new technologies. Therefore, for AI to effectively reduce environmental impact, collaboration among

policymakers, technology developers, and fashion industry leaders is essential to align on sustainability goals (Akter, 2024).

This research proposes the development of an AI model utilizing optimization algorithms to forecast trends and promote personalized capsule wardrobes. By focusing on inclusivity within data models, the research aims to create a recommendation system that encourages sustainable fashion choices and discourages overconsumption. Aligning fashion strategies with consumer-driven style preferences will inform the model's emphasis on trends and personalization to allow it to resonate with individual tastes (Nikolic & Kostic-Stankovic, 2022). The technical component will explore AI-driven trend prediction and personalized wardrobe curation, optimizing selections for each user. Meanwhile, the Science, Technology, and Society (STS) analysis will examine how the cycles of fast fashion and trend-chasing influence consumer behavior, intersecting with identity, social pressures, and environmental responsibility.

Transforming AI in Fashion: From Trend-Driven Production to Sustainable Consumption

Current AI applications in fashion primarily support demand forecasting, trend analysis, and consumer behavior modeling. However, many AI-driven models fail to prioritize sustainability. For example, SHEIN's use of AI to mass-produce inexpensive garments accelerates waste and fuels overconsumption (Mulkey, 2024). Generative AI compounds this issue by enabling the creation of high volumes of digital content, which, due to high energy consumption, contributes significantly to digital waste and environmental harm (Ultz & DiPaolo, 2023). This challenge highlights the need to shift AI applications toward promoting sustainable consumption rather than reinforcing fast fashion cycles and digital overconsumption.

The proposed solution is to develop an AI-based model using combinatorial optimization techniques, which involves selecting the optimal combination of items from a large set based on various criteria to generate wardrobe recommendations (Bengio et al., 2021). This model will promote sustainable consumption through capsule wardrobe practices, enabling consumers to create a range of outfits with fewer, higher-quality pieces. By incorporating metrics like visual dissimilarity and number of good coordinates (ensuring that wardrobes remain functional even when some items are unavailable), the model balances variety and functionality. This helps consumers invest in more meaningful and durable wardrobe choices (Tanaka & Ozaki, 2022). Existing AI models often limit variety by recommending visually similar items, leading to repetitive options. Incorporating visual dissimilarity mitigates this, ensuring that selections offer distinct styling possibilities. Additionally, the model addresses practical issues of item availability through incorporating the number of good coordinates, allowing wardrobes to remain versatile and functional even with fewer items.

An integrated literature review on the relationship between perceived quality and clothing lifetimes highlights that quality is perceived both objectively and subjectively, influencing whether garments are kept longer or discarded early. Findings suggest that higher quality garments are associated with extended lifetimes, supporting more sustainable practices by reducing the need for frequent purchases and minimizing waste (Aakko & Niinimäki, 2021). However, while better quality can promote longer clothing use, it may not reduce consumption if consumer behaviors don’t shift. This perspective will guide the AI model to emphasize both quality and durability, promoting selections that encourage long-term use.

Many models also overlook critical user-specific factors like body shape, preferences, and consumption habits (Dong et al., 2019). Integrating the Personalized Capsule Wardrobe with Dual Compatibility (PCW-DC) framework, which combines garment compatibility (how well clothing items complement each other) with user modeling (considering personal preferences and body shape), enhances the model's quality and relevance. While individual preferences are essential, the compatibility between garments is key to generating visually cohesive and personalized outfit recommendations.

The development of this model aims to address the limitations of current fashion AI applications by aligning consumer choices with sustainability goals. This approach supports broader shifts toward environmental responsibility by promoting mindful consumption habits, directly connecting the technical solution to the STS problem. Through careful model design and dataset selection, this AI tool can foster a sustainable approach to fashion.

Redefining Fashion: AI, Consumer Identity, and Sustainable Choices

The integration of AI in fashion raises important questions about the relationship between technology, consumer behavior, and environmental sustainability. Fashion serves as an expression of identity, social values, and cultural heritage. The integration of the *politics of novelty* as a framework provides a critical lens to examine how new technologies, including AI-driven fashion models, are shaped by and reinforce existing power dynamics. This perspective emphasizes that technology does not emerge in a vacuum but is instead deeply embedded in societal structures, where its development, dissemination, and impact are often controlled by a few powerful entities.

The development and deployment of AI in fashion, like other industries, are predominantly driven by corporate interests and elite stakeholders. These entities often prioritize innovations that align with profit motives or market dominance, potentially marginalizing alternative approaches to sustainable fashion.

The politics of novelty highlight the uneven distribution of technological benefits and harms. For example, if AI algorithms fail to accommodate varied body types or cultural aesthetics, they may promote a narrow vision of fashion that alienates diverse consumer identities. Moreover, the environmental benefits of these technologies may be overshadowed if their adoption primarily benefits wealthier, urban populations, leaving underserved communities without access to these tools.

Consumer fashion choices are deeply influenced by social dynamics, such as the need for social belonging and validation. A study investigated 13 women who adopted capsule wardrobes and they were interviewed regarding their experiences. They all said they experienced a shift in identity, a decrease in social pressure, and an increased focus on self awareness (Sobreira et al. 2022). This transition toward mindful consumption aligns with the principles of sustainability by fostering an appreciation for quality over quantity. In a digital age, however, social pressures around fashion are often intensified by influencers and rapidly changing online trends, which dictate what is “in” or “out” almost instantly (Kondort et al., 2023).

Exploring fashion among immigrant populations illustrates how clothing can serve as a platform for negotiating identity, suggesting that AI-driven fashion tools should be inclusive and culturally sensitive (Loscialpo, 2019). Clothing can be used to defy stereotypes, assert cultural pride, and navigate complex social dynamics.

The environmental impact of AI-driven fashion models highlights the need to integrate sustainable values into technology, drawing on both traditional craftsmanship and modern techniques. This complexity aligns with a call for a redefined fashion industry, one that sees fashion as a means for critical engagement with environmental concerns (Vänskä, 2018). For example, while Kyoto's kimono production exemplifies slow fashion traits like craftsmanship and durability, the introduction of digital techniques challenges assumptions that traditional methods are inherently sustainable due to the value that these modern techniques bring (Hall, 2018).

The politics of novelty also involve navigating short-term disruptions in favor of long-term sustainability. While introducing AI-driven capsule wardrobe models may face initial resistance due to infrastructure and cost challenges, their potential to reshape consumer behaviors toward sustainability could yield significant long-term benefits (Gabriel, 2024). Governmental and non-governmental organizations have increasingly needed to intervene, as the industry's inability to self-regulate has proven insufficient to address environmental impacts. Effective policy intervention, however, must consider the complexity of fashion's supply chains and the environmental footprint of production and distribution. This highlights the need for systemic changes, both within the fashion industry and in the regulatory frameworks governing it (Khan et al., 2024).

Ultimately, addressing the politics of novelty within the fashion industry requires a holistic approach that balances innovation with equity, inclusivity, and sustainability. Any solutions developed will hinge on consumers' mindsets and their understanding of concepts like capsule wardrobes.

Research Question and Method

To address the research question—how can machine learning and optimization algorithms be applied to create personalized capsule wardrobes that promote sustainable fashion—this study will use a qualitative, participatory approach, inspired by a call for actionable frameworks that incorporate consumer-relevant sustainability indicators (Garcia-Torres et al.'s, 2017). A workshop conducted with members of my engineering sorority, Alpha Omega Epsilon, will serve as the primary method of data collection. This workshop will blend education and activities to explore the role of AI-driven capsule wardrobes in addressing sustainability challenges while gathering qualitative feedback on their potential design and impact.

The workshop will begin with an educational presentation introducing the challenges of fast fashion and the concept of capsule wardrobes as a solution to overconsumption. The discussion will highlight how AI-driven fashion models can enhance capsule wardrobes by optimizing garment compatibility and user preferences while addressing issues of inclusivity and access. Using the politics of novelty framework, the presentation will reframe these challenges within the broader context of societal dynamics, emphasizing how power structures influence innovation in the fashion industry.

Following the presentation, participants will engage in a hands-on activity to simulate the decision-making process of creating a sustainable capsule wardrobe. They will begin by completing a brief questionnaire about their daily activities, style preferences, and values related to fashion, answering questions such as “What are your three most-worn pieces of clothing?” and “What factors do you consider when buying new clothes?” Participants will then be provided

with mock clothing options, described by material, durability, and style, and tasked with assembling a capsule wardrobe of 10 items. This activity will challenge participants to balance versatility, sustainability, and personal alignment in their selections. Afterward, participants will share their capsule wardrobes with the group, reflecting on their decision-making processes and responding to prompts such as, “What challenges did you face while choosing items?” and “How did you balance sustainability with personal preferences?”

The workshop will conclude with a moderated discussion to gather qualitative feedback on participants’ perspectives. Key questions will explore how the activity influenced their views on sustainable fashion, whether AI could simplify or improve the process, and what barriers they see to adopting capsule wardrobes. Insights from this discussion will be analyzed to identify themes related to consumer attitudes, obstacles to sustainable practices, and areas for improvement in AI-driven tools.

Conclusion

The fashion industry’s substantial environmental footprint calls for immediate action to reduce waste and foster sustainable consumer habits. This project proposes an AI-driven model to promote capsule wardrobes, with the goal of shifting consumer behavior from disposable trends to thoughtfully curated, lasting wardrobe investments. By incorporating both technical and STS perspectives, this research demonstrates how AI can not only drive innovation in fashion but also address ethical and social dimensions, ultimately encouraging more sustainable practices.

A key focus of this project is the need to shift consumer mindsets away from the appeal of fast fashion's constant novelty toward valuing versatility, quality, and longevity in their clothing choices. This model aims to guide consumers in building capsule wardrobes.

The expected outcomes include a functional AI model that promotes sustainable wardrobe choices and an STS analysis that highlights the societal benefits of mindful consumption. If successful, the model could drive individual behavioral change and systemic shifts within the industry, reducing fashion's environmental impact while preserving its role as a meaningful form of self-expression.

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