Anti-Counterfitting in Footwear Industry using Blockchain Technology- A Survey

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Abstract

Counterfeiting in the footwear industry has become a major concern, resulting in revenue losses, brand damage, and erosion of consumer trust. The absence of end-to-end visibility and weak traceability mechanisms in conventional supply chains allow counterfeit products to infiltrate markets undetected. This survey paper investigates the use of blockchain technology as a solution to the counterfeit problem within the footwear sector. It reviews blockchain-based frameworks that enable secure tracking of each shoe's lifecycle—from raw material sourcing, manufacturing, and logistics to retail and post-purchase verification. By analyzing approaches such as QR code and RFID integration, digital product passports, and smart contract–based authentication, this paper compares existing models that ensure data immutability and transparency across stakeholders. The survey also discusses key blockchain platforms (Ethereum, Hyperledger, and VeChain) used in footwear traceability systems and evaluates their effectiveness in maintaining authenticity. Finally, the paper highlights implementation challenges such as scalability, cost, and interoperability, and outlines future research directions for developing efficient, consumer-friendly blockchain-based anti-counterfeit frameworks for the footwear industry

Keywords: Blockchain, Counterfeit Prevention, Footwear Supply Chain, Smart Contracts, Product Authentication, Decentralized Transparency, QR Code Integration

1. Introduction

The global footwear industry is one of the most dynamic and rapidly expanding sectors within the fashion and lifestyle economy, contributing billions of dollars to international trade and employment generation. According to global market reports, the footwear industry is projected to exceed USD 500 billion by 2027, driven by the rise of e-commerce, brand collaborations, and increased consumer demand for fashion-oriented and performance-driven products. However, alongside this rapid growth, the industry continues to suffer from a persistent and complex challenge - the proliferation of counterfeit footwear in domestic and international markets. The circulation of fake footwear results in substantial financial losses for manufacturers and retailers, reduces tax revenues for governments, and exposes consumers to products that lack quality and safety compliance. International trade authorities estimate that counterfeit goods account for nearly 3% of global trade, and footwear remains one of the most targeted product categories (13; 12).

The modern footwear supply chain is characterized by long multi-stage processes that involve raw material sourcing, manufacturing, warehousing, logistics, retail distribution, and online sales. This multilevel structure spans multiple countries and multiple stakeholders, making visibility and trust crucial factors for authenticity verification. As supply chains expand globally, challenges such as fragmented record keeping, data manipulation, counterfeit infiltration, and a lack of end-to-end transparency have become major concerns (1; 2). Traditional supply chain systems commonly rely on centralized authorities and paper-based documentation, which are vulnerable to human error, data loss, alteration, and unauthorized access (15; 8). These limitations create blind spots that allow counterfeit products to be inserted into legitimate supply chains without detection, making it difficult to verify the origin and movement of footwear at any stage.

In recent years, blockchain technology has emerged as a promising and transformative solution to address these gaps. Blockchain is a decentralized, distributed, and tamper-resistant digital ledger that enables transparent and secure data sharing across multiple untrusted parties (3; 4). Its fundamental characteristics are immutability, decentralization, consensus-driven validation, and transparency make it particularly suitable for supply chain traceability and product authentication. Every event in the supply chain, such as manufacturing, packaging, quality inspection, shipment, retail transfer, or customer purchase, can be recorded as a transaction on the blockchain. Since these records are time-stamped and immutable, they provide verifiable proof of origin and ownership without dependence on intermediaries (25; 7). This prevents fraudulent alterations, increases accountability, and builds trust between manufacturers, retailers, and end consumers.

Blockchain-enabled Product Ownership Management Systems (POMS) (16) and IoT-assisted authentication mechanisms (14; 7) have shown strong potential in combating product duplication and grey-market trading. The integration of QR codes, RFID tags, and NFC-based digital identifiers allows customers to verify product authenticity instantly using smartphones or web applications. When combined with blockchain, these identifiers link each physical footwear item to its corresponding digital identity on the ledger, ensuring data integrity throughout its lifecycle. Such solutions help brands protect their intellectual property, allow consumers to verify originality, and enable regulatory bodies to monitor product flow.

Furthermore, blockchain has demonstrated successful adoption across various industries beyond footwear. In healthcare, blockchain supports drug traceability, counterfeit prevention, and secure logistics monitoring (6; 11). The agriculture and food sectors utilize blockchain to certify product quality, guarantee freshness, and reduce fraud in production and distribution stages (10; 9). These applications highlight blockchain's capability to establish transparent, tamper-proof, and end-to-end traceable supply chains. Lessons learned from these industries can be extended to footwear manufacturing, which faces similar challenges in authenticity verification and product certification.

Despite these advantages, the widespread implementation of blockchain in supply chain management still encounters several challenges. Issues such as scalability, interoperability between blockchain platforms, limited standardization, high deployment costs, and energy consumption remain critical barriers (13; 4). To overcome these limitations, emerging research explores hybrid solutions that integrate blockchain with advanced technologies such as the Internet of Things (IoT), Artificial Intelligence (AI), Non-Fungible Tokens (NFTs), and cloud-edge architectures (17; 7). IoT sensors can collect real-time environmental and logistics data, while AI can automate decision making, detect fraud patterns, and forecast supply chain risks. NFTs can create unique digital identities for products, ensuring secure and transferable ownership records across the supply chain.

In the footwear industry, where brand value, aesthetics, and originality are extremely critical, the increasing circulation of counterfeit shoes demands a reliable technological intervention. Consumers often lack direct means to verify authenticity, especially in online marketplaces where counterfeit sellers imitate brand packaging and product designs. Likewise, manufacturers struggle to maintain visibility once products leave their warehouses and enter complex retail or distributor networks. These challenges highlight the need for a blockchain-based framework that provides transparency, auditability, and tamper-proof documentation at every step of the product journey.

In this context, the objective of this research is to provide a comprehensive review of blockchain-based frameworks applied to counterfeit prevention and supply chain transparency, specifically focusing on their applicability to the footwear sector. This study reviews existing models, analyzes key technologies such as smart contracts, distributed ledgers, hash-based identifiers, and IoT integration, and compares the strengths and limitations of current approaches. Additionally, the paper identifies open research challenges and proposes future opportunities for building a decentralized, secure, and counterfeit-free footwear ecosystem.

The key contributions of this work are as follows:

1. A detailed review of blockchain-based approaches for supply chain transparency and counterfeit prevention across various industries.
2. A comparative analysis of existing frameworks, focusing on blockchain platforms, data management models, and verification mechanisms.
3. Identification of major challenges such as scalability, interoperability, standardization, and consumer accessibility in real-world deployments.
4. Discussion of future research directions and opportunities for implementing blockchain-based counterfeit-free frameworks in the footwear industry.

By systematically analyzing the current landscape of blockchain-based supply chain systems, this paper provides insights into how emerging technologies can be utilized to build a secure, transparent, and trustworthy footwear supply chain that effectively prevents counterfeit infiltration and enhances consumer confidence.

In addition to improving transparency, blockchain also supports consumer-level product authentication, which has become increasingly important with the massive growth of e-commerce and third-party marketplaces. Customers frequently purchase footwear online where the chances of receiving counterfeit items are much higher. Blockchain-based verification allows users to scan embedded QR codes, RFID tags, or NFC chips and validate authenticity directly from the distributed ledger, eliminating the need for intermediaries or retailer verification (12), (13). This consumer-side validation improves trust and encourages brands to adopt secure traceability and anti-counterfeiting mechanisms (16).

Another emerging concept is Digital Product Passports (DPPs), where every footwear item is assigned a permanent digital identity stored on blockchain. This identity may include details such as material sourcing, production batch, warehouse transfers, transportation logs, and ownership history. Since blockchain records are immutable, product data cannot be altered or manipulated, enabling consumers, regulators, and manufacturers to verify authenticity in real time (14). DPPs also support sustainability initiatives by providing transparent proof of ethical sourcing and environmentally responsible manufacturing (1), (10).

Despite these advantages, large-scale blockchain deployment still faces certain challenges. Common issues include high setup cost, computational overhead, interoperability limitations, and lack of standardization across supply chain participants (8). Small and medium-scale businesses may also require additional infrastructure and technical support to integrate blockchain with existing systems. Moreover, even if digital records are tamper-proof, counterfeiters may attempt to clone RFID or QR tags. Therefore, blockchain solutions must be combined with secure hardware such as tamper-proof RFID, encrypted NFC, or smart holographic labels to prevent physical duplication (3), (7).

To overcome these issues, researchers have proposed hybrid blockchain models integrating IoT devices, cloud platforms, smart contracts, and AI-based analytics. IoT sensors can monitor product location and environmental conditions throughout transportation, while smart contracts automate validation and update product states without manual intervention (4), (11). Artificial Intelligence and machine learning can further analyze blockchain logs to detect anomalies, identify high-risk suppliers, and prevent counterfeit distribution at an earlier stage (25).

With these advancements, blockchain has the potential to transform the traditional opaque footwear supply chain into a secure and transparent ecosystem. By providing immutable proof of origin, tamper-proof product history, and complete end-to-end traceability, blockchain can significantly reduce the circulation of counterfeit footwear in legitimate markets (15). As a result, global brands can protect their intellectual property, increase customer trust, and maintain competitive advantage.

Therefore, this research paper focuses on exploring how blockchain and related technologies can create a counterfeit-free footwear supply chain. The study reviews existing literature, compares blockchain-based anti-counterfeiting models, identifies current challenges, and highlights future opportunities for real-world implementation in the global footwear industry.

2. Background and Technical Concepts

This section explains the key technological concepts that form the foundation of blockchain-based anti-counterfeiting systems for supply chain management. Understanding these concepts is important before analyzing existing frameworks and designing new solutions for counterfeit-free product verification.

2.1. Blockchain Technology

Blockchain is a distributed digital ledger where data is stored in the form of blocks linked together in chronological order. Unlike traditional centralized databases managed by a single authority, blockchain is decentralized, meaning that every participant in the network maintains a copy of the ledger. Once a record is stored in the blockchain, it becomes extremely difficult to modify or delete, ensuring data security and trust among participants.

Blockchain operates on consensus mechanisms such as Proof of Work (PoW), Proof of Stake (PoS), or Practical Byzantine Fault Tolerance (PBFT), where nodes must agree before a new block is added to the chain. This feature makes blockchain resistant to manipulation, unauthorized modifications, and fraud.

2.2. Public vs. Private Blockchain

Blockchain networks can be broadly categorized into public and private types:

- **Public Blockchain:** These networks are open to everyone. Anyone can join, view the ledger, and participate in transaction validation. Examples include Bitcoin and Ethereum. Public blockchains provide high transparency but are slower and computationally expensive.
- **Private Blockchain:** These are restricted networks where only authorized participants can access or validate data. Private blockchains are widely used in supply chain applications because they offer better privacy, controlled access, faster transactions, and improved scalability.

For anti-counterfeiting in industries like footwear and pharmaceuticals, private or consortium blockchains are preferred because only legitimate manufacturers, retailers, and logistics partners need to record product transactions.

2.3. Smart Contracts

Smart contracts are self-executing programs stored on the blockchain. They automatically perform actions when predefined conditions are met. For example, a smart contract can verify product ownership, release payment after delivery, or generate alerts if unauthorized tracking data appears.

Smart contracts remove the need for intermediaries and eliminate the possibility of manual tampering. In supply chains, they ensure that every product movement—manufacturing, packaging, shipping, warehousing, and retail—is recorded and authenticated without human intervention.

2.4. Supply Chain Tracking Using Blockchain

Traditional supply chains rely on physical documents, centralized data storage, and manual verification. This lack of transparency makes it easy for counterfeit goods to enter legitimate markets. Blockchain solves this problem by:

- Recording every product transfer as a transaction
- Storing immutable product history
- Allowing authorized members to verify records anytime
- Detecting fake entries since unauthorized parties cannot write to the ledger

With blockchain-based tracking, each footwear item can be traced from raw materials to the end customer. If a counterfeit item appears, authorities can identify where the fake product entered the chain and isolate fraudulent suppliers.

2.5. Role of IoT, QR Codes, RFID, NFC, and NFTs

Modern blockchain-based supply chains often combine multiple technologies for automated tracking and authentication:

- **IOT (Internet of Things):** IoT sensors collect real-time data about temperature, location, handling conditions, and transportation. This is useful for monitoring high-value footwear shipments and detecting any unauthorized access or route changes.
- **QR Codes:** Each product can have a QR code linked to blockchain data. Customers or retailers can scan the code to view manufacturing details, shipment records, and authenticity certificates.
- **RFID and NFC Tags:** RFID and NFC chips store encrypted product information. Unlike QR codes, they cannot be easily copied or printed, making them harder for counterfeiters to duplicate. These tags allow automatic scanning during warehousing and retail handling.
- **NFTs (Non-Fungible Tokens):** NFTs create a permanent digital ownership certificate for physical goods. Brands can assign an NFT to each shoe pair, which the buyer receives after purchase. If a counterfeit seller tries to resell the product without a valid NFT, it becomes immediately verifiable.

Combining blockchain with IoT and smart identification technologies builds a secure and transparent product lifecycle—from manufacturing to resale—making counterfeiting extremely difficult.

3. Architecture

Blockchain technology helps to stop counterfeit shoes by using a secure digital record system that connects every real shoe with its digital identity. When a footwear company like TrueStep manufactures a new pair of shoes, its factory system calls a smart contract on the blockchain (for example, on Ethereum or Hyperledger Fabric). This smart contract runs a function such as registerProduct() that stores the shoe's unique details — serial number, manufacturer name, and timestamp — on the blockchain. A hash value (a digital fingerprint) is created using a cryptographic function like keccak256, and this value is saved in a public ledger that no one can edit or delete. Each shoe is then given a QR code or NFC chip containing its blockchain ID, linking the physical shoe to its digital record.

As the shoes move through the supply chain, from the manufacturer to the distributor, retailer, and finally the customer, another

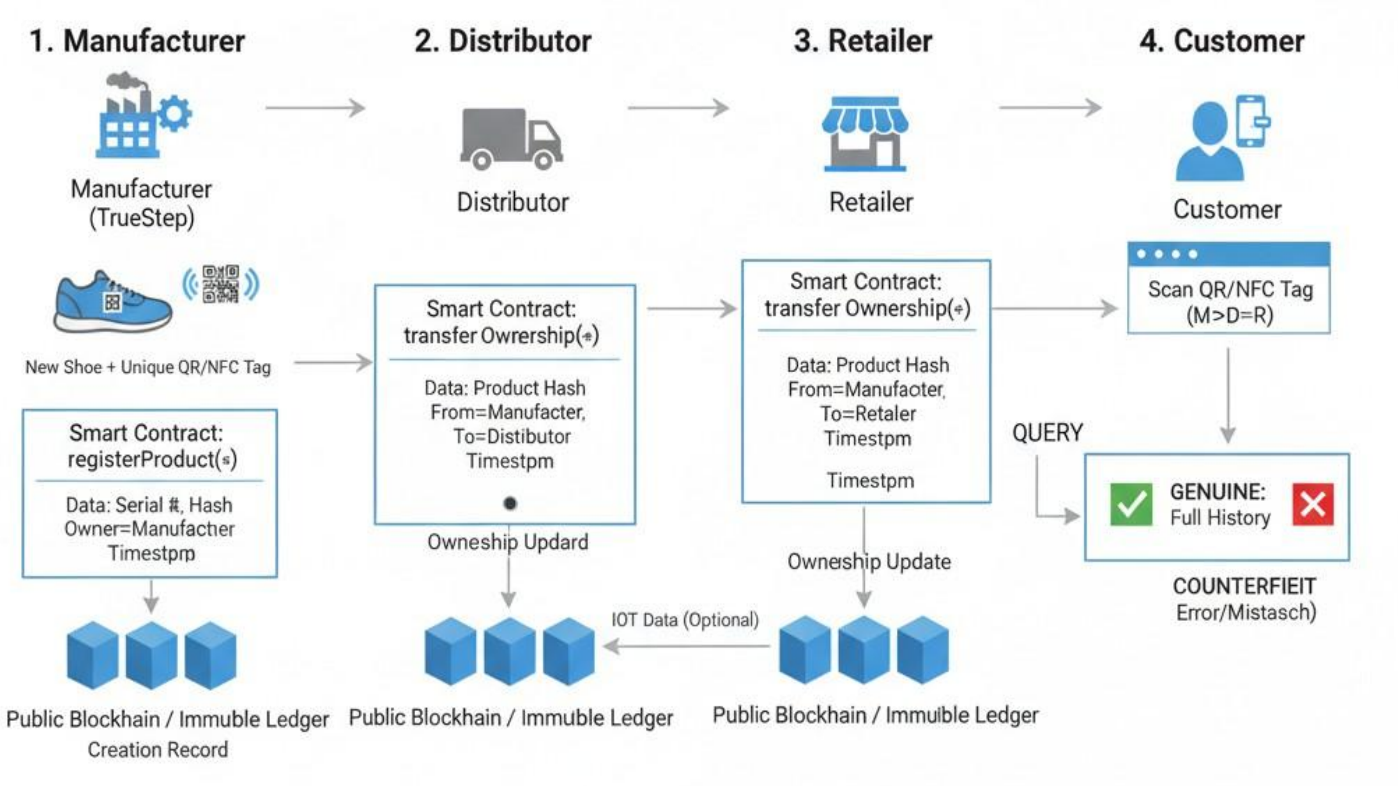

Fig. 3.1 - Architecture Diagram

smart contract function like transferOwnership() is used. This records each ownership change as a new block in the blockchain, including the sender's address, receiver's address, timestamp, and product hash. Every transaction is digitally signed by both parties and verified through a consensus mechanism such as Proof of Authority (PoA) or Proof of Stake (PoS). This ensures that all updates are validated by trusted nodes and cannot be faked.

When a customer scans the QR code in a store, the mobile app communicates with the blockchain through Web3.js or REST APIs to fetch real-time product details directly from the blockchain.

If the shoe is genuine, the app displays the complete history — manufacturer, distributor, retailer, and final sale information. If it's counterfeit, the blockchain will show an error or mismatched data, proving it's fake. Some advanced systems also use IoT sensors and AI algorithms to record shipment temperature, location, or delays, with the data hash stored on the blockchain for integrity checking.

Technically, this system turns every shoe into a traceable digital asset on the blockchain. Every movement or update becomes a verified transaction, forming a transparent, tamper-proof history from factory to customer. Hence, blockchain technology provides an easy yet powerful technical framework that ensures authenticity, eliminates fake entries, and builds complete trust in the footwear industry.

4. Related Work

The increasing concern over counterfeit products and lack of transparency in global supply chains has motivated researchers to explore blockchain as a secure alternative to traditional tracking systems. Over the past few years, a considerable number of studies have introduced blockchain-based frameworks for improving traceability, product authentication, and trust among supply chain participants.

Early research focused on understanding how blockchain could enhance supply chain transparency, efficiency, and structural optimization. Wang et al. analyzed multi-layer supply chain networks and highlighted the significance of key nodes for monitoring product flow and maintaining green and sustainable logistics [1]. Xu and Bo further emphasized the role of computational intelligence and analytics to increase supply chain resilience, particularly under uncertain conditions [2]. Although these studies demonstrate improvements in visibility and optimization, they do not specifically address counterfeit prevention.

To tackle authentication challenges, several researchers proposed blockchain-supported IoT and cryptographic solutions. Assaqty et al. introduced SPUFChain, a lightweight authentication model that uses Physical Unclonable Functions (PUF) for secure identity verification of IoT devices within supply chains [3]. Ahmad et al. developed a blockchain-IoT integrated framework for smart city logistics to ensure secure tracking and queue-based resource allocation [4]. These approaches show that IoT connectivity combined with blockchain strengthens tamper-proof tracking, but real-world scalability remains a challenge.

Significant progress has been made in survey-oriented research as well. Jadon et al. presented a detailed review of blockchain adoption in the electronics supply chain, explaining how decentralized ledgers can mitigate fraud, reduce paperwork, and enhance coordination between manufacturers and distributors [5]. Similar studies in healthcare and pharmaceutical logistics also demonstrate the impact of blockchain in preventing fake medical products and ensuring secure distribution channels [6], [14]. These systems are closely related to footwear authentication because pharmaceuticals and footwear both suffer from counterfeit infiltration during intermediate logistics stages.

IoT-assisted blockchain frameworks have also gained attention for real-time monitoring. Chbaik et al. proposed a blockchain-assisted IoT wireless model for equipment monitoring, enabling secure data sharing among supply chain entities [7]. Oguz et al. performed a systematic review of blockchain in logistics and concluded that decentralized ledgers can improve traceability and operational efficiency but require global standardization for industry-wide deployment [8].

In the agricultural and food sector, Raza et al. designed Agri-4-All, a blockchain-based model that provides end-to-end tracking of agricultural goods while ensuring trust between farmers, distributors, and consumers [9]. Casino et al. also demonstrated that blockchain can improve food authentication and address the issue of tampered food labels through auditable records [10]. These solutions prove that blockchain traceability works effectively in supply chains where product authenticity is critical.

During the COVID-19 crisis, blockchain was successfully used for secure tracking of medical equipment and waste disposal. Ahmad et al. proposed a forward-supply chain system where blockchain ensured proper management of protective gear and critical medical assets [11]. Zhu et al. introduced a blockchain platform for anti-counterfeit medicine tracking, enabling consumers to verify authenticity using QR/NFC-enabled product scanning [12]. Similar anti-counterfeiting frameworks were later extended to general goods using blockchain-based ownership tracking [13].

Several researchers also explored more advanced mechanisms. Chen et al. introduced IoT-based drug traceability using blockchain for tamper-proof medical product management [14]. Narayanan et al. emphasized blockchain's role in improving overall supply chain performance by reducing fraud, increasing automation, and streamlining logistics [15]. A foundational contribution in this field is the Product Ownership Management System (POMS), proposed by Toyoda et al., which assigns a secure digital identity to every product and records ownership transfers on blockchain [16]. This model is highly relevant to footwear authentication, where ownership transparency plays a major role in resale markets.

Beyond traceability, the rise of Non-Fungible Tokens (NFTs) has expanded blockchain's application in digital ownership. Razi et al. discussed how NFTs can represent secure digital certificates for real-world assets, enabling anti-counterfeit verification and proof of originality [17]. Agarwal et al. further reviewed blockchain-based supply chain security models and identified open issues such as interoperability, high deployment cost, and lack of universal standards [18].

5. Comparative Analysis of Existing Systems

Traditional anti-counterfeiting systems used in the footwear supply chain rely on methods such as barcodes, hologram labels, and serial numbers. Although widely adopted, these techniques can be easily duplicated or removed, making them insufficient for high-value footwear authentication. Most of these mechanisms store product records in centralized databases, which creates a single point of failure and allows data to be altered or deleted without leaving forensic evidence [8], [15]. As a result, once products leave

Table 1. Comparison of Existing Blockchain and SCM Research Papers

Ref	Year	Domain	Key Contribution	Technology Used	Limitations
[1]	2025	Green SCM	Key node identification in multi-layer chains	Multi-scale analytics	No blockchain implementation
[2]	2025	Supply Chain Resilience	Computational intelligence for resilience	Advanced analytics, AI	No transparency/traceability
[3]	2025	IoT SCM Security	Lightweight authentication with PUF	Permissioned BC + PUF	Only security, no full tracking
[4]	2024	Smart City SCM	IoT + BC secure framework with queue model	IoT + Blockchain	High complexity, scalability
[5]	2024	Electronics SCM	Blockchain survey	Literature review	No implementation
[6]	2024	Healthcare SCM	Review of BC in medical supply	Blockchain review	No performance evaluation
[7]	2024	IoT Equipment SCM	Blockchain-assisted monitoring	IoT sensors + BC	Monitoring only, no anti-counterfeit
[8]	2024	Logistics SCM	Systematic review of BC in logistics	Survey	No novel system proposed
[9]	2023	Agriculture SCM	Blockchain food traceability	Smart contracts	Not validated on large scale
[10]	2022	Food SCM	BC adoption review	Review	No experimental work
[11]	2021	Medical SCM	BC for waste	Smart contracts	Limited to COVID scenario
[12]	2020	Medicines	Anti-counterfeit and tracing	Blockchain ledger	Domain-specific
[13]	2020	Product Authenticity	BC-based app for authenticity	DLT	Limited adoption
[14]	2020	Drug SCM	IoT-based anti-counterfeit	IoT + RFID + BC	Hardware cost
[15]	2024	General SCM	Role of BC in SCM	Survey	No experiments
[16]	2017	Product Ownership	POMS system	Blockchain	Early tech, low scalability
[17]	2023	NFT Applications	NFT evolution survey	NFTs + BC	No SCM-focused system
[18]	2022	Secure SCM	Comprehensive BC review	Blockchain	Theoretical

manufacturing facilities and move through distributors, wholesalers, and retailers, the authenticity record becomes difficult to verify independently.

To improve traceability, several industries introduced RFID and QR-based identification, enabling each product to carry a machine-readable identity. However, the data stored behind these tags still depends on centralized backend servers, which remain vulnerable to manipulation or insider attacks [4], [9]. Counterfeiters can clone or reprint QR codes and attach them to fake footwear, causing confusion in the retail market. Therefore, although these systems provide convenience, they lack tamper-proof validation.

Another solution found in literature is the Product Ownership Management System (POMS), where ownership changes are recorded throughout the post-supply chain [16]. POMS focuses on tracking product reselling and transfer of possession. While the idea reduces unauthorized resale, it still relies on a controlled database environment operated by a single organization. Thus, it cannot eliminate trust issues when multiple international stakeholders are involved.

In recent years, researchers proposed IoT-enabled and cloud-based monitoring platforms, where logistics information such as temperature, storage duration, transport location, or warehouse conditions is captured automatically [7]. Although these systems offer improved real-time visibility, data integrity still depends on centralized cloud providers. A malicious supplier or compromised server can modify or delete records without leaving any audit trail [1]. Furthermore, cyber-attacks on centralized infrastructure can expose confidential trade information or alter product histories, making these solutions risky for high-value branded footwear.

Compared to these traditional systems, blockchain-based solutions provide significant improvements. Since blockchain stores product information on a decentralized and immutable ledger, no participant can alter or remove past transactions [15]. Solutions such as blockchain-enabled QR codes, RFID/NFC tags, IoT sensors, Digital Product Passports, and NFTs make product verification secure and independent of central authorities [3], [12], [17]. Consumers and retailers can simply scan embedded tags, retrieve data from the ledger, and confirm product authenticity without relying on manufacturers or resellers.

In summary, non-blockchain systems offer only basic tracking and are vulnerable to duplication, insider attacks, and database manipulation. Blockchain-integrated authentication overcomes these challenges by providing tamper-proof records, secure ownership transfer, distributed trust, and transparent provenance, making it a more reliable choice for counterfeit prevention in the global footwear industry [18].

6. Research Gap and Limitation

Although several studies demonstrate the potential of blockchain and IoT in supply chain security, noticeable gaps still exist—especially for industries like footwear, where counterfeiting continues to grow rapidly. Most existing research focuses on pharmaceuticals, electronics, food, and medical supply chains, while very few solutions are designed specifically for footwear authentication and lifecycle tracking. This indicates a lack of domain-focused implementation and practical deployment in the footwear sector.

Another major limitation is **scalability**. Systems that combine IoT sensors, RFID, NFC, and blockchain often require high storage, computing power, and network resources. Many solutions work well in controlled experiments but are difficult to scale for millions of products moving across global supply chains. Small manufacturers and retailers may struggle with the cost of deploying tags, scanners, or blockchain infrastructure.

Cost is another barrier. Hardware components like RFID/NFC tags or IoT devices add expense, and training employees to use blockchain-enabled platforms requires additional investment. As a result, many companies continue to rely on cheaper but insecure methods such as barcodes or QR codes without blockchain protection.

Even when blockchain is implemented, **consumer-side verification** remains weak. Most customers do not scan products or interact with blockchain systems. A secure system only works if consumers can easily verify authenticity, which is still not fully addressed in most research.

Additionally, there is **limited real-world deployment data**. Many papers propose frameworks or simulations, but only a few provide long-term field testing with real product lifecycle tracking. This makes it difficult to evaluate performance, latency, transaction costs, or user adoption in real supply chain conditions.

Finally, very few studies combine blockchain with **AI or advanced IoT analytics**. Artificial intelligence could detect suspicious patterns, predict counterfeit risks, or automate alerts, but integration of AI in anti-counterfeiting supply chain systems is still rare.

These research gaps clearly highlight the need for a dedicated, scalable, and real-world usable blockchain framework for the footwear industry—one that supports consumer authentication, is cost-efficient, and can be integrated with modern technologies like IoT and AI.

7. Future Scope

The integration of blockchain technology in supply chain management is still evolving, and there are several opportunities for further development and research:

1. Integration with IoT and AI: In the future, blockchain can work together with Internet of Things (IoT) devices and Artificial Intelligence (AI). This will allow companies to monitor their supply chains in real time, predict possible issues before they happen, and even make automatic decisions to improve efficiency.
2. Wider Industry Adoption: Blockchain won't just be limited to one field — it can be used in many industries like pharmaceuticals, agriculture, electronics, and automobiles. This will help make products more traceable, reduce the chances of fraud, and ensure that items are genuine.
3. Enhanced Smart Contracts: Smart contracts will become more powerful and capable of handling complex tasks. They could automatically manage payments, insurance claims, and legal compliance, reducing the need for manual work and increasing accuracy.
4. Better Speed and Scalability: Future research will focus on making blockchain faster, more energy-efficient, and capable of handling a larger number of transactions. This will make it practical for use in global supply chains that deal with millions of transactions daily.
5. Clear Regulations and Standards: As blockchain becomes more common, there will be a need for global rules and standards.

These will ensure that blockchain systems are secure, private, and legally compliant, encouraging more organizations to adopt the technology confidently.

6. Sustainability and Green Supply Chains: Blockchain can help companies monitor their environmental impact by tracking carbon emissions, energy usage, and sourcing methods. This will promote eco-friendly and ethically responsible supply chain practices.

8. Conclusion

In conclusion, the problem of counterfeiting in the footwear industry causes serious harm to brands, customers, and the overall market trust. Traditional methods like barcodes or holograms are not fully reliable because they can be copied or altered. Blockchain technology provides a strong solution to this problem because it offers a secure, transparent, and tamper-proof way to record every step of a product's journey — from manufacturing to the customer. Each transaction or movement of the footwear can be stored permanently on the blockchain, making it impossible to fake or change later. This builds trust among consumers, helps brands protect their reputation, and ensures that only genuine products reach the market. Therefore, using blockchain for anti-counterfeiting in the footwear industry is an effective and reliable approach to ensure product authenticity and supply chain transparency.

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