Enhancing Transparency and Ethical Sourcing in Handicraft Supply Chains through Blockchain, Smart Contracts, NFTs, and IPFS Integration

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Abstract. This paper discusses a framework for supply chain management in the handicraft industry, aiming to address the challenges of transparency and ethical sourcing. We introduce a system that integrates blockchain technology, smart contracts, Non-Fungible Tokens (NFTs), and the InterPlanetary File System (IPFS) to enhance the traceability and integrity of handicraft supply chains from creation to consumer. The study reviews related work that demonstrates the importance of blockchain for trust and transparent practices within supply chains. Our methodology was tested across multiple EVM-compatible platforms, examining the operational performance and economic feasibility of the system. The results of these tests inform our analysis of the system's functionality in terms of transaction speed, cost efficiency, and reliability in data management. Our findings indicate that the proposed framework can significantly contribute to the handicraft industry by providing a transparent, reliable, and efficient approach to supply chain management.

Keywords: Handicrafts Supply Chain, Blockchain, Smart Contracts, NFTs, IPFS

1 Introduction

The handicraft industry, characterized by its diverse and intricate supply chains, often encounters challenges in maintaining transparency and ethical sourcing due to the lack of complete traceability[20,13]. Traditional supply chain structures, extending from artisan creation to consumer purchase, frequently struggle to provide the necessary visibility and assurance required to uphold ethical standards[8,7]. The implementation of blockchain technology, along with the strategic use of smart contracts, Non-Fungible Tokens (NFTs), and the InterPlanetary File System (IPFS), presents a potential framework for addressing these issues[17]. By integrating these technologies, we aim to construct a supply chain management system specifically for the handicraft sector, which is designed

to bolster transparency and ensure the integrity of data throughout the entire chain of custody.

Research by Le et al. and Ha et al. has shed light on the capacity of blockchain to bolster trust and facilitate transparent practices, which are critical to the integrity of supply chains and the principle of fair trade [12,9]. Work by Dietrich et al. and Shahid et al. expands on these findings, illustrating how smart contracts can reduce risks and improve traceability, a feature that is particularly relevant to the intricacies of handicraft production. The concept of integrating 'virtual operations' into supply chain management, as explored by Dolgui et al., and the convergence of blockchain with IoT for monitoring by Hasan et al., have been identified as progressive steps toward more dynamic and transparent supply chain systems. Collectively, these studies highlight the promise of blockchain and related technologies in transforming the management of supply chains by enhancing transparency and trust among stakeholders.

Our approach is designed to cater to the specificities of the handicraft supply chain, employing smart contracts, NFTs, and IPFS to build a cohesive management system. This system is engineered to document and safeguard the integrity and transparency of the data from the artisan's workspace to the end-user. It addresses the particular challenges of the handicraft sector, with a strong focus on traceability and ethical sourcing. By integrating IPFS with blockchain, our system ensures the durability and fidelity of supply chain records, overcoming the challenges of scalability and data integrity highlighted by Pawar et al. and enhancing trust and authenticity in line with the findings of Hawashin et al. [15,11]. Anchored by distributed ledger technology, the platform serves as a dependable ledger for all recorded transactions, providing stakeholders with consistent and accurate data, thereby fostering a transparent, responsive, and fair supply chain environment.

Our system was subjected to rigorous testing on several EVM-compatible platforms, including Binance Smart Chain, Polygon, Fantom, and Celo, to assess its capability to support the handicraft supply chain. During these tests, we focused on critical functions such as recording supply chain information, minting NFTs for product traceability, and transferring NFTs for secure data circulation. The findings provided us with a comprehensive understanding of how the system performs in terms of transaction speed, resource utilization, and overall reliability. A review of the transaction costs associated with each platform also offered insight into the economic aspects of the system, highlighting the potential for reducing expenses and enhancing the efficiency of supply chain operations within the handicraft industry.

2 Related Work

2.1 Sustainable Supply Chain and Transparency

The significance of blockchain technology in advancing sustainable supply chain management is well-documented in recent research. Saberi et al. delve into how

blockchain can bolster trust and authenticate sustainable practices across supply chains, underscoring its role in enhancing transparency [18]. In a similar vein, Yoo et al. examine the mechanisms for transparent pricing within supply chains, which are vital for the verification of fair trade practices, further highlighting the utility of blockchain in ensuring fairness and transparency in supply chain operations [21].

The application of smart contracts within blockchain frameworks is explored by Dietrich et al., who argue that such technology can significantly reduce supply chain risks, thereby contributing to the overall sustainability of these networks [5]. This notion is echoed in the work of Shahid et al., who present a blockchain-based model specifically tailored for the agri-food sector, aimed at achieving traceability from the point of production to the end consumer [19]. Further contributions to this field include Alvarado et al., who view blockchain as a pivotal technology for achieving greater transparency in supply chains, a factor that is critical for enhancing sustainable practices [2]. Similarly, Bai et al. propose a methodological framework to assess the impact of blockchain on creating supply chains that are not only transparent but also sustainable, indicating the broad potential of blockchain technology in redefining supply chain management [3].

2.2 Blockchain and Smart Contracts for Supply Chain Management

Blockchain technology and smart contracts are being thoroughly investigated for their potential to improve supply chain management. Dolgui et al. integrate the concept of 'virtual operations' into smart contracts to synchronize the physical and digital aspects of supply chains [6]. Hasan et al. present a blockchain framework that combines smart contracts with IoT to monitor shipments in real-time, allowing for an immediate response to logistical changes [10]. Agrawal et al. examine the use of blockchain for resource sharing within business networks, ensuring data integrity through smart contracts [1]. Li et al. address the issues of information asymmetry and collaboration efficiency by standardizing information exchange via smart contracts, thus securing supply chain data [14]. Putri et al. explore the educational application of blockchain in agricultural supply chains through a serious game that simulates transactions using smart contracts [16], while Chang discusses the role of blockchain in re-engineering supply chains, highlighting the automation benefits provided by smart contracts [4].

3 Approach

3.1 Foundations and Functions: The Classical Architecture of Academic Knowledge Management

The architecture depicted in the flowchart represents a traditional supply chain model for handicrafts, a sector that is characterized by the labor-intensive creation of goods often imbued with cultural significance. This model outlines the sequential progression of a product from its inception by artisans to its eventual

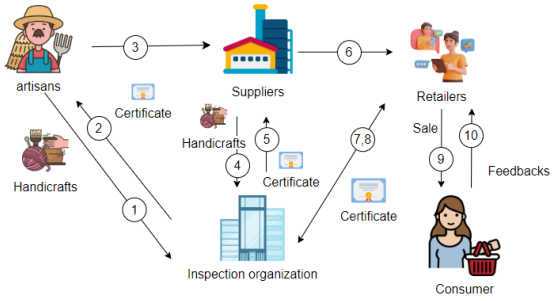

Fig. 1. Traditional Supply Chain Management Architecture for Handicrafts

acquisition by consumers, delineating the key stages and entities involved in the supply chain. At the very foundation of this supply chain are the artisans, skilled individuals or groups engaged in the crafting of handicrafts. Their craftsmanship is not merely a means of livelihood but often a preservation of cultural heritage. The initial stage involves the artisans creating the handicrafts, which are then subject to certification. This certification process serves as a preliminary quality and ethical sourcing check, intended to assure that the products adhere to certain standards before they are introduced into the broader market.

Following this, the certified handicrafts are conveyed to suppliers. These suppliers act as the intermediaries between the artisans and the market, playing a crucial role in the scaling of distribution. They are responsible for acquiring and amassing various handicrafts from multiple artisans, thereby aggregating supply to meet market demand. A subsequent critical juncture in the supply chain is the involvement of an inspection organization. This entity is tasked with a thorough examination of the handicrafts, ensuring that they meet specific standards that may include but are not limited to, quality, safety, and ethical sourcing. Issuing a certificate post-inspection provides a formal assurance that the handicrafts have been scrutinized and deemed compliant with the required standards.

The certified handicrafts are then distributed to retailers, the agents who provide the necessary infrastructure for the handicrafts to reach the consumer market. Retailers play a vital role in this architecture as they facilitate the transition of handicrafts from being a product available at a specific location to one that is accessible to a broad consumer base. It is at this stage that the products are made available for purchase, thereby entering the commercial mainstream. The final link in this traditional supply chain is the consumer, the end-user of the handicraft. Upon purchase, consumers have the opportunity to provide feedback regarding their experience with the product. This feedback can be instrumental in shaping future production, distribution, and certification processes, potentially influencing the entire supply chain.

3.2 Implementing Blockchain, Smart Contracts, NFTs, and IPFS for Supply Chain Integrity in the Handicrafts Sectors

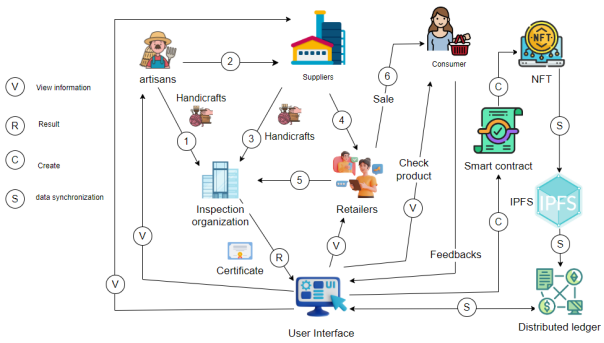

Fig. 2. Blockchain-Enabled Management Model in the Handicraft Supply Chain

The diagram illustrates a structured approach to managing supply chain transparency for handicraft products through the integration of blockchain, smart contracts, non-fungible tokens (NFTs), and the InterPlanetary File System (IPFS). This model delineates a sequence of interactions between various stakeholders and technologies that collectively contribute to an enhanced visibility and verification mechanism within the supply chain.

Artisans, at the beginning of the supply chain, are responsible for creating the handicrafts. Once a product is completed, its information is logged and verified by an inspection organization, which then issues a certificate indicating compliance with predefined standards. This certificate, along with detailed product information, is subsequently recorded on a blockchain, creating an immutable ledger entry that accompanies the product through the supply chain.

The blockchain serves as a foundational layer in this architecture, ensuring that each transaction and certification associated with the handicraft is securely and permanently recorded. Smart contracts automate the verification process at each transfer point, executing predefined rules that must be met before the product can proceed to the next stage. These contracts facilitate a trustless system where compliance with ethical sourcing and quality standards can be enforced without the need for intermediary verification at each step.

In parallel, each handicraft is associated with a unique NFT. This digital representation on the blockchain provides a singular, verifiable identity for the physical product, enabling clear ownership tracking and provenance tracing from the artisan to the consumer. The utility of NFTs extends to encapsulating the product's lifecycle information, providing buyers with a comprehensive background check capability. Additionally, IPFS is employed to store the associated data of each handicraft, including certificates of authenticity and ethical sourcing. This decentralized storage solution ensures that the data is not only tamper-resistant

but also accessible across the network without reliance on centralized servers, thus enhancing the robustness of the system.

Feedback from consumers, gathered post-sale, is also recorded on the blockchain, providing a feedback loop that can inform and potentially improve future production practices. The user interface acts as a portal for the various stakeholders to interact with the system, view product information, and confirm certifications.

4 Evaluation

To adequately assess the capability of our system in the context of handicraft supply chain management, we plan to deploy our smart contracts on a selection of EVM-compatible platforms, namely Binance Smart Chain, Polygon, Fantom, and Celo. These platforms have been chosen for their distinct characteristics and performance metrics, which will be scrutinized to ascertain their suitability for our application. In tandem with the blockchain component, we will be using the IPFS for storing certification and related data, with Pinata providing the necessary gateway to this distributed network. The integration of Pinata is aimed at streamlining the management of information within the handicraft supply chain in a decentralized and structured fashion.

4.1 Environment Simulation

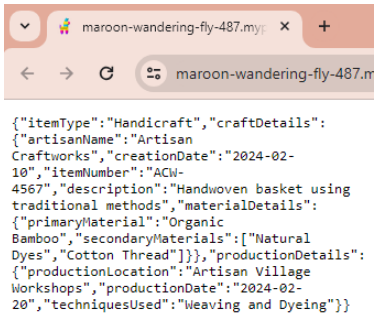

Fig. 3. IPFS Stored Metadata Viewed in a Web Browser

Fig. 4. JSON Structure for Handicraft Item Metadata

The framework presented here constructs a blockchain network specifically designed to assess the functionality of NFTs and IPFS within the domain of a handicraft supply chain. This network is composed of interconnected nodes, each fortified by a unique set of cryptographic keys, ensuring secure transactions and interactions within the blockchain. The nodes symbolize different supply chain stakeholders, such as artisans, quality inspectors, and retailers, utilizing their

public keys for transactional activities while relying on their private keys for authentication purposes.

In this environment, the nodes are assigned responsibilities crucial to the management of the handicraft supply chain. They oversee the creation and distribution of NFTs, engage with smart contracts, and facilitate the storage of data on IPFS. The network is equipped with a sufficient allocation of ether to support operations without the limitations often encountered due to resource scarcity. This test network aims to methodically investigate how NFTs and IPFS can be effectively applied to document management and validation processes within the handicraft sector. By simulating the dynamics of an actual supply chain, the network enables an evaluation of the system's efficacy in a risk-free, controlled setting, thus avoiding the uncertainties associated with deploying new technologies in an operational market environment.

4.2 Implementing IPFS for Handicrafts Supply Chain Management

In the process of generating an NFT and uploading it to IPFS, Figure 4 represents the initial step, which involves creating a JSON structure that encompasses all the relevant metadata for a handicraft item. This JSON file includes details such as the type of item, the artisan's name, the date of creation, and material specifics. This metadata forms the core of the NFT, encapsulating the unique attributes and the provenance of the handicraft, which are essential for future verification and tracking in the supply chain.

Following this, as depicted in Figure 5, the smart contract responsible for handling the NFT is executed within a test environment. The result shown verifies the successful execution of the smart contract function, specifically confirming the proper setting of an unlock time parameter. This step is critical to ensure that the smart contract operates as intended, managing the NFT lifecycle events like creation, transfer, and access control based on predefined rules.

Figure 6 displays the successful upload of the metadata JSON file to Pinata, a service that interfaces with IPFS. The screenshot confirms that the metadata file has been uploaded and assigned a unique content identifier (CID), which acts as a reference point for accessing the file on the IPFS network. This step is crucial as it ensures the metadata is stored in a decentralized manner, enhancing the durability and accessibility of the data associated with the NFT.

Through these sequential steps, we can see the practical aspects of creating a digital representation of a handicraft item in the form of an NFT and ensuring its metadata is securely stored and accessible on IPFS. This process not only adds a layer of security and transparency to the supply chain but also enhances trust among all participants by providing a reliable and immutable record of the item's data.

4.3 Testing on EVM-Supported Platforms

In this study, we utilize the Ethereum Virtual Machine (EVM) to facilitate the implementation of smart contracts on a selection of compatible platforms, in-

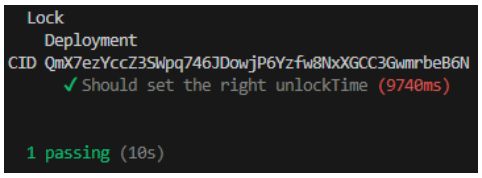

Fig. 5. Test Result for Smart Contract Execution

Fig. 6. Pinata Cloud Storage Confirmation for Metadata File

cluding Binance Smart Chain, Polygon, Fantom, and Celo. These platforms were selected to evaluate their capabilities in managing a transparent supply chain for handicrafts. We concentrated on fundamental operations such as recording supply chain events, generating Non-Fungible Tokens (NFTs) for product identification and lineage, and executing NFT transfers to maintain a secure chain of custody. Our assessment focused on transaction processing efficiency, cost-effectiveness, and the usability of the interface, all of which are critical for professionals managing supply chain activities. The intent of this examination is to discern the suitability of each platform for reinforcing a supply chain that is both transparent and operates seamlessly, with an emphasis on secure and dependable NFT-based transactions.

Table 1 presented outlines the transaction costs associated with various blockchain platforms, an essential factor in evaluating the financial practicality of employing blockchain in the management of supply chains for handicrafts. These transaction fees contribute significantly to the operational expenditures of the blockchain infrastructure. The table also captures the market values of the respective platform tokens as of January 27, 2024, at 7:00 AM UTC, providing a snapshot of the economic landscape within these blockchains operate. This information serves to inform stakeholders of the current financial implications of utilizing these networks in supply chain applications. On the Binance Smart Chain, initiating a transaction is listed with a fee of 0.0273134 BNB, approximately valued at $8.27. The creation of an NFT on this chain costs 0.00109162 BNB, or $0.33, while an NFT transfer requires a fee of 0.00057003 BNB, which translates to $0.17. These figures suggest that while Binance Smart Chain offers a robust environment for transaction processing, the costs associated might be higher compared to other platforms.

Fantom's transaction fee for the creation of a new transaction is 0.00957754 FTM, with no significant dollar value attributed, indicating a negligible cost. Similarly, creating and transferring an NFT on Fantom's network incurs fees of 0.000405167 FTM and 0.0002380105 FTM, respectively, both also reflecting minimal dollar value amounts. This implies a cost-effective platform for supply chain transactions, particularly for operations involving NFTs. For transactions on Polygon, the cost to create a transaction is noted at 0.006840710032835408 MATIC, or $0.01. Creating an NFT on Polygon is even less expensive, at 0.000289-405001852192 MATIC, and transferring an NFT costs 0.000170007501088048 MATIC, both carrying essentially no dollar value, which demonstrates a very

Table 1. Transaction fee

	Transaction Creation	Create NFT	Transfer NFT
BNB	0.0273134 BNB ($8.27)	0.00109162 BNB ($0.33)	0.00057003 BNB ($0.17)
Fantom	0.00957754 FTM ($0.00)	0.000405167 FTM ($0.00)	0.0002380105 FTM ($0.00)
Polygon	0.006840710032835408 MATIC ($0.01)	0.000289405001852192 MATIC ($0.00)	0.000170007501088048 MATIC ($0.00)
Celo	0.007097844 CELO ($0.005)	0.0002840812 CELO ($0.000)	0.0001554878 CELO ($0.000)

low-cost structure for supply chain operations on this platform. Lastly, Celo's transaction fee for creating a new transaction stands at 0.007097844 CELO, equivalent to $0.005. NFT creation and transfer on Celo are also cost-effective, with fees of 0.0002840812 CELO and 0.0001554878 CELO, respectively, both translating to less than a cent. These fees point to Celo being a financially viable platform for managing transactions within a handicraft supply chain.

5 Conclusion

The exploration of blockchain technology in the handicraft supply chain has revealed a pathway to enhanced transparency and the assurance of ethical sourcing practices. The framework we have developed integrates smart contracts, NFTs, and IPFS into the supply chain management process, creating a system that not only promotes transparency but also supports the integrity and traceability of handicraft items. Testing on multiple blockchain platforms has shown that our approach is both viable and effective, suggesting that it could lead to improvements in the economic and operational aspects of supply chain management for handicrafts. The deployment of this technology could represent a significant step forward for the industry, providing stakeholders with a reliable record of transactions and item histories, and ultimately fostering a supply chain that is accountable, transparent, and equitable. Our research indicates that the application of these technologies has the potential to reshape supply chain practices, making them more aligned with the current demands for sustainability and fair trade in the handicraft sector.

References

1. Agrawal, et al.: Demonstration of a blockchain-based framework using smart contracts for supply chain collaboration. International Journal of Production Research **61**, 1497–1516 (2022)
2. Alvarado, et al.: New era in the supply chain management with blockchain. Research Anthology on Blockchain Technology in Business, Healthcare, Education, and Government (2021)

3. Bai, et al.: A supply chain transparency and sustainability technology appraisal model for blockchain technology. International Journal of Production Research **58**, 2142–2162 (2019)
4. Chang, et al.: Supply chain re-engineering using blockchain technology: A case of smart contract based tracking process. Technological Forecasting and Social Change (2019)
5. Dietrich, et al.: Smart contract-based blockchain solution to reduce supply chain risks pp. 165–173 (2020)
6. Dolgui, et al.: Blockchain-oriented dynamic modelling of smart contract design and execution in the supply chain. International Journal of Production Research **58**, 2184–2199 (2020)
7. Duong-Trung, N., et al.: Multi-sessions mechanism for decentralized cash on delivery system. Int. J. Adv. Comput. Sci. Appl **10**(9) (2019)
8. Ha, X.S., Le, H.T., Metoui, N., Duong-Trung, N.: Dem-cod: Novel access-control-based cash on delivery mechanism for decentralized marketplace. In: 2020 IEEE 19th International Conference on Trust, Security and Privacy in Computing and Communications (TrustCom). pp. 71–78. IEEE (2020)
9. Ha, X.S., et al.: Scrutinizing trust and transparency in cash on delivery systems. In: Security, Privacy, and Anonymity in Computation, Communication, and Storage: 13th International Conference. pp. 214–227. Springer (2021)
10. Hasan, et al.: Smart contract-based approach for efficient shipment management. Comput. Ind. Eng. **136**, 149–159 (2019)
11. Hawashin, et al.: Using composable nfts for trading and managing expensive packaged products in the food industry. IEEE Access **11** (2023)
12. Le, H.T., et al.: Introducing multi shippers mechanism for decentralized cash on delivery system. International Journal of Advanced Computer Science and Applications **10**(6) (2019)
13. Le, N.T.T., et al.: Assuring non-fraudulent transactions in cash on delivery by introducing double smart contracts. Int. J. Adv. Comput. Sci. Appl **10**(5), 677–684 (2019)
14. Li, et al.: Design of supply chain system based on blockchain technology. Applied Sciences (2021)
15. Pawar, et al.: Secure and scalable decentralized supply chain management using ethereum and ipfs platform pp. 1–5 (2021)
16. Putri, et al.: Supply chain management serious game using blockchain smart contract. IEEE Access **11**, 131089–131113 (2023)
17. Quoc, K.L., et al.: Sssb: An approach to insurance for cross-border exchange by using smart contracts. In: Mobile Web and Intelligent Information Systems: 18th International Conference. pp. 179–192. Springer (2022)
18. Saberi, et al.: Blockchain technology and its relationships to sustainable supply chain management. International Journal of Production Research **57**, 2117–2135 (2018)
19. Shahid, et al.: Blockchain-based agri-food supply chain: A complete solution. IEEE Access **8**, 69230–69243 (2020)
20. Son, H.X., et al.: Towards a mechanism for protecting seller's interest of cash on delivery by using smart contract in hyperledger. International Journal of Advanced Computer Science and Applications **10**(4) (2019)
21. Yoo, et al.: A study on the transparent price tracing system in supply chain management based on blockchain. Sustainability (2018)