Jurnal Infotel
Vol. 16, No. 4, November 2024, pp. 740–757. doi:10.20895/infotel.v16i3.1195

Research Article

West Nusa Tenggara Traditional Weave Supply Chain Using Blockchain and Inter Planetary File System

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Received: June 06, 2024; Revised: August 19, 2024; Accepted: August 19, 2024.

Abstract: Traditional weaving is a significant cultural heritage in West Nusa Tenggara, Indonesia, renowned for its unique and intricate woven fabrics. However, the industry faces challenges such as product counterfeiting and the need for more transparency in the supply chain, hindering its growth and economic potential. This paper proposes a novel solution by leveraging blockchain technology to enhance traceability, security, and efficiency throughout the supply chain of traditional woven products. By integrating the Inter Planetary File System (IPFS) and Quick Response (QR) codes, the proposed framework further fortifies data integrity and provides consumers with comprehensive and easily accessible product information. Developing a prototype web application demonstrates this innovative solution's practical implementation and feasibility. Rigorous testing of the prototype, including verifying the registration of supply chain actors (such as distributors, manufacturers, and retailers), the addition of raw materials, thread creation, fabric distribution and weaving, sale of fabric, and purchase of assets, validates the correct functionality of the proposed solution. This comprehensive framework aims to safeguard the authenticity and sustainability of the traditional woven products from West Nusa Tenggara, fostering a more competitive, secure, and transparent industry while preserving the region's cultural heritage and providing economic opportunities for local communities.

Keywords: blockchain, IPFS, QR, supply chain, traditional woven

1 Introduction

The art of weaving reflects a society's deep connection to its knowledge, cultural heritage, beliefs, and environment, resulting in distinctive fabrics unique to each region [1]. West Nusa Tenggara Province is renowned for its traditional weaving, attracting international recognition and interest from collectors and tourists worldwide [2]. This craft stands out for its unique motifs and exceptional quality, characterized by intricate patterns and vibrant colors deeply rooted in the region's cultural heritage. The weaving process itself is an important part of the cultural heritage, with each step carefully crafted to ensure the highest quality and durability of the fabric, providing employment opportunities and showcasing local skills and creativity.

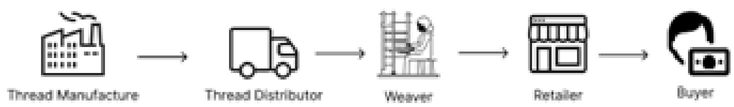

Figure 1: Traditional weave supply chain.

As depicted in Figure 1, the supply chain for traditional weaving involves several main actors: thread manufacturers, thread distributors, weavers, and retailers. While the popularity of woven fabrics surges, the industry grapples with several challenges because traditional supply chains are primarily manual and need more integration; they present issues with data falsification, inefficient operations, and poor traceability [3]. Additionally, the industry faces the mass production of imitations using methods like machine printing or embroidery, illegal copying of traditional fabric motifs, and a need for more transparency in the supply chain. This results in variations in quality and diminishes the reputation of original traditional woven fabrics. Failure to address these issues could result in a decline in the cultural significance and viability of the traditional weaving industry in West Nusa Tenggara.

Blockchain technology, a decentralized digital ledger secured by cryptographic principles [4, 5], offers a solution to challenges in the traditional weave supply chain by enhancing traceability, efficiency, and security [6]. Smart contracts, which are digital protocols replicating real-world contracts, allow for transactions without intermediaries by having network nodes verify code execution [7]. In this program, smart contracts manage supply chain processes, with all data securely stored on the blockchain. Integrating IPFS (Interplanetary File System) can further benefit this initiative by storing documentation of each supply progress. IPFS uses content addressing, assigning unique cryptographic hashes to files based on their content, enabling efficient data retrieval and verification [8]. Combining blockchain with IPFS improves throughput and reduces latency compared to traditional blockchain storage solutions [9].

Additionally, implementing QR codes can enhance user satisfaction by providing seamless access to detailed supply chain information for weave products. A Quick Response (QR) code is a two-dimensional barcode that stores significant information in a visually square pattern [10]. When scanned, these QR codes can direct consumers to a webpage or application with comprehensive details about the product's journey through the supply chain.

Our solution leverages these technologies to address the challenges of transparency and traceability in the traditional weave supply chain. Our contribution is the creation of a website prototype that integrates blockchain, the Interplanetary File System (IPFS), and QR code technology, creating a decentralized and transparent platform for tracking the production and distribution of traditional woven fabrics. This prototype introduces a new approach to product traceability by utilizing a QR code system, which enables easy tracking throughout the entire supply chain. Additionally, we have conducted extensive testing to ensure all features of the prototype function correctly, with the results thoroughly documented and recorded on the blockchain.

The structure of this paper is as follows: section 2 delves into the relevant research literature, addressing each challenge and outlining our purpose for addressing these issues or improving the solution. section 3 provides the methodology, including the project workflow, system design, and explanations of blockchain and smart contracts. section 4 presents the testing results, section 5 depicts the discussion, and the conclusion is provided in section 6.

2 Related Works

This section reviews prior literature on blockchain technology in supply chains. Studies show blockchain's potential to improve transparency, security, and efficiency. However, there is a gap in the accessibility and comprehensiveness of transparency and documentation across the supply chain. Our research addresses this gap by providing an integrated approach that ensures thorough documentation and transparency at each step, enhancing traceability and accessibility in supply chain management.

Research in [11] explore the transformative potential of blockchain technology in supply chain management, particularly in addressing the challenges of counterfeit and stolen goods that threaten the authenticity and credibility of products in the retail sectors. The proposed blockchain-based product circulation system aims to enhance transparency, security, and efficiency in the supply chain by leveraging dual security layers. These layers include RFID tags and holographic labels, which are complemented by the use of Non-Fungible Tokens (NFTs). To improve transparency, our solution facilitates customer access to information through QR codes, enabling customers to easily verify the history of the product's supply chain on the website.

In [12] explore the use of blockchain technology to enhance traceability in textile and clothing supply chains. They highlight the importance of transparency, information exchange, and trust in complex supply networks. The textile industry faces challenges like lack of visibility, information asymmetry, counterfeit products, and ethical concerns. To address these, we propose creating a product tracker that records the product's supply chain history and documentation, ensuring authenticity and verifiability.

Research in [13] explore the benefits and challenges of blockchain technology in agrifood supply chains, emphasizing the crucial role of user interfaces in enhancing traceability and transparency. They highlight that many blockchain-based traceability applications lack detailed analysis and visualization of user interfaces, which affects usability and effectiveness. To address this, our solution involves designing a user-friendly interface using, accessible via a web platform. This approach allows users to easily check the detailed history of a product, improving overall user experience and system efficiency.

In [14] focuses on the critical role of COVID-19 infographics in conveying complex information simply and understandably to combat the pandemic. With the surge in infographic dissemination, ensuring the accuracy and authenticity of these infographics has become a pressing concern. One of the main challenges highlighted in the paper is the potential for incorrect information to be included in Covid-19 infographics. To mitigate the problems, we provide detailed information that can only be added by authorized personnel and make this information accessible on a public website. By implementing blockchain, the data will be tamper-proof, thereby enhancing its credibility and trustworthiness.

Research in [15] address the integrity and security challenges of electronic medical records, which are vital for disease prevention, treatment improvement, and legal evidence. Traditional storage methods often fail to protect against unauthorized access, tampering, or data breaches. The paper proposes a novel scheme combining attribute-based encryption, IPFS storage, and blockchain technology. By storing encrypted data on the decentralized IPFS platform, security is enhanced, and single points of failure are eliminated. Similarly, we are implementing IPFS for data storage in our supply chain to ensure transparency and significantly improve security.

Research in [16] discusses the utilization of Quick Response (QR) codes on food packaging as a means to enhance information transmission in the food supply chain. Manufacturers and consumers face challenges related to asymmetric information in the food industry, which can pose risks to food safety and supply chain integrity. The paper proposes the use of QR codes on food packaging as a solution to the limitations of traditional paper labels. With the same approach were also using QR code validation for our system, providing detailed and historical supply chain information stored in the blockchain, accessible through a web-based interface.

The existing academic literature extensively explores the implementation of blockchain technology across diverse industry sectors, each providing unique solutions to specific challenges. Our proposed blockchain-based supply chain solution aims to enhance the transparency of the traditional weave industry in West Nusa Tenggara by documenting and recording the historical details of each production process, which are securely stored in the decentralized IPFS network and readily accessible to users through the integration of QR code technology.

3 Research Method

The application leverages project workflow management to coordinate tasks, resources, and information, ensuring projects are completed efficiently and effectively. Research supports this approach, showing that workflow management enhances project performance. For example, a study in [17] found that workflow management improves project quality by ensuring tasks are completed in the correct order. Figure 2 illustrates the project workflow for this research and development project.

3.1 Problem Identification

This step is crucial for determining the need for research, as it helps to identify a clear problem that needs to be solved. The identified issues include unauthorized duplication of fabric motifs and mass production through methods like embroidery or printing, lack

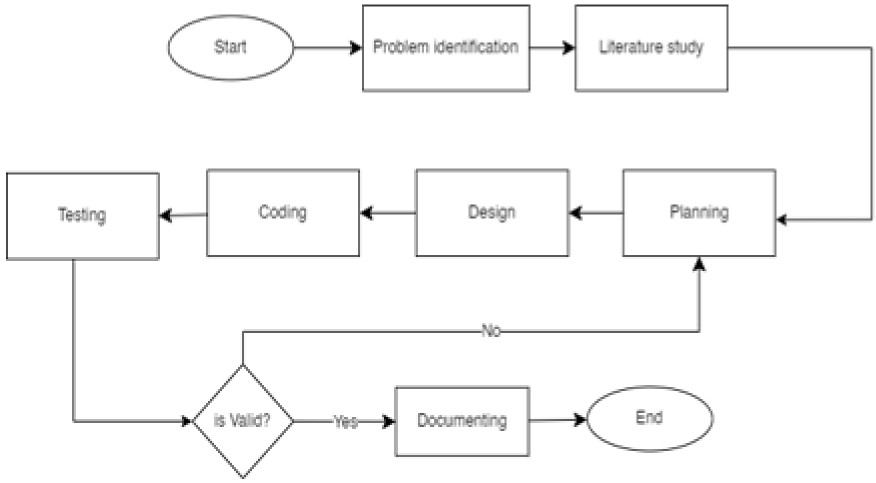

Figure 2: Project workflow.

of transparency within the supply chain, and the predominantly manual nature of traditional supply chains. These factors lead to problems such as poor traceability, operational inefficiency, and potential data falsification.

3.2 Literature Study

Research journals related to system development, including those focusing on supply chains and blockchain, were collected as supporting material. By incorporating insights from research journals, it can create products or systems that are more efficient, secure, and tailored to the specific needs of its target audience or industry.

3.3 Planning

This step involves collecting detailed requirements from various stakeholders to ensure the product meets their needs. The stakeholders include thread manufacturers, distributors, weavers, retailers, and customers.

3.4 Design

This phase involves defining the architecture schema and selecting the appropriate technologies, features, and program flow. These decisions set the foundation for the entire development process, ensuring that the final product effectively meets user expectations.

3.4.1 Purpose supply chain schema

Our proposed schema for this solution is illustrated in Figure 3. All actors in the supply chain are required to store their data on the blockchain. The Interplanetary File System (IPFS) is used to store documentation, while smart contracts ensure the completeness and integrity of the data stored on the blockchain. Each product is assigned a unique QR code, which facilitates user access to detailed information about the product's supply chain.

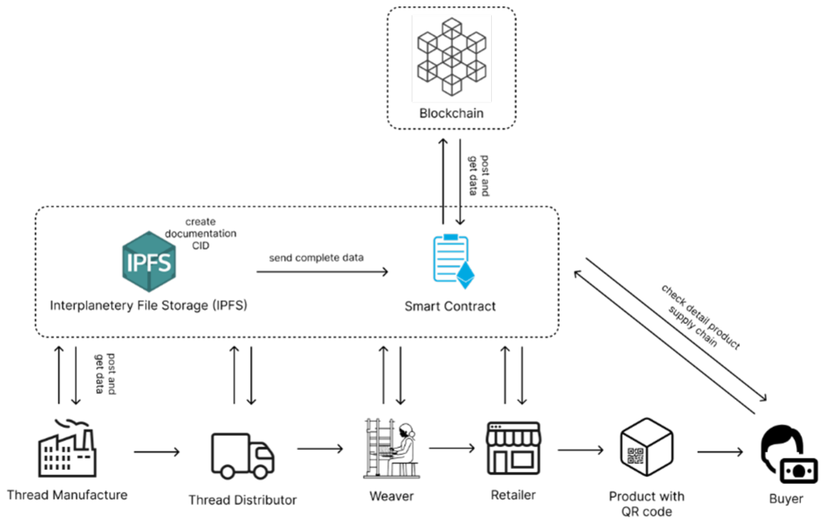

Figure 3: Purpose traditional weave supply chain schema.

3.4.2 Sequence diagram

Sequence diagram is an interaction diagram that details how operations are carried out, including what messages are sent and when. Sequence diagrams illustrate how events or activities in a use case are mapped into operations [18]. This is some of the process: The process of adding weave thread to blockchain is illustrated in Figure 4 begins with the manufacturer sending a data request. The validation system receives and checks the data against the required standards. If valid, the system confirms to the manufacturer that the data can be added to the blockchain. The process of buying weave thread, as illustrated in Figure 5, starts with a weaving artist requesting thread from a distributor. The distributor sends the thread, and the artist creates a new weave product. The artist then requests to add the weave product data to the system. The system validates the data to ensure it meets the required standards and criteria.

3.5 Coding

In this stage, we actualize the features outlined in the design phase. We establish the development environment by setting up the necessary infrastructure, tools, and dependencies required to build the blockchain-based supply chain solution. We select JavaScript as the programming language due to its widespread adoption, robust ecosystem, and suitability for developing blockchain applications. To streamline the development process, we employ the React library, which provides a component-based architecture and efficient rendering of the user interface.

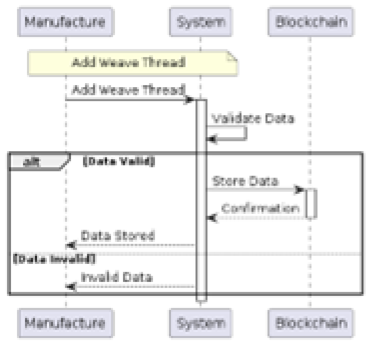

Figure 4: Adding weave thread sequence diagram.

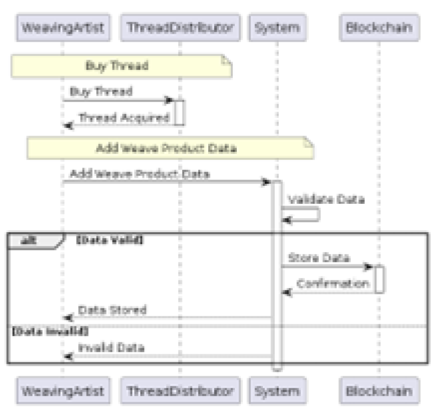

Figure 5: Buying weave product sequence diagram.

3.6 Testing

This phase helps identify potential bugs before the software is released, playing a crucial role in maintaining the effectiveness, accuracy, and reliability of the blockchain-based traceability system [19]. It is especially important for verifying smart contract functionality and ensuring data can be accurately traced on the blockchain. If any issues are detected, the process will cycle back to the planning phase to address and resolve them. For this program, testing is conducted using Remix IDE to ensure the smart contract is functioning correctly. Additionally, the stored data on the blockchain is checked using a block explorer to ensure that the transparency of the stored data can be publicly verified.

3.7 Documenting

The documenting phase in the project workflow is to capturing and organizing essential information for the project's success. Research, such as the study in [20], emphasizes the significance of workflow documentation in enhancing project performance, improving communication, and facilitating knowledge transfer. We utilizing GitHub to make project documentation easier to maintain and collaborate on, ensuring that stakeholders have access to accurate and updated information.

4 Results

Present a comprehensive analysis of the features implemented in our blockchain-based supply chain solution for traditional weave. This section aims to provide a detailed of the key features developed and their respective objectives. This implementation focuses on enhancing the transparency of supply chain transactions and making it easier for users to trace the product's journey, improving upon the previous papers [11–13]. The key features developed include:

4.1 Smart Contract

The smart contract is a critical function that facilitates communication between the website and the blockchain. It is designed to manage the flow of data securely and efficiently. The algorithms manage and track the lifecycle of assets, likely in a blockchain system related to fabric or thread production. Algorithm 1 starts by verifying that the asset is in the correct initial state and owned by the user. If these conditions are met and the price is set above zero, the algorithm updates the asset's state, tracks its changes, records the timestamp, and adjusts the fabric's details accordingly. Algorithm 2 handles the distribution phase by checking if the asset is ready for distribution (in state 2), confirming ownership, and ensuring the price is valid. If all conditions are satisfied, it updates the asset's state, tracker number, timestamp, and ownership details, completing the distribution process.

Algorithm 1 Create Thread Process

payableAssetsById: A mapping that stores the state, tracker number, and price of assets by their ID.
tracerAssets: A mapping that tracks the state, owner, price, timestamp, and buy status of an asset by its ID and tracker number.
fabricDetailsById: A mapping that stores details about the fabric, such as raw material, thread type, thread quality, dye type, pattern, origin, and fabric type by asset ID.
if payableAssetsById[_assetId].state = 1 **then**
    if haveAsset(msg.sender, _assetId) **then**
        if _price $>$ 0 **then**
            Store the current state of the asset (*oldState*).
            Increment the asset's state (*payableAssetsById[_assetId].state*++).
            Increment the tracker number (*payableAssetsById[_assetId].trackerNumber*++).
            Update *payableAssetsById[_assetId]* with the new state, tracker number, and price.
            Store the current block timestamp (time).
            Retrieve the *buyStatus* from *tracerAssets* using the asset ID and tracker number.
            Update *tracerAssets[_assetId][trackerNumber]* with the new state, owner, price, time, and buyStatus.
            Update *fabricDetailsById[_assetId]* with the new thread type and thread quality.
            Emit an event indicating that the asset (thread) was successfully created.
        else
            Revert the transaction and display an error message ("Asset price must be greater than 0").
        end if
    else
        Revert the transaction and display an error message ("This actor doesn't have the asset that they want to process").
    end if
else
    Revert the transaction and display an error message ("Asset initial state is not correct").
end if

Algorithm 2 Create Thread Process

```
payableAssetsById: A mapping that stores the state, tracker number, and price of assets by their ID.
tracerAssets: A mapping that tracks the state, owner, price, timestamp, and buy status of an asset by its ID and tracker number.
fabricDetailsById: A mapping that stores details about the fabric, such as raw material, thread type, thread quality, dye type, pattern, origin, and fabric type by asset ID.
if payableAssetsById[_assetId].state = 2 then
    if haveAsset(msg.sender, _assetId) then
        if _price > 0 then
            Store the current state of the asset (oldState).
            Increment the asset's state (payableAssetsById[_assetId].state++).
            Increment the tracker number (payableAssetsById[_assetId].trackerNumber++).
            Update payableAssetsById[_assetId] with the new state, tracker number, and price.
            Store the current block timestamp (time).
            Retrieve the buyStatus from tracerAssets using the asset ID and tracker number.
            Update tracerAssets[_assetId][trackerNumber] with the new state, owner, price, time, and buyStatus.
            Update fabricDetailsById[_assetId] with the new thread type and thread quality.
            Emit an event indicating that the asset (thread) was successfully created.
        else
            Revert the transaction and display an error message ("Asset price must be greater than 0").
        end if
    else
        Revert the transaction and display an error message ("This actor doesn't have the asset that they want to process").
    end if
else
    Revert the transaction and display an error message ("Asset initial state is not correct").
end if
```

4.2 Authentication

Authentication is a critical security mechanism for verifying the identities of users, devices, or systems. In the context of Web3, we leverage MetaMask as a provider for user registration on our website. MetaMask is a widely adopted cryptocurrency wallet and browser extension that enables users to interact seamlessly with decentralized applications built on the Ethereum blockchain. The registration page in Figure 6 serves as the entry point for new actors to join the supply chain ecosystem. To interact with the website, users must connect their MetaMask account, which ensures a secure and efficient registration experience. The page prominently displays a comprehensive list of available actor roles, each with its distinct responsibilities and significance. This feature is designed to validate and ensure the transparency of all registered actors within the program.

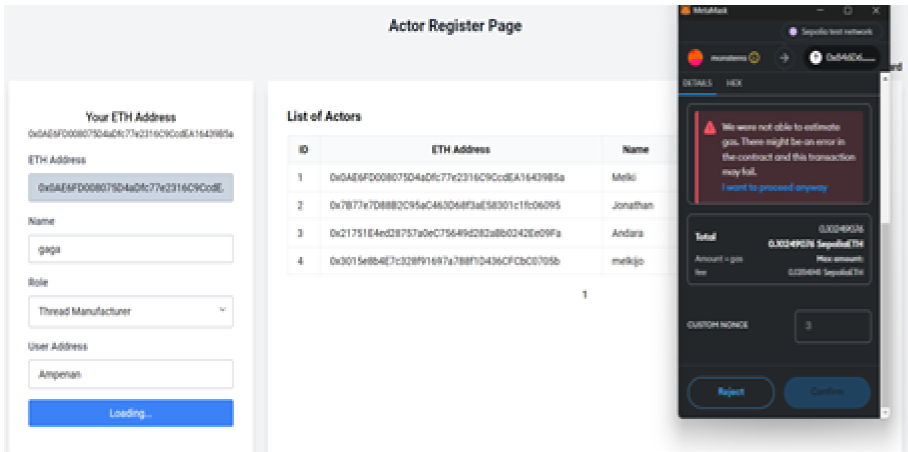

Figure 6: Registration page.

4.3 Thread Created

This process is the stage exclusively undertaken by the thread manufacturer. During this phase, the manufacturer is responsible for inputting comprehensive data about the raw materials utilized, the associated costs, and the documentation detailing the manufacturing process. Figure 7 illustrates the input form that thread manufacturers must fill out to register their credentials on the blockchain. To reinforce accountability and transparency, the manufacturer must make a monetary transaction using Sepolia test network currency. This transaction ensures the secure storage of data on the Sepolia test network, a blockchain environment for testing and development.

4.4 QR Code Generator

This is designed to empower users with a seamless and efficient means of validating the provenance and authenticity of the woven products they purchase. Example of the QR code for the supply chain process is shown in Figure 8. Each woven product is associated with a unique QR code, which encapsulates a query link tailored to retrieve the comprehensive supply chain data pertinent to that specific item. By simply scanning the QR code, users can initiate a query that retrieves the product's supply chain history.

4.5 Supply Chain Tracking

The tracking feature in our blockchain-based supply chain uses IPFS to address the limitations of storing large volumes of data on the blockchain. At each stage of the weaving process, comprehensive documentation, including images and descriptions, is generated and hashed to create a unique Content Identifier (CID) on the IPFS network. Figure 9 is the

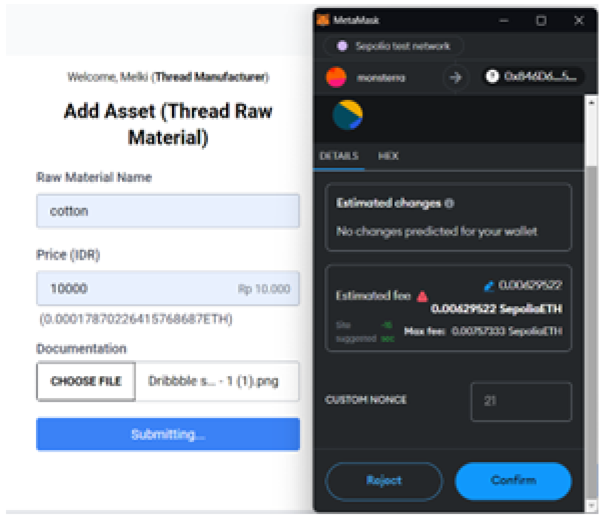

Figure 7: Thread add asset process.

Figure 8: QR code generator for weave data.

display of the product that has been searched using an ID is shown, along with the supply chain data. By integrating IPFS, our tracking feature empowers stakeholders with the ability to seamlessly retrieve and visualize the comprehensive documentation associated with each stage of the weaving process. This visualization capability fosters transparency and provides valuable insights into the intricate details of the production methods employed.

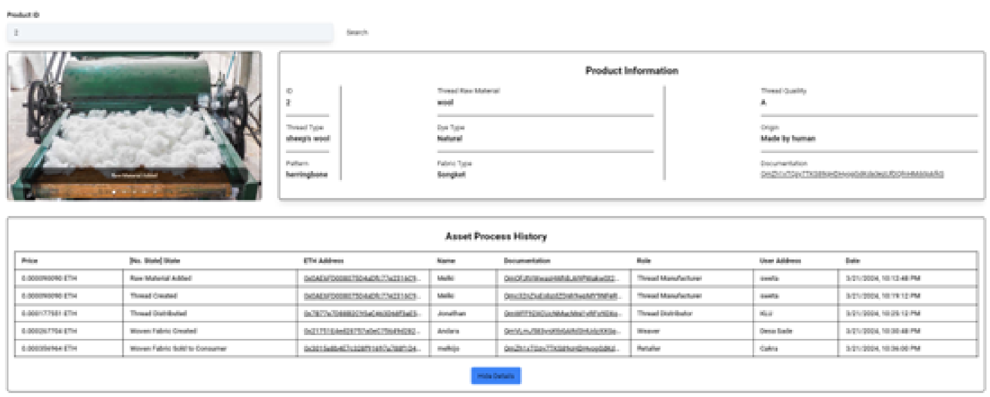

Figure 9: Weave product information.

4.6 Testing

Thorough testing is crucial in software development, especially for smart contracts, to ensure all functions operate as expected. Unit tests using Remix IDE can verify the correct behavior of the contract, confirming its reliability and security. Key verifications include testing the registration of supply chain actors, the addition of raw materials by authorized suppliers, the creation and distribution of threads for fabric manufacturing, the weaving of fabric, the sale of fabric to authorized retailers, and the purchase of assets by end consumers. These comprehensive tests collectively guarantee the seamless and intended functioning of all supply chain aspects. As shown in Figure 10.

To validate the testing process, we conducted transactions using the registered actors listed in Table 1. Each registered actor has a unique role associated with their specific MetaMask ID. The transaction processes are recorded and can be explored on a public network, as illustrated in Figure 11. These figures demonstrate that all transactions are transparent and traceable in the public network, ensuring the integrity and accountability of the process.

The performance is carried out using the load testing method through HTTP requests on the Jmeter application. In the testing process, 10 virtual users will be created who will request data from the system within 30 seconds. In Table 1, it can be seen that the system is able to generate a total of 20 data sets from each endpoint. The average time for the system to respond to the received requests is about 571 milliseconds. The system continued to operate without failure during the load test, with constant requests from 10 virtual users for 60 seconds, as can be seen from the valid status column that was received.

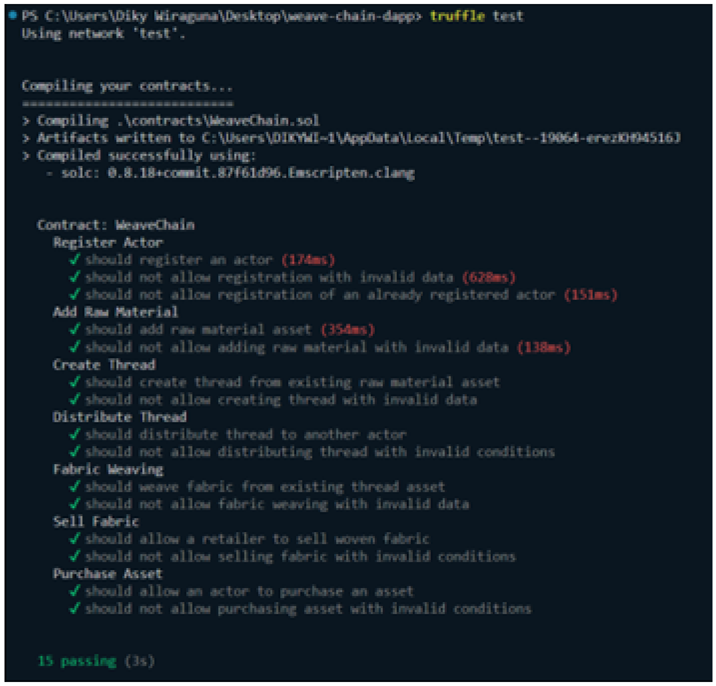

Figure 10: Testing result.

5 Discussion

This study successfully implemented a blockchain-based supply chain solution for traditional weaving in West Nusa Tenggara, enhancing transparency, traceability, and efficiency in the industry. By integrating blockchain technology, IPFS, and QR codes, the research created a decentralized and transparent platform for tracking the production and distribution of traditional woven fabrics. This innovative approach aims to address the challenges of product counterfeiting and lack of transparency in the supply chain, ultimately benefiting both producers and consumers.

The findings suggest that leveraging blockchain technology, IPFS, and QR codes can significantly improve transparency and traceability in the traditional weaving supply chain. By securely storing historical production data on the blockchain and enabling easy access through QR code technology, stakeholders can verify the authenticity and journey of woven products. This enhanced transparency fosters trust and credibility in the industry, providing consumers with comprehensive and easily accessible product information.

In comparison with existing literature on blockchain technology in supply chains, our approach presents several improvements over previous studies. Notably, our work builds on the findings of a previous paper in [12], which highlighted the advantages of using blockchain for supply chain traceability and developed a prototype implementation. Our proposed schema enhances this by incorporating IPFS for file storage, thus improving the documentation of the supply chain process and further enhancing traceability.

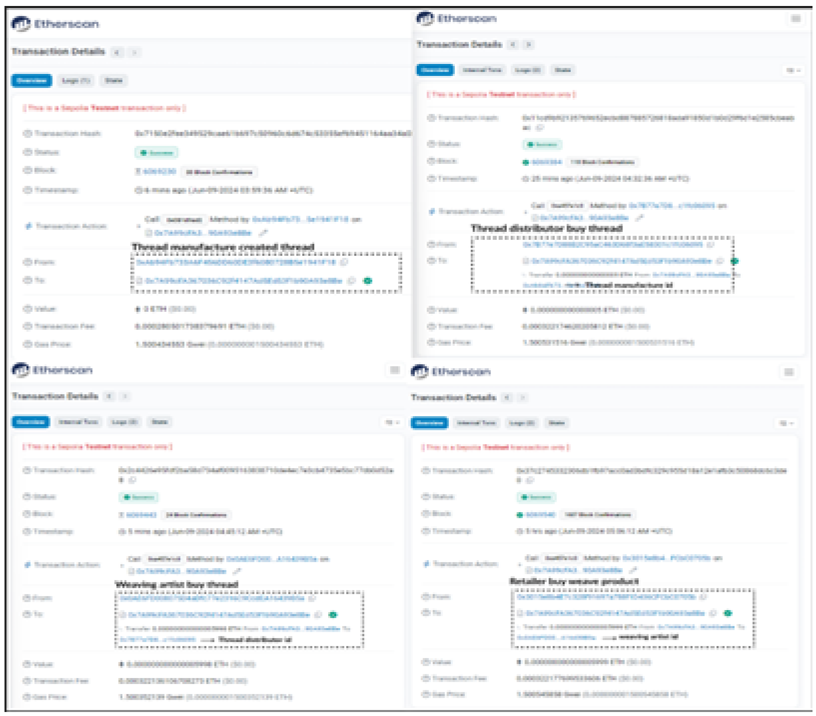

Figure 11: Thread creation and distribution transaction on blockchain.

Table 1: Performance testing data

Start time	Label	Sample time (ms)	Status	Bytes	Send bytes	Latency	Connect time (ms)
20:12:40.217	Dashboard	524	VALID	859	196	524	51
20:12:40.742	Market	592	VALID	858	133	592	100
20:12:41.335	Trace-product	446	VALID	858	140	446	13
20:12:41.782	Register	1560	VALID	859	135	1560	1071
20:12:46.230	Dashboard	534	VALID	861	196	534	54
20:12:46.765	Market	503	VALID	859	133	503	54
20:12:47.269	Trace product	409	VALID	860	196	409	6
20:12:47.678	Register	498	VALID	860	133	497	52
20:12:52.228	Dashboard	426	VALID	859	140	425	12
20:12:52.654	Market	519	VALID	859	135	519	50
20:12:53.174	Trace-product	516	VALID	860	196	516	9
20:12:53.691	Register	714	VALID	859	133	713	90
20:12:58.237	Dashboard	530	VALID	858	140	530	12
20:12:58.768	Market	536	VALID	858	135	536	59
20:12:59.304	Trace-product	589	VALID	860	196	588	90
20:12:59.894	Register	545	VALID	859	133	544	45
20:13:04.235	Dashboard	542	VALID	859	140	452	13
20:13:04.687	Market	524	VALID	860	135	523	60
20:13:05.211	Trace-product	408	VALID	859	140	408	7
20:13:05.620	Register	504	VALID	858	135	504	53

Another significant piece of research in [11] focuses on implementing blockchain in supply chains by leveraging dual security layers, including RFID tags and holographic labels, complemented by the use of Non-Fungible Tokens (NFTs). Our solution advances this approach by facilitating customer access to information through QR codes, allowing customers to easily verify the product's supply chain history on a website. This enhancement not only improves security but also increases transparency and ease of access for end-users.

However, one limitation of the study may be the scalability of the proposed solution and the adoption challenges faced by stakeholders in implementing new technologies. Methodological constraints in testing the system in real-world scenarios could also be a limitation that needs to be addressed in future research. Future studies could focus on conducting more extensive testing of the prototype web application in real-world supply chain environments to evaluate its scalability and practicality. Additionally, exploring the integration of emerging technologies such as Internet of Things (IoT) devices for data collection and verification could further enhance the transparency and efficiency of the traditional weaving supply chain.

6 Conclusion

The traditional weaving industry in West Nusa Tenggara, Indonesia, faces significant challenges, including imitation, lack of transparency, and inefficiencies within the supply chain. This research proposed a blockchain-based solution to enhance traceability, security, and overall supply chain efficiency. By integrating IPFS, product information is securely stored in a tamper-proof manner. The developed prototype successfully demonstrated the feasibility and benefits of this solution, including secure authentication, streamlined market distribution, accurate product tracking, and QR code verification. Performance testing showed that the system responds to requests in an average of 571 milliseconds, and during a load test involving 10 virtual users sending continuous requests for 30 seconds, the system maintained stable operation without any failures, as indicated by the successful packet status. While this program is specifically designed for West Nusa Tenggara, its implementation in other traditional weaving industries would require additional research and adaptation. Future work could focus on refining the system, exploring additional technologies, and expanding its application to other regions or industries, thereby promoting the broader adoption of blockchain technology in supply chain management.

Acknowledgments

We extend our heartfelt gratitude to Mataram University for their invaluable support through the internal funding scheme, which facilitated the timely completion of this research.

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