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Supply Chain Management in Construction Using Blockchain

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Abstract: *The increasing complexity of global supply chains has underscored the need for greater transparency, trust, and traceability across all stages of product lifecycle management. Traditional centralized supply chain systems are often plagued by data silos, limited visibility, and vulnerability to fraud or tampering. This research presents a decentralized Supply Chain Management (SCM) framework developed using Blockchain and Web3 technologies, aimed at overcoming these limitations. Leveraging the immutability and distributed consensus of blockchain, the proposed system enables secure and transparent tracking of goods from origin to destination. Smart contracts, deployed on the Ethereum blockchain, automate critical processes such as shipment verification, ownership transfers, and quality assurance, reducing reliance on intermediaries and manual paperwork. A Web3-enabled frontend, integrated with digital wallets, provides seamless, permissioned access for stakeholders including manufacturers, suppliers, distributors, retailers, and consumers. The construction industry faces persistent challenges in managing its supply chain due to its complexity, involving multiple stakeholders, fragmented processes, and frequent disputes over transparency and accountability. Blockchain technology offers transformative potential to address these challenges by providing a decentralized, immutable, and transparent ledger system. This paper explores the integration of blockchain technology into supply chain management within the construction sector, focusing on its ability to enhance trust, streamline operations, and ensure real-time traceability of materials and transactions. The study highlights how blockchain can mitigate inefficiencies such as delays, fraud, and cost overruns by enabling smart contracts, secure data sharing, and automated compliance with project milestones. By reviewing current implementations, challenges, and future prospects, the paper aims to present a roadmap for adopting blockchain technology to create more resilient, efficient, and collaborative supply chain systems in construction projects.The integration of blockchain technology into supply chain management within the construction industry presents a transformative approach to enhancing transparency, efficiency, and trust among stakeholders. This research paper explores the potential of blockchain to address prevalent challenges such as payment delays, material traceability, and contract enforcement. By leveraging decentralized ledgers and smart contracts, the study highlights how blockchain can streamline processes, reduce fraud, and improve collaboration among contractors, suppliers, and clients.*

Keywords: Supply Chain Management, Blockchain Technology, Smart Contract, AWS S3

I. INTRODUCTION

The construction industry is characterized by its complex and fragmented supply chains, involving multiple stakeholders such as contractors, suppliers, manufacturers, and project managers. Managing these supply chains is often fraught with challenges, including delays, cost overruns, miscommunication, and a lack of transparency. Traditional supply chain systems rely heavily on manual processes, centralized databases, and paper-based documentation, which are prone to errors, fraud, and inefficiencies.

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For instance, tracking the movement of materials and verifying compliance with project milestones often becomes a tedious and time-consuming process, leading to disputes and affecting project timelines. Additionally, trust between stakeholders is frequently undermined due to the absence of a unified, transparent platform for managing transactions and information. Blockchain Technology offers a transformative solution by introducing a ledger that is immutable and decentralized ensuring transparency, trust and accountability across supply chain.

Blockchain technology offers a decentralized, immutable ledger that ensures data integrity and transparency across all participants in the supply chain. By leveraging smart contracts, automated and trustless execution of transactions can be achieved, minimizing intermediaries and reducing operational inefficiencies. Web3, which encompasses decentralized internet applications built on blockchain protocols, facilitates enhanced user control, peer-to-peer interactions, and secure data sharing.

Combined with cloud-based services, blockchain can facilitate secure storage, real-time access to data, and streamlined operations. This research proposes an integrated architecture that leverages blockchain, smart contracts, Ethers.js, and cloud computing to address these issues. The architecture focuses on automating key processes such as material tracking, payment settlements, and contract execution while providing stakeholders with a user-friendly interface hosted on a scalable cloud platform.

The proposed system uses Ethereum smart contracts for automating critical tasks, ensuring data integrity, and enabling tamper-proof records. Ethers.js acts as a bridge between the blockchain backend and the React.js-based frontend, ensuring seamless communication. Furthermore, cloud services such as AWS S3 are employed for hosting and deploying the frontend, offering scalability and accessibility. With features like Metamask wallet integration, the system ensures secure transactions and smooth user interactions.

The proposed architecture is designed to streamline workflows, enhance stakeholder collaboration, and ensure data integrity throughout the construction supply chain. By leveraging decentralized technology and cloud-based services, this model addresses critical inefficiencies in construction management, paving the way for more resilient and sustainable practices. This paper delves into the technical implementation of the architecture, evaluates its potential benefits, and explores challenges that may arise during its adoption.

II. PROBLEM STATEMENT

The construction industry is one of the most significant sectors contributing to global economic development. However, its supply chain management (SCM) is plagued by inefficiencies, lack of transparency, fragmented workflows. Construction projects typically involve numerous stakeholders, including contractors, suppliers, clients, and regulatory bodies, each with their own systems and processes. These disconnected systems often lead to miscommunication, errors in data transfer, and delays in decision-making.

Additionally, the lack of a centralized mechanism for tracking materials, payments, and project milestones contributes to frequent disputes and a loss of trust between parties.A major challenge in construction SCM is the limited visibility across the supply chain. Stakeholders often struggle to access real-time information about the flow of materials and progress on-site, making it difficult to identify bottlenecks or address delays promptly. Moreover, paper-based documentation and manual processes are still prevalent, increasing the risk of fraud, document forgery, and data loss.

As a result, projects frequently experience cost overruns and delays, leading to significant financial and reputational losses for all involved parties.Trust and accountability are additional pain points in the construction supply chain. Payments are often delayed due to a lack of verifiable evidence of work completion, and disputes over contracts or material quality are common. Without a transparent system to record transactions and verify compliance with project terms, stakeholders are left relying on intermediaries, which adds costs and complexity.

III. LITERATURE SURVEY

Several studies have explored the application of blockchain in construction SCM. Perera et al. (2020) emphasized the ability of blockchain to improve data traceability and ensure tamper-proof records throughout the supply chain lifecycle. Their research highlighted that blockchain could enhance stakeholder trust by creating a single source of truth, which records all transactions, material movements, and contractual agreements. Similarly, Turk and Klinc

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(2017) investigated the use of smart contracts in automating processes such as payment settlements and material verification. They demonstrated that smart contracts could eliminate intermediaries and reduce the risk of disputes by enforcing pre-defined conditions automatically.

Transparency and accountability have been recurring themes in blockchain-based SCM research. Lu et al. (2019) discussed how blockchain provides real-time visibility into the movement of materials and progress tracking, which is particularly valuable in large-scale construction projects with geographically dispersed teams. Their study also addressed the challenge of integrating blockchain with existing enterprise resource planning (ERP) systems to create seamless workflows. By ensuring that all stakeholders have access to consistent and real-time data, blockchain can significantly reduce communication gaps and enhance decision-making.

Recent literature has also highlighted the integration of blockchain with complementary technologies such as cloud computing and the Internet of Things (IoT). For example, Zheng et al. (2021) proposed a framework combining blockchain with IoT sensors to track materials in real-time. Their research demonstrated that IoT-enabled blockchain systems could provide end-to-end visibility of the supply chain while enhancing efficiency and reducing delays. Additionally, cloud computing has been identified as a key enabler for hosting blockchain applications, storing large datasets, and ensuring scalability. Xu et al. (2020) discussed the benefits of using cloud services to deploy decentralized applications, particularly in scenarios where stakeholders require secure and remote access to supply chain data.

Despite the benefits, the adoption of blockchain in construction SCM is not without challenges. Wang et al. (2022) highlighted technical barriers such as the high computational costs associated with blockchain implementation, as well as operational challenges, including resistance to change from stakeholders. The lack of standardized frameworks and legal ambiguity regarding smart contract enforceability further complicate adoption. However, their research also pointed out that pilot projects and collaborative industry efforts could pave the way for broader adoption.

IV. METHODOLOGY

The system's backend begins with the creation and deployment of smart contracts on the blockchain. Smart contracts are self-executing programs that automate various supply chain activities, such as material tracking, payments, and compliance verification. These contracts are written in Solidity (a programming language for Ethereum) and deployed on the Ethereum blockchain. The deployment generates a unique contract address, which serves as the point of interaction for all stakeholders. comprehensive metadata for each NFT, encompassing title, description, and pertinent details.

V. PROPOSED METHODOLOGY

The proposed methodology showcases a supply chain management (SCM) system tailored for construction using blockchain technology and cloud services. The system integrates various technological components such as smart contracts, Ethers.js, and cloud storage to establish a transparent, efficient, and decentralized workflow. The architecture is divided into three primary sections: Smart Contract, Ethers.js, and Cloud, with both backend and frontend elements intricately connected to ensure seamless functioning.The Smart Contract layer is the foundation of the blockchain component.

It begins with the deployment of smart contracts, which serve as immutable, self-executing digital agreements containing the rules and logic of the supply chain. Once deployed, the contract generates a unique address, which becomes its identifier on the blockchain. This address is used for communication and interaction with the contract. Smart contracts bring transparency and trust to the SCM process by ensuring that all predefined conditions are met before executing transactions, eliminating intermediaries.Moving to the Ethers.js layer, this component acts as the bridge between the blockchain and the frontend application.

Ethers.js, a lightweight JavaScript library, facilitates communication with the Ethereum blockchain, enabling developers to connect to the smart contract deployed earlier. Through this connectivity, Ethers.js enables function calls to the smart contract. This allows various operations, such as verifying transactions, updating data, or querying the blockchain for information, to be executed securely and efficiently. The frontend application, built using React.js, interacts with Ethers.js to enable user-friendly access to blockchain functionalities. This integration ensures that end-

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users can interact seamlessly with the blockchain without needing technical expertise, as the complexities are handled in the background by Ethers.js.

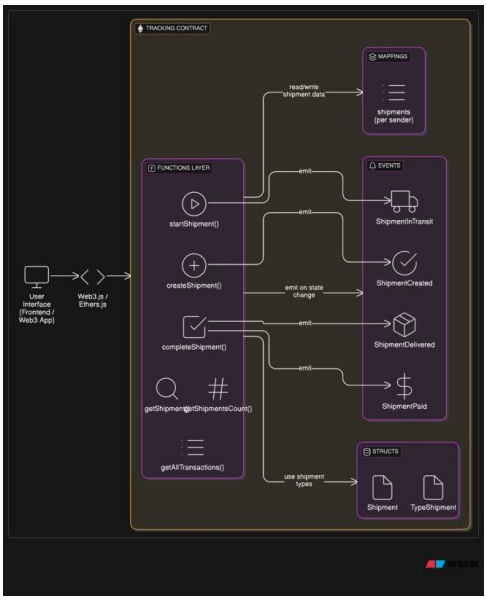
The proposed methodology leverages a permissioned blockchain framework to implement a decentralized Supply Chain Management system, focusing on data integrity, transparency, and stakeholder trust. The architecture consists of a blockchain network where authorized participants—manufacturers, suppliers, logistics providers, and retailers—maintain synchronized copies of an immutable ledger. Smart contracts, coded in Solidity (or an appropriate language based on the blockchain platform), govern the automated execution of supply chain transactions, including asset transfers, quality checks, and payment conditions, ensuring compliance without human intervention. Web3 technologies enable the development of decentralized applications (dApps) that provide user interfaces for interacting with the blockchain, facilitating real-time monitoring and validation of goods movement.

The Cloud layer provides scalability and accessibility to the system. Here, the static files of the frontend application are stored on AWS S3, a reliable and scalable cloud storage service. The deployment of these files is achieved using an S3 bucket, ensuring that the frontend is always accessible to users with minimal latency. This cloud-hosted frontend acts as the interface for the end user, facilitating real-time interaction with the blockchain. The integration of cloud services ensures that the application is not only robust but also capable of handling a high volume of traffic, which is essential in a dynamic industry like construction.

On the frontend, additional functionalities include the integration of a MetaMask wallet. This wallet is a browser-based cryptocurrency wallet that allows users to manage blockchain-based assets and interact with smart contracts directly. Through MetaMask, users can authenticate themselves, approve transactions, and manage tokens seamlessly, adding another layer of security and convenience. By connecting the React.js frontend to the backend via Ethers.js, users can invoke functions on the smart contract, whether for verifying shipments, managing payments, or other supply chain tasks.

Overall, the system's design showcases a highly innovative approach to modernizing supply chain management in construction. Blockchain's decentralized nature ensures data integrity and transparency, while the cloud's scalability addresses the challenges of real-time data access and storage. By leveraging these technologies, the proposed architecture achieves a harmonious blend of trust, efficiency, and accessibility, driving the digital transformation of supply chain operations in the construction sector.

VI. SYSTEM DIAGRAM



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VII. RESULTS & DISCUSSION

The Smart Contract component forms the backbone of the system, introducing trust and automation into the supply chain processes. Smart contracts are self-executing scripts stored on the blockchain that automatically enforce predefined rules and conditions. In this framework, the smart contract is deployed on a blockchain network, and upon deployment, it generates a unique address, which becomes the key identifier for interactions. These smart contracts are crucial for ensuring secure transactions, managing contractual obligations, and eliminating reliance on intermediaries. For example, in the construction supply chain, the smart contract can automatically release payments to suppliers upon confirmation of material delivery, thus reducing delays and disputes.

The integration of Ethers.js plays a pivotal role in enabling seamless communication between the blockchain backend and the user-facing frontend. Ethers.js, a lightweight JavaScript library for Ethereum, provides the necessary tools to connect the deployed smart contract with the web application. It handles functions such as initiating blockchain transactions, retrieving contract data, and performing other blockchain-related operations. The framework ensures that the frontend application, developed using React.js, communicates effectively with the blockchain backend. This connection empowers the users to invoke specific functions on the smart contract, such as verifying material delivery, updating project statuses, or logging transactions in a tamper-proof manner.

The frontend interface, built using React.js and supported by MetaMask wallet integration, allows end-users to interact with the blockchain in a secure and user-friendly environment. MetaMask, a popular browser extension, acts as a bridge for users to manage blockchain-based assets, sign transactions, and access the Ethereum network. In the context of construction supply chain management, this integration enables stakeholders such as contractors, suppliers, and project managers to authenticate transactions and participate in the blockchain ecosystem without needing in-depth technical knowledge. The frontend serves as the visual representation of the entire system, ensuring that stakeholders can access real-time data, monitor processes, and interact with the blockchain seamlessly.

The Cloud component, specifically leveraging AWS S3, ensures the scalability and reliability of the system. The static files of the frontend application are stored on AWS S3, which offers high availability and durability. This cloud storage enables the application to handle a high volume of concurrent users, an essential feature in the construction industry where multiple stakeholders need access to supply chain data simultaneously. Additionally, by deploying the static site using an S3 bucket, the frontend application becomes highly accessible and responsive, enhancing the overall user experience.

By combining blockchain technology with cloud computing and modern web development tools, this system transforms traditional supply chain management in construction. The immutable and decentralized nature of blockchain ensures data integrity and transparency, reducing fraud and building trust among stakeholders. The cloud infrastructure, on the other hand, provides the necessary scalability and accessibility to meet the dynamic demands of the industry.

Together, these technologies establish a robust, efficient, and secure framework that addresses the unique challenges of the construction supply chain while paving the way for a more collaborative and streamlined approach to project management. This cutting-edge technology has the potential to completely transform the way that supply chains in the construction industry function by delivering increased levels of automation, accountability, and transparency.treamlined approach to project management.

g assets and providing users with seamless access to their tokenized possessions.

By scrutinizing these key elements, our study sheds light on the intricate ecosystem of blockchain-based digital asset management. We provide insights into how individuals securely authenticate their identities, participate in the vibrant world of digital assets, tailor NFT characteristics to their preferences, and effectively tokenize their assets on a decentralized ledger. This research contributes to a deeper understanding of the mechanisms underpinning digital ownership in the blockchain era, paving the way for further advancements in decentralized asset management and distribution.

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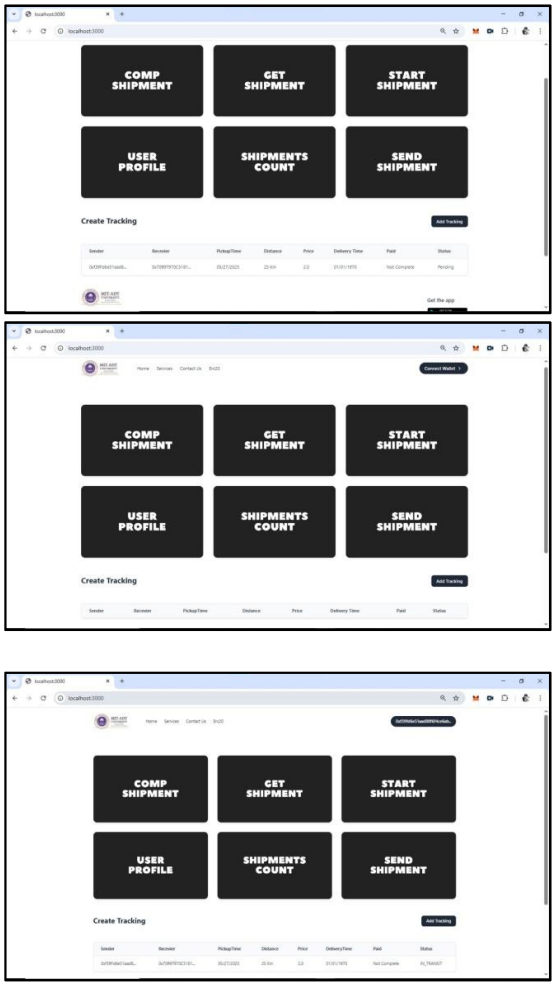

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