



APPLICATION OF ARTIFICIAL INTELLIGENCE IN SUSTAINABLE PRODUCTION IN THE FASHION INDUSTRY

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ABSTRACT: *In conditions of increasing demands for sustainability and efficiency, the fashion industry is turning to digital and intelligent technologies. In this work, the focus is on the application of artificial intelligence in the optimization of production processes and the development of sustainable production models. Clo3D software is seen as a key platform for implementing AI (artificial intelligence) solutions through digital prototypes and simulations. The analysis indicates that the combination of AI (artificial intelligence) and 3D simulation significantly contributes to reducing waste, optimizing resources and improving decision-making in design and production.*

Keywords: *artificial intelligence, sustainable fashion, digital production, optimization.*

PRIMENA VEŠTAČKE INTELIGENCIJE U ODRŽIVOJ PROIZVODNJI U MODNOJ INDUSTRIJI

APSTRAKT: *U uslovima sve većih zahteva za održivošću i efikasnošću, modna industrija se okreće digitalnim i inteligentnim tehnologijama. U ovom radu fokus je primena veštačke inteligencije u optimizaciji proizvodnih procesa i razvoju održivih modela proizvodnje. Clo3D softver se posmatra kao ključna platforma za implementaciju AI (veštačke inteligencije) rešenja kroz digitalne prototipove i simulacije. Analiza ukazuje da kombinacija AI (veštačke inteligencije) i 3D simulacije značajno doprinosi smanjenju otpada, optimizaciji resursa i unapređenju donošenja odluka u dizajnu i proizvodnji.*

Ključne reči: *veštačka inteligencija, održiva moda, digitalna proizvodnja, optimizacija.*

1. INTRODUCTION

The global textile and fashion industry represents one of the most powerful economic drivers in the modern world, with a market value exceeding \$1.2 billion and a clear projection of growth to over \$1.5 billion, while simultaneously employing tens of millions of workers along global and deeply intertwined supply chains. However, this permanent economic contribution and expansion has been accompanied by an unsustainably high,



destructive ecological and social footprint. For decades, the traditional fashion sector has been operating according to the rigid and linear economic principle "take-make-use-dispose", which leads to the uncontrolled exploitation of natural resources. This linear pattern results in the annual consumption of enormous amounts of clean water and fossil fuels, while at the same time generating toxic waste, liquid effluents saturated with heavy metals and countless amounts of solid textile waste that most often end up in overcrowded landfills or are incinerated without energy efficiency. The emergence of the phenomenon of fast fashion (Fast Fashion) has drastically accelerated this destructive cycle, dramatically shortening the lifespan of clothing items and creating systemic hyperproduction that far exceeds the real needs of the global market. According to the latest environmental studies, it is estimated that the fashion industry is responsible for as much as 8 to 10% of the total global greenhouse gas emissions, which puts it at the very top of the global environmental polluters [4].

Faced with increasing, coordinated pressure from international regulatory bodies, environmental organizations and conscious consumer groups, business entities in the fashion sector are forced to implement a radical and comprehensive transformation of their traditional production and logistics models. The transition to sustainable business and a clean circular economy imperatively implies extending the life of the products themselves, maximizing the efficiency of using raw materials, eliminating harmful chemical substances and closing the material loop through the processes of upcycling and advanced recycling. In order to achieve these ambitious goals in practice, it is necessary to implement new methodologies that analyze and optimize the impact of a product on the environment throughout its entire life cycle, from cradle to grave (LCA - Life Cycle Assessment), focusing on reducing the carbon and water footprint [3].

In this complex technological and environmental context, digitization, advanced three-dimensional (3D) simulations and systems based on artificial intelligence (AI) are recognized as the primary and most effective drivers of the systemic transformation of the fashion industry. Artificial intelligence enables the processing of mass data (Big Data), prediction of market demand with a high degree of accuracy and making automated, optimized decisions in real time along the entire vertical value chain. The aim of this paper is to shed new light on the modalities and mechanisms by which artificial intelligence can transform the fashion sector from a linear polluter into a sustainable, circular and fully transparent ecosystem through a detailed scientific analysis of modern software tools for virtual modeling, such as the Clo3D platform, and advanced regulatory-technological mechanisms, such as the Digital Product Passport (DPP).

2. SUSTAINABILITY, CIRCULAR ECONOMY AND ESG STANDARDS

The transition from a linear to a circular economy in the fashion and textile sector is not only a technical issue, but requires a deep and radical change in the corporate paradigm, as well as the widespread adoption of rigorous environmental, social and governance (ESG - Environmental, Social, Governance) standards. Sustainability strategies can no longer rest on superficial and partial solutions; companies today must have an exact, empirically



supported and transparent insight into the complete life cycle of a garment, from the extraction and processing of primary raw materials, through industrial production and distribution logistics, all the way to the stage of consumption and final waste management at the end of life (End-of-Life). Traditional approaches often suffer from a lack of standardization and transparency, which opens up space for manipulative marketing, while the integration of holistic ESG frameworks and environmental accounting allows businesses to accurately quantify and monitor their environmental impacts [2].

Circular economy models within the fashion industry stimulate and open completely new, environmentally neutral and economically profitable business opportunities. These opportunities are primarily related to eco-design, systems of organized repair (repair), platforms for reuse (reuse) and the development of new technologies for mechanical and chemical recycling of high-grade textile fibers. With the introduction of mandatory instruments of due diligence in terms of human rights, working conditions in textile factories and rigorous environmental procedures against pollution, the formation of transparent ESG reports becomes a legal obligation for all economic entities that wish to operate in the single market of the European Union.

In establishing this new framework, the technological solutions of the fourth industrial revolution (Industry 4.0) provide the necessary digital and hardware infrastructure. Through the networking of IoT (Internet of Things) sensors, blockchain technology and advanced AI analytics, textile companies gain the ability to generate accurate, immutable and instantly available data on the consumption of electricity, resources and raw materials in each individual production facility [9]. In this way, artificial intelligence serves as a key validation mechanism that enables a radical transition from declarative and often false sustainability (greenwashing) to scientifically based, measurable and verifiable business sustainability.

3. ARTIFICIAL INTELLIGENCE AND 3D SIMULATIONS IN DESIGN AND PRODUCTION OPTIMIZATION

One of the primary and materially most pronounced sources of textile waste and financial losses in the traditional chain of the fashion industry lies in the early stages of prototyping and development of new garments. In the conventional industry model, design teams are forced to create dozens of physical garment samples that are then shipped across oceans for management and client approval, often going through numerous time-consuming iterations of fit corrections, texture changes, and color shade adjustments. This process consumes hundreds of thousands of kilometers of quality fabric before mass production can even begin, generating high transport emissions and increasing time-to-market. The implementation of artificial intelligence in synergy with software solutions for advanced 3D simulation, such as the Clo3D platform, fundamentally transforms this inefficient and environmentally unacceptable process.

3.1. The role of the Clo3D platform and AI algorithms

The Clo3D software platform is the leading industry standard for creating high-precision (Digital Twins) textile and clothing products. In this advanced digital ecosystem, the



process completely moves into the virtual space. Specialized AI algorithms integrated into the software perform an instant analysis of the mechanical and physical properties of the fabric precisely taking into account parameters such as resistance to stretching, coefficient of friction, weave density, weight, elasticity and drape. Based on these inputs, the real-time system faithfully simulates the behavior of the material and its interaction with adaptive three-dimensional digital avatars of the human body in motion. The combined application of AI analytics and 3D simulation models brings multiple, documented benefits for sustainable manufacturing processes:

1. Radical reduction of pre-production textile waste: Physical sampling of materials is reduced to an absolute minimum or completely eliminated from the cycle. Large fashion brands and manufacturing facilities can successfully approve and validate complete seasonal collections without a single meter of fabric being physically cut, saving resources and eliminating waste at the source.

2. Intelligent optimization of tailoring images (Computer-Aided Marker Making): The textile tailoring process has traditionally been a source of significant waste due to inefficient placement of patterns on the fabric. Today, advanced algorithms and machine learning systems driven by artificial intelligence calculate the most mathematically efficient possible arrangement of cut parts on a textile bale. By optimizing stacking in a fraction of a second, AI minimizes the empty space between cuts, reducing production waste on the line by significant percentages, which at the level of mass industrial production generates millions in material savings.

3. Predicting consumer behavior and preventing overproduction: By integrating AI models that analyze historical sales data and current trends from social networks, companies can test virtual garments on digital channels or through pre-order systems before making the decision to launch mass series production. This drastically reduces the risk of creating unsold goods (dead stock) which in the traditional model of fast fashion usually end up in illegal landfills in developing countries or are destroyed in industrial furnaces [7].

This digital revolution in design is directly linked to the broader concept of the digital fashion revolution, where virtual clothing and digital sampling are opening up new avenues to drastically reduce the carbon footprint of the entire sector, transforming the way consumers and manufacturers interact [7].

4. TRANSPARENCY AND DIGITAL PRODUCT PASSPORT (DPP)

While artificial intelligence successfully optimizes internal operational and design processes within the factories themselves, sustainability in a broader macroeconomic sense requires the establishment of absolute, uncompromising transparency and traceability along the entire and often fragmented global supply chain. The new Regulation on ecological design for sustainable products (Ecodesign for Sustainable Products Regulation - ESPR), adopted by the European Commission, mandates a strict legal obligation to introduce the Digital Product Passport (DPP) by the end of 2026 for all key industrial

sectors, with the textile and fashion sector being marked as an absolute priority for implementation.

4.1. Concept, parameters and technological architecture of DPP

DPP is defined as a decentralized, standardized digital file or structured database that faithfully tracks and documents a garment through absolutely all phases of its life cycle. Access to this verified data will be provided to end consumers, sustainability managers, logistics operators, customs authorities and recycling plants through integrated physical data carriers on the product itself, such as unique QR codes, high-frequency NFC (Near Field Communication) chips or robust RFID tags. In this complex information ecosystem, artificial intelligence systems play a critical role as they serve as a powerful analytical engine capable of collecting, structuring, and validating massive, heterogeneous data collected from geographically dispersed stages of the supply chain (from cotton fields, to chemical dyeing labs, to tailoring plants).

At the technical level, these systems rely on advanced search methods and semantic analysis, similar to architectures using Retrieval-Augmented Generation (RAG) systems and vector databases (like FAISS), to ensure maximum accuracy, prevent the structuring of false data and enable immediate verifiability of all entered product information [6]. According to official regulatory guidelines, DPP must accurately map and store parameters divided into key categories:

- Ecological footprint and emissions: Exact, quantified emission of carbon dioxide equivalents through all stages of production and transport, level of generated noise and waste gases.
- Resources and energy efficiency: Total amount and origin of consumed electrical and thermal energy; detailed volume of water consumption and level of effluent treatment (water footprint).
- Composition, toxicity and origin: Accurate data on raw material composition (percentage of virgin, organic or recycled fibres); presence and concentration of potentially dangerous chemicals and heavy metals.
- Circular potential and End-of-Life: Detailed, illustrated instructions for maintenance, possibilities and locations for repair, reuse, disassembly of components (zippers, buttons) and optimal chemical or mechanical recycling methods [10].

The DPP conceptual framework is seen as a fundamental pillar and technological enabler of the digital circular economy, as it provides the necessary transparency and infrastructure for monitoring material flows at the macro level [11]. From a technological point of view, the introduction of digital product passports represents a direct transition from theoretical models of sustainability to practical and operational application in modern industry [12].

4.2. Mechanisms of DPP contribution to sustainable business modelsA

comprehensive implementation of the Digital Product Passport powered by AI analytics acts as a transformative catalyst for the fashion industry through three specific, practical mechanisms:



- Complete suppression of green washing and empowerment of consumers: By simply scanning the label with a smartphone before purchase, the consumer gets access to transparent and legally verified data on the origin and ecological price of the garment. This prevents brands from using manipulative and vague marketing terms (like the phrases "eco-friendly" or "sustainable") without solid, empirical evidence behind them.
- Catalysis of circular design (Design for Circularity): Access to precise DPP data allows designers to select only those materials and components that have a proven low environmental impact and can be easily recycled already at an early stage of sketching within the Clo3D system. AI systems can analyse millions of DPP cartons from previous production runs to suggest optimal fibre combinations that maximize garment longevity and durability.
- Automation and optimization of textile recycling: When a garment has reached the end of its life and arrives at the sorting centre, advanced robotic systems equipped with AI vision and DPP readers can instantly recognize the exact internal composition of the fabric (for example, recognizing a precise blend of 65% cotton and 35% polyester). This drastically speeds up, cheapens and automates the waste sorting process, which currently represents the biggest techno-economic barrier to mass and profitable textile recycling on a global level.

The introduction of digital passports and standardized data sheets on circularity, as foreseen by new international standards (ISO/DIS 59040), creates a unified language for all actors in the value chain, from producers to recyclers [8].

5. CHALLENGES AND PERSPECTIVES OF IMPLEMENTATION OF INTELLIGENT TECHNOLOGIES

Although the technological fusion of artificial intelligence, advanced 3D simulations and the concept of Digital Product Passport brings revolutionary environmental, economic and ethical benefits, the process of their comprehensive and mass implementation on a global level is accompanied by a series of extremely complex challenges and systemic barriers. The first and most pronounced challenge is reflected in the high technological and financial barrier for small and medium-sized enterprises (SMEs), which form the backbone of the textile industry in many developing countries. While multinational fashion conglomerates possess the vast capital necessary to acquire expensive AI systems, purchase Clo3D licenses, train engineers and integrate complex DPP databases, smaller business entities face serious liquidity problems when trying to implement this transformation. Adapting legacy information and ERP systems within factories to meet rigid local and international environmental standards requires significant financial investment and a lengthy process of restructuring operational processes.

Another critical challenge relates to the problem of interoperability, data management and standardization at the global level. A typical supply chain in the fashion industry includes hundreds of independent actors (farms, mills, weavers, dyers, logistics centres) that are geographically dispersed around the world and often use completely different information systems and data formats. The exchange of critical information between them requires



strict adherence to unique open standards, such as ISO/DIS 59040, which defines product circularity data sheets. In addition, the complex issue of cyber security and protection of intellectual property and trade secrets opens up. Under the pressure of the regulator, companies are obliged to transparently share data on the chemical composition and origin of materials for the purpose of forming DPP, but at the same time they justifiably strive to protect their unique production formulas, technological innovations and commercially sensitive contracts from the competition. Due to all of the above, it is necessary to conduct further extensive, multidisciplinary scientific research that would define optimal political, legal and technological protocols for a safe and inclusive digital transition of the fashion industry [10].

6. CONCLUSION

Modern fashion and textile businesses can no longer maintain stability and profitability by maintaining outdated, linear, resource-intensive and non-transparent production models. The challenges posed to humanity by accelerated climate change, critical lack of primary natural resources and progressive ecological degradation of the planet require an urgent, radical and structural transformation of the entire fashion sector. Artificial intelligence, in direct synergy with sophisticated software tools for 3D simulation and virtual modeling such as Clo3D software, offers concrete, tested and highly efficient technological solutions for the elimination of material waste and optimization of resources already in the embryonic, creative phase of textile design.

Building on these optimized pre-production processes, the Digital Product Passport (DPP) concept successfully and efficiently closes the circle of the circular economy. DPP ensures full, unadulterated transparency of the supply chain, eliminates information asymmetry in the market, empowers consumer awareness and lays a solid economic foundation for the development of profitable repair, reuse and high-level automated textile recycling systems [10].

The upcoming mandatory introduction of these digital instruments by the end of 2026, encouraged by the rigorous and uncompromising regulatory framework of the European Union, no longer leaves business entities room for passivity and postponing radical changes. The implementation of intelligent technologies within the fashion industry has definitely ceased to be a matter of free choice, a tool for superficial ecological marketing or a means for isolated optimization of operational costs; it has become a fundamental legal and economic prerequisite for legal, competitive and sustainable business in the modern global market. Companies that timely, strategically and comprehensively integrate artificial intelligence into their operational and manufacturing processes will successfully minimize their environmental footprint, ensure full compliance with legislation and build a strong, long-term competitive advantage based on the trust and loyalty of modern, environmentally conscious consumers.



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