BLOCKCHAIN + AI FOR TRANSPARENCY AND ETHICAL SOURCING IN LUXURY FASHION: A COMPREHENSIVE REVIEW

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Abstract

Luxury fashion sector is in the midst of a galvanic shift, whereby consumers of the world demand high-quality brands to be transparent, ethically sourced and environmentally responsible. Traditionally, luxury houses based on the heritage of craftsmanship and an aura of exclusivity by rarely revealing their source of materials or labor. Combined with other technologies, blockchain and Artificial Intelligence (AI) have proven to be highly effective and transient across the entire supply chain. Each offers supply-chain traceability that is nearly impossible to manipulate and decentralizing data storage, and the other offers the analytical intelligence needed to analyze data in its supply-chain, identify anomalies, and automate the process of evaluating sustainability. Through such synergistic integration, automated systems are able to track the raw materials, labour practices and carbon output systematically, and the systematic monitoring provides previously unseen insight into the ethical and environmental costs of luxury fashion products. This review article looks at the theory and practice of the integration of the Blockchain and AI in luxury fashion supply chains, their challenges, and future opportunities. It examines how the technologies will drive traceability and anti-counterfeiting efforts, assess labor conditions, measure carbon emission, and provide the sustainability assertions with verifiable data. This paper will show how Blockchain and AI is transforming standards of accountability and trust in luxury fashion by synthesizing the existing research, practical applications, and technological trends.

1. Introduction

The high-end fashion market has always been connected to innovativeness, luxuriance, and excellent craftsmanship. The story behind luxury products has always been about craftsmanship, as opposed to disclosure, and the companies rarely disclose their sourcing strategy (Sargiacomo, 2018). However, global consumerism has changed to ethical consumerism, and this has offered new expectations. Customers have now turned to know where materials are sourced, how workers are treated and whether production causes minimal effects on the environment (Vadakkepatt et al., 2021). Luxury fashion supply chains are usually complex, global, and decentralized and facing these concerns brings very special challenges to luxury fashion chains. Any product can have various levels of suppliers, special crafts, diverse transportation systems, and complex finishing mechanisms (Ramjaun et al., 2024). Meanwhile, the luxury goods often engage the rare or high quality of natural materials, the authenticity of which, and their impact on the environment, needs to be tested exactly.

The luxury brands are studying digital applications to restore confidence and ensure responsibility. The inherent nature of blockchain technology as a decentralized system to record events in a supply-chain, with its basic characteristic of remaining immutable, provides a decentralized way to create a statement on the state of the supply chain that cannot be changed (Selvaprabhu, 2023). In the meantime, AI converts raw supply-chain data into insights in action by using predictive analytics, anomaly detection and automatically certifying data. Blockchain and AI provide a greater amount of transparency than ever before. They develop systems that could automatically trace raw materials, the state of labor, the amount of carbon emissions and produce verifiable sustainability reports (Hong & Xiao, 2024).

This review assesses how the concepts of Blockchain and AI can be combined with ethical sourcing in the luxury fashion, especially the capacity of automated systems to guarantee the provision of transparency. It talks of the technological basis of Blockchain and AI, their joint potential, their current applications, their advantages to the stakeholders, the technical and ethical issues involved, and future prospects. The main idea of the given paper is that the integration of Blockchain and AI implies a radical change, as it will allow a brand to switch to transparent, responsible ecosystems by passing the opaque supply chain.

2. Background

Luxury fashion industry faces significant challenges of achieving traceability and accountability in ethics. The supply chains are often spread in various continents and raw materials, such as leather, cashmere, organic cotton, alpaca wool, rare silks, and many others, travel through a number of hands before reaching the main producer of a brand (Matthes et al., 2021). Most luxurious homes rely on artisans and small-scale subcontractors who present their work through traditional approaches that do not have advanced record-keeping systems. This scattering inhibits transparency that makes it tough to verify sustainability claims, ethical labor practices and material authenticity.

The use of artificial intelligence supplements blockchain and improves its data integrity, scalability, and interpretability. The supply chains produce extensive data, most of which is unstructured, including shipping restrictions, sensor data, electronic invoices, audit, and manufacturing images (Talakola, 2025). AI analytical systems can automatize the analysis of this data, discover patterns, predict results and find anomalies that might not be observed by human accountants. Machine learning can test the authenticity of the materials by analyzing the chemical, spectral, or visual features, and natural language processing can generalize the meaning of sustainability report or supplier agreement (Wu et al., 2022). Predictive models have the ability to create an approximation of the carbon emission at every stage of a supply chain, and thus spot potential areas of environmental impact.

3. Integrating Blockchain and AI in Luxury Fashion Supply Chains

The implementation of the blockchain technology and artificial intelligence in the luxury supply chain requires the layered architecture where data capturing, smart analysis, and unchangeable storage work together (de Boissieu et al., 2021). It is normally started by deploying sensing devices of Internet of Things, mobile devices, or manual data-entry systems that acquire the raw material properties, production, employee facts, environmental facts or certification facts. The given inputs form the base layer of traceability by creating a holistic data set based on which further analytical operations are performed (Qian et al., 2022).

The incoming data are in turn processed by artificial intelligence algorithms, which can perform functions like authentication checks, inconsistency checks and generation of insights (Katru et al., 2024). An AI-powered machine vision system can be applied to textile fibers or leather surfaces, detecting the authenticity of the material and determining the compliance of the production procedure with the sustainability statements provided (Amjad & Joshi, 2025). AI based on sensor can be used to track energy usage, water use, or chemical release during the production process. Predictive analytics can approximate transport route derived carbon emissions or production schedules (Ojadi et al., 2024). In the context of labor monitoring, AI is able to detect odd labor work patterns or employee employment records, and thus publishes possible breaches of the labor standards.

After the processing of the data under analysis, validated ones are uploaded into a blockchain ledger. The procedures, including certifying that standards are upheld, paying suppliers after fulfilling sustainability requirements, or outlining discrepancies of which a human verdict is required, may be automated accordingly with smart contracts (Groschopf, Dobrovnik & Herneth, 2021). The fact that blockchain records are immutable also means that after adding data, it cannot be modified or deleted, giving protection against fraudulent manipulation of material origins, audit results, or calculation of carbon-emission.

An interface that is consumer-facing, then, can facilitate end users to scan a QR code or NFC tag on a luxurious product. When scanned, the system retrieves blockchain authenticated data about the provenance of the item, the material combinations, labor environment, environmental impact, and the supply chain path (Wilson et al., 2024). The fact that this knowledge is easily accessible makes brands more certain and allows them to stand out in the competitive luxury market.

4. Tracking Raw Materials

One of the most significant uses of the relationship between blockchain technology and artificial intelligence in the luxury fashion industry is tracking raw materials (Singh et al., 2024). Luxury goods often are of limited supply and priced high so that they are vulnerable to fraud and alternatives. The cashmere found in Mongolia or Inner Mongolia, which is uniquely designed with its quality identifiers and ecological meaning. High quality leather is usually farmed in farms of European certification which conform to high welfare policies on the animals whereas silk can be produced in specific regions which have a reputation of sustainable sericulture (Altman & Farrell, 2022).

The technology of artificial intelligence is used to improve material authentication through analysis of structural patterns, chemical patterns, or spectral reflectance measures using specialized sensors. Machine-vision lights are able to identify minute differences in fibre structure and this will mean that materials being sold as organic, sustainable or ethically sourced actually match the assertion of the claims made (Agrawal et al., 2025). These AI tools reduce the chances of using fake or low quality materials entering the supply chain.

Every step of material movement, including cultivation and harvest, through processing and transport, are documented by blockchain. For instance, wool may be marked during the shearing period, and each new processing process, such as washing, dyeing, spinning, etc., may be registered in an immutable blockchain transaction (Alves et al., 2022). With leather, blockchain can record the origin of the animal, the tanning procedure and the chemical processes applied in finishing. When combined with the blockchain traceability method, the brands can ensure the authenticity and sustainability of materials to a great extent and be highly accurate with the help of AI verification.

5. Tracking Labour Conditions

Labor transparency is a key core in the conceptualization of ethical sourcing. Luxury supply chains often hire some of the most talented craftsmen, but subcontracting systems that lie behind them might bring on the board the facilities in which working conditions are not sufficiently controlled (Redini, 2024). In order to practice ethical labor ways, there is the general call to institute a systemic check-up of wage, hours at work, safety terms and contractual fairness thus making sure that a constant control and prerequisite are maintained.

Labor monitoring systems based on artificial intelligence can study complex specific patterns in employee data, including sudden changes in reported working hours or payroll damages, which can indicate the breach of the existing labor norms (Kelley, 2023). When combined with Internet of Things (IoT) technologies, AI can identify environmental anomalies in the factory the reason is that excessive thermal exposure or poor quality of air can be seen as an example of unsafe working conditions. Additionally,one may use the algorithms of natural language processing and analyze audit documentation, supplier contracts, or worker feedback forms, thus, retrieving relevant risk signs and managing the risks in advance (Ekeh et al., 2025).

The blockchain technology will ensure the integrity of labor-related data. Workers, third-party audit results, welfare certification records, and compliance records may be safely stored in blockchain transparent ledgers, and accountable suppliers are unable to make post-audit amendments or falsify the records (Iqbal, 2025). Smart contracts can become ethical standards, such as that a payment is not given automatically or some form of review is launched when the AI systems identify discrepancies (Chatterjee, 2025). Blockchain and AI would put in place a stable system of protecting the rights of workers and maintaining high compliance with ethical standards of labor.

6. Tracking Carbon Emissions

Environmental sustainability is becoming the theme of luxury fashion, and brands are working towards diminishing the carbon footprints and meeting the goals of being climate-neutral (Vezzoli et al., 2022). AI is a critical point of estimating and quantifying emissions in different experiences of the supply chain. Analyzing the information based on one or the other manufacturing plants, mechanisms of transportation or processing of different materials, the AI can determine the trends of energy use, fuel consumption, and inefficient use of resources (Ojadi et al., 2024). These estimates help brands identify intensive periods of emission and consider alternative plans like optimum route, equipment with much low energy usage, or the use of the material that is not harmful.

After the verification of emission data with AI,the given values are encircled with the help of blockchain technology in an unchangeable registry, thus providing accountability and openness. Blockchain systems can also have sustainability certification, carbon credits, and environmental audits. Consumers have been welcomed to access carbon footprints of individual products thereby making informed choices when buying (Basu, Deb & Singh, 2024). To brands, emission tracking which involves surveillance through blockchain technology is beneficial in attaining regulatory compliance especially under new regulatory frameworks like Digital Product Passports in the European Union.

The convergence of artificial intelligence and blockchain make carbon accounting not a semi-manual audit period (once every 12 months) but an ongoing and automated procedure. This change will also increase precision, reduce greenwashing, and achieve true sustainability.

7. Current Industry Adoption

Luxury fashion industry has already initiated experimentation with Blockchain-AIs, but the usage is not equal. A number of brands have led in the use of blockchain on authentication and traceability. LVMH has also initiated the AURA Blockchain Consortium, a common platform or infrastructure that promotes tracking the origin of products and authenticating them (Cedrola, Kulaga & Pomi, 2024). Other companies to have followed in the same platform include Prada group and Cartier hence showing growing industry collaboration.

Although the use of blockchain has already advanced, the use of AI is not as swift. Technology companies like Stella McCartney have collaborated with technology companies to use AI-based data analytics to make sustainable sourcing decisions, including using AI to decide the environmental performance of raw material decisions (Iseal, 2025). The suppliers of materials, especially those focused on organic cotton or eco leather, are gradually adopting AI based grading systems to check on quality and sustainability factors prior to the materials being sent to the supply cycle.

Luxury producers incorporate QR codes or NFC chips into items on the consumer side to allow buyers to see information on the blockchain-verified sourcing process (Cordeiro & Ferreira, 2025). This practice implies the movement towards more transparency and consumer empowerment. Still, as most brands, they are based on pilot projects but not entirely implemented Blockchain-AI. There are still technical, financial and regulatory challenges that limit the widespread adoption, but the increased focus on sustainability is speeding up movement by the industry in this direction.

8. Benefits of Blockchain-AI Systems

The use of blockchain in AI gives high benefits to luxury brands, customers, regulatory bodies and supply-chain providers. The technology allows improving anti-counterfeiting efforts by linking each physical object to a digital ID that is secure. Forgery of luxury items works off multi-billion-dollar of revenues lost each year, and authentication based on blockchain will reduce the threat (Gross, 2021). Furthermore, the AI-based analytics provide a source of operational intelligence, which minimises waste, optimises resource use, and increases efficiency in the supply-chain. It is argued that blockchain reduces the time and complexity of the audit process by providing easy-to-use, read-only records through which a company can simplify certifications and compliance initiatives. Consumers are subjected to more trust and transparency.

With a product tag, a customer can check authenticity and obtain proven information about sourcing, labor practices, and environmental impact. The knowledge increases brand loyalty and supports the idea of making ethical buying choices. Regulators and third party certifiers enjoy quality and standardized information (Tanveer et al., 2021). The blockchain makes the certification authentic and verifiable sustainability claims. AI helps monitor compliance in real time to provide regulators with a more precise view of the situation within the supply-chain. Finally, the Blockchain-AI systems will strengthen the corporate responsibility and ensure that luxury brands are aligned with global sustainability goals.

9. Challenges in Implementation

Blockchain-AI systems, regardless of all this potential, face significant issues. On the list of these issues, the issue of data quality takes the first place. Although highly advanced AI processing is utilized, errors in, or missing data in the entry point may affect the integrity of the whole system. The partners in the supply chain can be deficient in the digital infrastructure or motivation to maintain proper records. The standardization of the data formats between several suppliers is still a problem, especially in global networks. Another important issue is scalability. Latencies and high maintenance of blockchain networks are common particularly when operating with large scale of data and complex smart contracts. Whereas public blockchain can be limited regarding latency and transaction costs, trade-offs in decentralization can be reduced by private blockchain. One of the issues of concern is privacy, especially concerning labor data.

Though the transparency must be needed, sensitive information on workers should be prevented. In order to find a balance between privacy and transparency, the careful design of the systems is needed,

and adherence to the legal frameworks is obligatory. Similarly, information about suppliers owned privately might not be appropriate to make public and, hence, should be aimed at using approved blockchain frameworks. There are other ethical issues raised by AI. The algorithmic bias might influence the evaluation of the labour compliance or result in the environmental data misinterpretation. Excessive use of automated surveillance will either violate the privacy of workers or develop unfair monitoring protocols. This means that the adoption of Blockchain -AI systems requires a strong ethical control.

10. Future Directions
The future landscape of blockchain-AI implementation in the luxury fashion industry is positive, and various tendencies indicate the further growth of its use. Digital Product Passports (DPPs) and in particular those required by the European Union will compel manufacturers to reveal extensive information about the product provenance, material composition, and environmental implications. Blockchain-AI platforms are the only ones ideally positioned to accommodate such regulatory imperatives. The circular fashion paradigms also have the advantage of traceability technologies. Using the capability to follow materials through consecutive life cycles makes it possible to recycle, sell and remodel products efficiently. The demanded traceability can be provided with the help of blockchain, and AI can be used to determine the quality of the material and assess the opportunity to reuse it.

Self-governing compliance systems are soon to come to fruition. Smart contracts in combination with AI can automatically detect violations of sustainability, activate investigative procedures, or adjust remunerations to suppliers depending on established evidence of ethical conduct. These mechanisms have the potential to radically re-conceptualize the nature of governance of supply chains by making them self-governing in terms of compliance, rather than depending on periodic human auditing. Some other emerging frontiers are self-sovereign identity structures of laborers. These identity tools in blockchain will give workers the ability to manage the employment records, qualifications and skills, giving the workers a sense of power and relieving workers of the burden of poor labor laws. AI would also help verify the attributes of identity and detect fake credentials.

11. Conclusion
Blockchain technology combined with artificial intelligence presents a radical path forward to providing greater transparency, sourcing ethically and sustainably in the luxury fashion sector. These technologies can solve fundamental issues related to verifying the provenance of materials, implementing the ethical standards of labor, and measuring environmental effects. The combination of blockchain block-based immutability features with AI advanced analysis services can allow fashion houses to create a new automated, highly reliable and consumer-focused system that strengthens accountability.

However, there are still several obstacles, including standardization of data and privacy concerns, but the trend towards sustainable luxury and the increasing regulatory needs are accelerating the use of blockchain and AI solutions. With the evolution of the sector, the technologies are destined to become the core of supply-chain governance, allowing companies to meet the demands of responsible consumers and protect their artisanal heritage. The luxury fashion direction in future will also be determined not only by aesthetic renewal and exclusivity but also increased transparency, responsibility and technology. Blockchain and artificial intelligence are atop of the list of elements of this paradigm shift.

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