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Blockchain Technology for Sustainable Leather Goods Production: Transparency and Traceability Perspectives

R. S. Bature[1], U. B. Agballa[2], K. Umar[2], U. E. Okon[3]
[1]Department of Information and Communication Technology,
Nigeria Institute of Leather and Science Technology Zaria, Nigeria
[2]Department of Computer Science,
Nigeria Institute of Leather and Science Technology, Zaria, Nigeria
[3]Department of General Studies,
Nigeria Institute of Leather and Science Technology Zaria, Nigeria

ABSTRACT

The leather industry is increasingly scrutinized for its environmental and social practices, necessitating a shift towards sustainable production methods. This paper explores the application of blockchain technology as a transformative solution to enhance transparency, traceability, and accountability within the leather supply chain. By providing digital passports for products, blockchain enables consumers to verify the authenticity and ethical sourcing of leather goods, thereby promoting informed purchasing decisions. This study identifies the challenges associated with implementing blockchain, including technical hurdles, financial implications, and the need for organizational transformation. Ultimately, the integration of blockchain technology presents a viable pathway for the leather industry to align with contemporary demands for sustainability and ethical practices.

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INTRODUCTION

The burgeoning demand for environmentally sustainable and socially responsible practices in the fashion and luxury industries has revolutionized the way businesses operate. Conscious consumers increasingly expect authentic sustainable practices, driving the need for transparent and traceable supply chains (Rathore 2019; Olatubosun *et al*., 2021). The leather industry, with its intricate global supply chain and significant environmental implications, is under intense scrutiny. The complexity of the leather supply chain, coupled with the industry's history of environmental degradation and social exploitation, necessitates a paradigm shift in its operational practices.

Leather production, an industry dating back centuries, has evolved into a multifaceted and versatile sector. The transformation of raw hides and skins into luxurious leather goods involves a complex interplay of chemical, mechanical, and manual processes (Meli 2020). However, these processes can have devastating environmental and social consequences if not managed responsibly. The statistics are alarming: in 2020, approximately 27 million animals were slaughtered to produce raw hides and skins, with the majority being processed into leather goods. The widespread use of hazardous chemicals in tanneries exacerbates environmental degradation, posing serious health risks to humans and animals, particularly in developing countries with inadequate environmental regulations (Abdulhusein & Kadim 2024).

In response to these concerns, global consumers are increasingly demanding high-quality products that embody transparency, sustainability, and ethical practices. Legislation in many nations has been strengthened to ensure compliance with stringent environmental and social standards. The concept of sustainable leather goods is gaining traction, with a growing focus on minimizing waste, reducing environmental impact, and promoting responsible

Corresponding author: R. S. Bature
rsbature@gmail.com
Department of Information and Communication Technology, Nigeria Institute of Leather and Science Technology, Zaria.
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sourcing practices. However, the leather industry's transition to sustainable practices is hindered by the opacity of its supply chains, which obscures the origin, quality, and movement of raw materials.

As the demand for sustainable and ethically produced goods continues to rise, the leather industry must adapt to meet these expectations. Embracing innovative technologies like blockchain can facilitate this transition, ensuring that the supply chain is transparent and accountable to consumers and stakeholders alike.

Key Features of Blockchain

Blockchain technology is built on several fundamental features that ensure its integrity, security, and transparency. These features are depicted in Fig 1.

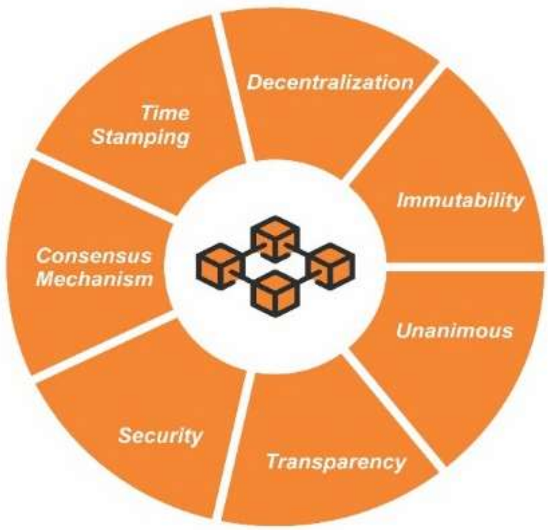

Fig 1: Key Features of Blockchain

Decentralization: Decentralization is a fundamental feature of blockchain technology, where no single entity controls the network. Instead, the network is maintained by a collective group of nodes, providing a decentralized and distributed architecture. This decentralization offers numerous benefits, including reduced vulnerability to failure, increased security, and improved transparency. With no single point of failure, decentralized networks are less vulnerable to attacks and can ensure continuous operation. Moreover, decentralization promotes security by making it difficult for a single entity to manipulate the network. Decentralization also provides transparency, as all nodes have access to the same information, promoting trust and accountability (Momoh *et al*., 2021).

Immutability: Immutability is another key feature of blockchain technology, ensuring that once data is recorded, it cannot be modified or reversed. This is made possible by the distributed ledger, where every node verifies transactions before adding them to the network. The immutability of blockchain provides a tamper-proof record, ensuring the integrity and accuracy of the data. Moreover, immutability promotes transparency, as all transactions are recorded in a public ledger, visible to all nodes. This transparency ensures accountability, as all transactions are recorded and cannot be altered. In addition, immutability builds trust among nodes, as all parties agree on the validity of transactions (Politou *et al*., 2022).

Unanimity: Unanimity is a critical feature of blockchain technology, ensuring that all nodes agree on the validity of transactions before adding

Corresponding author: R. S. Bature
rsbature@gmail.com
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them to the network. This consensus mechanism prevents a single entity from manipulating the network, ensuring the integrity of the blockchain. Unanimity ensures that all transactions are accurate and valid, preventing errors or fraudulent activities. Moreover, unanimity builds trust among nodes, as all parties agree on the validity of transactions. This trust promotes a secure and reliable network, where all nodes can trust the accuracy and validity of the transactions. Unanimity provides a clear audit trail, ensuring that all transactions are recorded and visible to all nodes (Maroufi *et al*., 2019).

Transparency: Transparency is a vital feature of blockchain technology, providing a public ledger that records all transactions. This transparency ensures that all nodes have access to the same information, promoting trust and accountability. Transparency promotes trust among nodes, as all parties have access to the same information. Moreover, transparency ensures accountability, as all transactions are recorded and visible to all nodes. This accountability prevents corruption, as all transactions are recorded and visible to all nodes. Furthermore, transparency provides a clear audit trail, ensuring that all transactions are recorded and visible to all nodes (Momoh *et al*., 2022).

Security: Security is a critical feature of blockchain technology, employing advanced cryptographic techniques to ensure the integrity of the network. Blockchain's security features include encryption, hashing, and consensus mechanisms, ensuring that all transactions are secure and protected. The use of encryption ensures that all data is secure and protected, preventing unauthorized access. Moreover, the use of hashing algorithms ensures that all data is tamper-proof, preventing manipulation. Finally, consensus mechanisms ensure that all nodes agree on the validity of transactions, preventing manipulation and ensuring security (Idrees *et al*., 2021; Daniel *et al*., 2021).

Consensus mechanisms: Consensus mechanisms are decision-making techniques employed by blockchain technology to facilitate agreement among nodes. These mechanisms ensure that all nodes agree on the validity of transactions, preventing manipulation and ensuring security. Consensus mechanisms promote trust among nodes, as all parties agree on the validity of transactions. Moreover, consensus mechanisms ensure that all transactions are accurate and valid, preventing errors or fraudulent activities (Idrees *et al*., 2021).

Time-stamping: Time-stamping is a critical feature of blockchain technology, ensuring that transactions are recorded in a specific order. This feature prevents tampering, as transactions are recorded in a specific order and cannot be altered. Time-stamping ensures the integrity of the network, providing a clear audit trail of all transactions. Time-stamping also provides transparency, as all transactions are recorded in a public ledger and visible to all nodes. This transparency ensures accountability as all transactions are recorded and visible to all nodes (Hepp *et al*., 2018).

CLASSIFICATION OF BLOCKCHAIN

Blockchain technology can be classified into three main types as illustrated in Fig 2: public, private, and consortium blockchain. Each type has its unique characteristics, advantages, and use cases.

Public Blockchain: Public blockchain are the foundation of the blockchain functional spectrum. They are open, public, and decentralized, allowing anyone to join and participate without permission. The core idea behind public blockchain is true decentralization, maintained by a global community of users. Public blockchain are decentralized and distributed networks, open and public, offering transparency and immutability. They provide decentralized security through cryptographic techniques and censorship resistance due to the lack of a central authority. Examples of public blockchain include Bitcoin and Ethereum.

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rsbature@gmail.com
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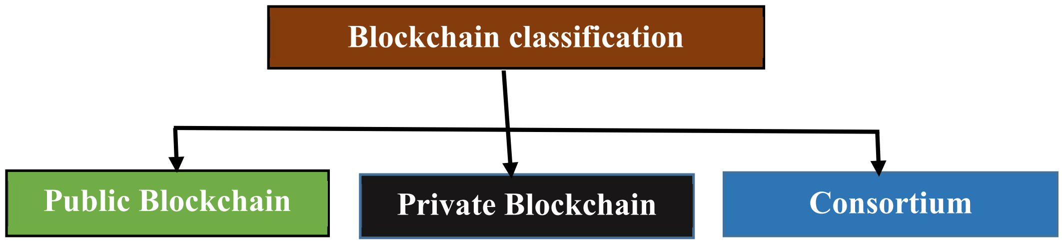

Fig 2: Classification of Blockchain

Private Blockchain: Private blockchain, in contrast, are restricted to specific organizations or groups. They are centralized, controlled by a single entity, and offer more control over transactions. Private blockchain are centralized and restricted, controlled by a single entity or organization. This provides increased privacy and security due to limited access, as well as efficient and regulated transaction costs. However, private blockchain have lower transparency compared to public blockchain. Private blockchain are commonly used in business applications, such as internal monitoring, revenue recording, and supply chain management.

Consortium Blockchain: Consortium blockchain, also known as permissioned blockchain, combine features of public and private blockchain. They are governed by a small group of organizations, allowing for selective sharing of control. Consortium blockchain are a hybrid model, combining public and private blockchain features. They are governed by a small group of organizations, allowing for selective sharing of control and decision-making. Consortium blockchain provide pseudonymity for transactions. However, they have complex governance and rule-definition processes. Consortium blockchain are commonly used in industries such as finance, healthcare, and supply chain management.

BLOCKCHAIN FORMATION PROCESS IN LEATHER PRODUCTION

A blockchain consists of two primary entities: blocks and chains. A block can be likened to a database record, containing specific data that forms the building block of the blockchain. Each block comprises a block head and block body, with the block head containing essential metadata such as the hash of the actual data, the hash of the previous block, and the generation time. Hashing is employed to prevent tampering with vital contents of previous blocks, and an effective hashing function must possess three key properties: collision resistance, pre-image resistance, and second pre-image resistance. Any modification to the content of a block or the hash of the previous block will result in a corresponding change to the hash of the current block, ensuring the integrity of the blockchain and making it extremely challenging to alter or manipulate data. The connection between each block and its predecessor forms a chain, hence the term "blockchain." During blockchain formation, a bifurcation may occur when two nodes write data simultaneously and in such cases, new nodes join the longest blockchain, ensuring the integrity of the network. The reliability of a blockchain is guaranteed through this tandem arrangement of blocks, ensuring that once data is written, it cannot be tampered with. This immutable nature of blockchain technology ensures transparency and traceability throughout the leather supply chain, enabling stakeholders to track and verify the origin, movement, and ownership of leather goods, promoting accountability and sustainability in the leather industry.

Blockchain Solutions for leather goods production

The leather goods industry has faced criticism for its environmental and social practices. Blockchain technology offers a transformative solution, providing unprecedented transparency, traceability, and accountability. We propose four blockchain-based solutions tailored to address the

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rsbature@gmail.com
Department of Information and Communication Technology, Nigeria Institute of Leather and Science Technology, Zaria.
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industry's specific challenges. Fig 3 depict the proposed solution.

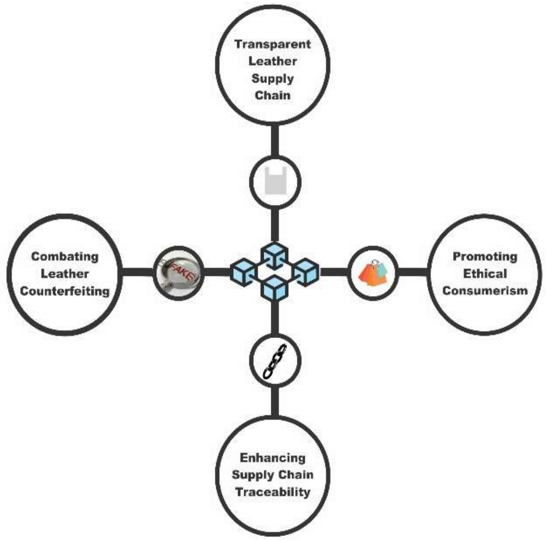

Fig 3: Proposed Blockchain solutions for leather goods production

Transparent Leather Supply Chain

Blockchain enables the secure and seamless transfer of certificates, such as raw material authenticity, organic certifications, and animal age. This data is accessible to all stakeholders, ensuring transparency throughout the supply chain. End-users can verify product authenticity and origin by scanning a QR code, accessing relevant details on farm, animal, slaughter, and hide data.

Combating Leather Counterfeiting

Counterfeiting has long plagued the leather industry, undermining brand authenticity and consumer trust. Blockchain technology creates an immutable record of all transactions, from raw material sourcing to retail. This end-to-end traceability ensures the integrity of the supply chain, preventing tampering and alteration of records.

Promoting Ethical Consumerism

The leather industry's lack of transparency has led to concerns over social, ecological, and environmental risks. Blockchain-based solutions provide digital passports for products, authenticating their origin and production process. This enables consumers to make informed decisions, supporting ethical and sustainable practices.

Enhancing Supply Chain Traceability

Blockchain technology can be applied to supply chains for consumer goods, such as clothing and leather goods. By focusing on organic cotton and leather goods, we can promote transparency and accountability throughout the production process. This includes labeling products to indicate whether they have been derived from debating or not.

CHALLENGES IN ADOPTING BLOCKCHAIN TECHNOLOGY FOR SUSTAINABLE LEATHER GOODS PRODUCTION

Technical Hurdles

The adoption of blockchain technology for sustainable leather goods production is faced with several technical challenges. One of the primary concerns is the high investment cost associated with designing and developing the

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rsbature@gmail.com
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technology. Additionally, implementing the network or consortium requires significant financial resources. Maintenance considerations, such as integrating with existing systems, managing supply chain members' turnover, and addressing software and hardware obsolescence, also pose significant technical challenges (Bucci 2019).

Financial Implications

The financial implications of adopting blockchain technology for sustainable leather goods production are substantial. The high investment costs, implementation costs, and maintenance costs can be prohibitive for many organizations. Furthermore, the potential need to replace existing traditional tracking systems with new blockchain solutions can lead to poor interoperability, adding to the financial burden (De Boissieu *et al*., 2021).

Organizational Transformation

Adopting blockchain technology for sustainable leather goods production requires significant changes in organizational culture and attitude. Stakeholders must be willing to adopt new technologies and processes, which can be a challenging task. The logistics paths for raw materials and components across countries must also be managed in accordance with local regulations, taxes, and limitations, adding to the complexity of change management (De Boissieu *et al*., 2021).

Regulatory Frameworks

The adoption of blockchain technology for sustainable leather goods production must comply with various regulatory requirements. The lack of a global institutional framework and commonly agreed-upon regulatory rules, laws, and norms can create uncertainty and challenges for organizations. Ensuring compliance with existing regulations while navigating the complexities of blockchain technology is a significant challenge (De Boissieu *et al*., 2021).

Supply Chain Complexity

The adoption of blockchain technology for sustainable leather goods production requires significant changes in supply chain management infrastructure and systems. Managing the financial and non-financial impacts of these changes on stakeholders, including suppliers, manufacturers, and consumers, is a critical challenge. Ensuring the integrity and transparency of the supply chain while adopting blockchain technology is essential (De Boissieu *et al*., 2021).

Global Cooperation and Governance

The adoption of blockchain technology for sustainable leather goods production requires global cooperation and agreement on regulatory rules, laws, and norms. The lack of a commonly agreed-upon framework can create challenges for organizations operating in different countries and regions. Ensuring global cooperation and agreement on these issues is essential for the widespread adoption of blockchain technology in the leather goods industry (De Boissieu *et al*., 2021).

CONCLUSION

The adoption of blockchain technology in the leather goods production sector holds significant promise for addressing the industry's longstanding issues of opacity and unethical practices. By fostering transparency and traceability, blockchain not only enhances consumer trust but also encourages manufacturers to adhere to sustainable practices, ultimately contributing to a more responsible leather industry. However, overcoming the technical, financial, and regulatory challenges will be crucial for the successful implementation of these solutions.

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rsbature@gmail.com
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rsbature@gmail.com
Department of Information and Communication Technology, Nigeria Institute of Leather and Science Technology, Zaria.
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