

Blockchain Based Way Billing System for Tracking and Monitoring in Manufacturing Firms

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Abstract:

The manufacturing sector has experienced significant growth, positioning the state as an economic powerhouse. However, effective waybilling and logistics management remain critical for the efficient operations of manufacturing firms. Traditional waybilling systems face challenges such as data manipulation, lack of transparency, and vulnerability to human errors. This paper examines the application of blockchain technology as a disruptive solution for waybilling systems, enabling decentralization, immutability, and the integration of smart contracts. The decentralized nature of blockchain eliminates the need for a central authority, enhancing transparency and reducing the risk of single points of failure. The immutability of blockchain records ensures the integrity of waybilling data, preventing tampering and fostering trust among stakeholders. Smart contracts automate processes such as verification, payment, and enforcement of contractual agreements, streamlining operations and minimizing human intervention. The paper concludes by providing recommendations for collaborative efforts, pilot projects, infrastructure investment, regulatory collaboration, and continuous improvement to facilitate the successful adoption of blockchain-based waybilling systems in manufacturing firms.

Introduction

Strategically positioned in the Southwest region of Nigeria, has emerged as a thriving economic hub, particularly for manufacturing activities. Its proximity to Lagos State, the nation's economic capital, has played a pivotal role in attracting numerous firms seeking to capitalize on the region's burgeoning landscape. The rapid urbanization and population growth in Lagos State has led to

significant challenges, including road gridlocks, stretched land mass, and overpopulation. As a result, many manufacturing firms and businesses from various sectors have sought refuge in the relatively less congested and more accommodating environment (Adesola, 2019). This migration has positioned an economic capital annex, seamlessly extending the economic opportunities and activities of the Lagos megacity. As the manufacturing sector continues to expand, it has fostered a ripple effect, spurring the growth of ancillary industries and service providers. This ecosystem has further solidified the state's position as an economic powerhouse, contributing significantly to the nation's overall economic development (Olayiwola & Okorie, 2020).

Waybillings play an important role in the operations of manufacturing firms, particularly in the context of logistics and supply chain management. As a document that accompanies goods during transportation, it provides essential details about the shipment, including the goods being transported, the sender, the recipient, and the route (Olusanya & Oluwasanmi, 2018). Waybillings encompass all the processes involved in documenting the movement of goods from their originating location to their predetermined destination. In the manufacturing sector, waybillings are a pivotal component that supports various aspects of logistics operations. One of its primary functions is the tracking of shipments, allowing firms to monitor the real-time location and status of their goods in transit (Ajayi & Omolayo, 2020). However, all of these operations are mostly done manually and even when automation is applied to certain degree there is still lapses that allow for manipulation and altering of data, impacting on the integrity of sensitive data. Within the manufacturing sector, companies will gain astronomically by leverage emerging technology to better operations and scale production. Blockchain technology emerges as one technology that holds immense potentials in operations within manufacturing and supply chain management. Within the context of logistics, blockchain holds tremendous possibilities for application. With its distributed ledger and cryptographic nature it can help in monitoring and tracking of movement of goods and materials, thus giving real information for prompt decision making process. This capability is particularly valuable for time-sensitive or perishable goods, enabling manufacturers to take proactive measures to mitigate delays or potential spoilage. Also, blockchain technology facilitates the verification of receipts, ensuring that the correct goods have been delivered to the intended recipients through its smart contract feature (Olusanya & Oluwasanmi, 2018) thus minimizing errors, preventing misrouting, and reducing the risk of losses or damages during transit. Data generated for the blockchain network are shared across units allowing for seamless coordination between various departments, such as procurement, production, and distribution, allow for prompt and real time decision making.

At the core of manufacturing and production operations is the need for monitoring and tracking in waybills, as the inflow and outflow of materials can impact significantly on the economic fortune of any manufacturing firm. The purpose of waybillings and logistics in supply chain management is simply to track the inflow and outflow of stock level needed for operation. That is managing stock and products along the production line and holding inventory used to balance and buffer the variation between production schedules and demand. As a delicate manufacturing process, the need for tracking and monitoring is essentially important and critically pivotal. Manual tracking and monitoring have its limitations as such endeavour is prone to human fatigue and errors and in some case deliberate and malicious activities. Automation of the tracking and monitoring system therefore becomes crucial to the sustainability of manufacturing firm's operations. Blockchain technology, with its decentralized, transparent, and immutable nature, has emerged as a game-changer in various industries, including waybill management in manufacturing firms. As noted by Adebayo and Ogunjobi (2021), the adoption of blockchain can transform supply chain management by providing real-time visibility, traceability, and accountability throughout the entire process. Blockchain also streamline the tracking and monitoring of goods on transit, mitigate the risk of counterfeiting, and enhance data integrity (Afolabi, 2022). By leveraging smart contracts and

distributed ledgers, warehouse operators can automate processes, reduce human errors, and ensure the authenticity of inventory records (Okonkwo & Nwankwo, 2020). Furthermore, as opined by Oladipo and Ogunwolu (2023), blockchain-enabled inventory management can foster trust and transparency among supply chain stakeholders, enabling seamless collaboration and optimizing resource allocation.

Application of Blockchain Technology in Waybilling: An Overview

The manufacturing industries rely a great deal on logistics, either to ship raw materials to plant or the onward transmission of finished products to customer and logistics is cardinal to streamline these operations. Waybilling systems are vital components of logistics and supply chain management, facilitating the tracking and documentation of the movement of goods from their origin through to their destination. Traditionally, these systems rely on centralized databases maintained by intermediaries, leading to issues such as data manipulation, errors, and lack of transparency. Blockchain technology offers a decentralized and immutable solution to these challenges by providing a distributed ledger where transactions are recorded in a transparent and tamper-proof manner.

Blockchain technology eliminates the need for a central authority in managing waybilling systems by decentralizing operations. Instead, it relies on a network of nodes, each maintaining a copy of the ledger. This decentralization enhances transparency within the waybilling operations and eliminates single points of failure, making the system more resilient and trustworthy. Blockchain technology operates on a decentralized network of nodes, where each node maintains a copy of the blockchain ledger (Zarrin et al, 2021). This decentralized nature ensures that records generated for each transaction is locked in a decentralized system where no single entity has control over the entire system, enhancing transparency and reducing the risk of manipulation or fraud. The distributed nature of blockchain ensures that transactions and data are verified and recorded by multiple nodes in the network. This consensus mechanism adds an extra layer of security and trust to the system (Habib et al, 2022). By eliminating the need for a central authority, blockchain technology enables peer-to-peer transactions and interactions, allowing participants to directly engage with each other without intermediaries. This decentralization promotes a more inclusive and democratic system. Transactions recorded on a blockchain are immutable, meaning they cannot be altered or deleted once validated and added to the ledger. This feature ensures the integrity of waybilling data, reducing the risk of fraud or tampering. The immutability of records on a blockchain applies to waybilling in the following ways:

- **Tamper-Proof Records:** When a waybill transaction is recorded on a blockchain, it becomes a permanent and unchangeable part of the ledger (Pehar, 2024). This means that once the transaction is validated and added to the blockchain, it cannot be modified or tampered with by any party, including the sender, recipient, or any intermediaries involved in the waybilling process. This ensures that the information contained in the waybill remains accurate and trustworthy throughout its lifecycle.
- **Data Integrity:** Immutability ensures that the data recorded in a waybill remains intact and unaltered. Any attempt to modify or tamper with the information would require the consensus of the entire network, making it highly improbable and practically impossible to alter the records without detection (Skillfloor, 2024). This provides a high level of assurance that the waybill data is reliable and has not been manipulated, enhancing trust between the parties involved in the waybilling process.
- **Fraud Prevention:** The immutability of blockchain records acts as a deterrent to fraudulent activities in the waybilling process. Since the data cannot be altered or deleted without consensus, any attempt to falsify information or manipulate the waybill records would be easily

detectable (Kisters, 2022). This reduces the risk of fraudulent activities such as unauthorized changes to the waybill details, double-spending, or unauthorized access to sensitive information.

- **Auditability:** The immutable nature of blockchain records facilitates easy and efficient auditing of waybill transactions. Auditors can verify the integrity of the waybill data by examining the blockchain's complete and indisputable history of transactions (Kisters, 2022). This simplifies the auditing process and provides a transparent and auditable trail of all waybill activities, ensuring compliance with regulatory requirements and industry standards.

Another component of blockchain technology is smart contract. Smart contracts are self-executing contracts with the terms of the agreement directly written into code. In the context of waybilling systems, smart contracts can automate various processes such as verification of payment and enforcement of contractual agreements. This automation can significantly enhance efficiency and transparency in supply chain transactions. Ways smart contracts automate waybilling processes:

- Smart contracts can automate the verification process by using predefined conditions to ensure the accuracy and authenticity of waybill records.
- Smart contracts can automate the payment process by releasing funds upon the successful completion of predefined conditions.
- If any party fails to meet their obligations, the smart contract automatically triggers penalties or other actions as specified in the contract.
- Smart contracts can maintain a secure and immutable record of waybill transactions on a blockchain.

Effects of Waybilling in Manufacturing Firms Operations

As a component in the operations of manufacturing firms, waybilling plays a central and decisive role. Its functions within these operations are pivotal to tracking and managing the movement of materials, components, and finished products throughout the supply chain. The impact of waybilling is instrumental in effective inventory management and control. By providing accurate and real-time information about the location, quantity, and status of materials and products, waybilling enables manufacturing firms to optimize their inventory levels and minimize the risk of stockouts or overstocking (Chopra & Meindl, 2016). This, in turn, leads to improved operational efficiency, reduced carrying costs, and better utilization of available resources. As goods and materials criss cross between raw material sites, manufacturing plants and finally to end users, there is need for visibility and transparency by tracking the movement of goods from suppliers to the manufacturing facility and ultimately to the end customers (Barratt & Oke, 2007). This visibility allows manufacturers to monitor the progress of shipments, identify potential bottlenecks or delays, and make informed decisions regarding production schedules, transportation modes, and inventory replenishment.

The data generated by tracking movement of goods can be leveraged for effective production planning and scheduling. By having accurate information about the availability of raw materials and components, manufacturers can optimize their production schedules, reduce downtime, and ensure uninterrupted operations (Jacobs & Chase, 2018). This leads to improved capacity utilization, increased productivity, and better adherence to delivery commitments. Waybilling system within manufacturing firms facilitate and ensures quality control and compliance efforts are well observed and sustained. By accurately tracking the movement of materials and products, the systems help identify potential issues or deviations from established quality standards (Slack et al., 2015). This information can be used to initiate corrective actions, maintain product integrity, and ensure compliance within regulatory requirements. By providing detailed information about shipment locations, routes, and delivery schedules, the systems enable manufacturers to optimize

transportation routes, reduce transportation costs, and improve delivery performance (Chopra & Meindl, 2016). This can lead to improved customer satisfaction, reduced carbon footprint, and increased operational efficiency.

Limitations of Existing Waybill System

Current operations within the traditional waybill system faces several hurdles that hinder their efficiency and effectiveness in manufacturing operations. Amongst other things traditional waybill systems rely heavily on manual processes, which are prone to human errors, delays, and inconsistencies (Helo & Shamsuzzoha, 2020). Data entry mistakes, misplaced documents, and miscommunication between stakeholders, this result to inaccurate information, compromising inventory management and supply chain visibility. Other challenges include:

- Vulnerability of centralized databases to data manipulation, unauthorized access and single points of failure.
- Inability to track and verify the authenticity of transactions in real time.
- The complexities and inefficiencies arising from the involvement of multiple intermediaries.
- Interoperability issues and lack of seamless integration can lead to siloed operations, hindering real-time visibility and decision-making processes.

Blockchain Integration and Effects in Logistics Management

Blockchain adoption in logistics management has the potential to transform the way supply chain operations are conducted, offering unprecedented levels of transparency, security, and efficiency. This groundbreaking technology is poised to alter various aspects of logistics management, from tracking and tracing shipments to streamlining processes and fostering trust among stakeholders. By exploring the concept of blockchain integration and its impact on logistics management, we can uncover its far-reaching implications and interconnected concepts that further strengthens the operations of logistics management. The decentralized and cryptographic nature of blockchain technology ensures data immutability and integrity (Kshetri, 2018; Montecchi et al., 2019). Once data is recorded on the blockchain, it becomes tamper-proof, preventing unauthorized modifications or alterations. This feature is particularly valuable in logistics management, where the integrity of data related to shipments, documentation, and transactions is crucial for maintaining trust and compliance. It further enables seamless collaboration and information sharing among various stakeholders in the logistics ecosystem, including manufacturers, suppliers, carriers, customs authorities, and retailers (Montecchi et al., 2019; Xu et al., 2019). The distributed nature of the blockchain ensures that all authorized parties have access to the same immutable ledger, fostering trust, reducing communication barriers, and facilitating informed decision-making.

In logistics management, provenance and compliance are essential aspects that can benefit from blockchain integration. Blockchain technology allows for the tracking of goods' origin, authenticity, and compliance with relevant regulations and standards (Montecchi et al., 2019; Abeyratne & Monfared, 2016). This capability is particularly valuable in industries such as pharmaceuticals, food, beverages and luxury goods, where counterfeit products pose significant risks to consumer safety and brand reputation. It has the potential to drive significant cost reductions and improve operational efficiency (Montecchi et al., 2019; Dobrovnik et al., 2018). By streamlining processes, reducing manual interventions, and enhancing transparency and collaboration, blockchain minimize delays, errors, and redundancies, ultimately leading to optimized resource utilization. The inherent security features of blockchain technology, such as cryptographic encryption and decentralization, can help mitigate various risks in logistics management (Kshetri, 2018; Abeyratne & Monfared, 2016). These risks include cybersecurity threats, data breaches, and fraudulent activities. By

ensuring the integrity and immutability of data, blockchain can enhance supply chain security and reduce the potential for malicious and fraudulent activities.

Scalability and Implementation Challenges of Blockchain in Waybilling System

As a decisive component of supply chain management, waybilling involves tracking and documenting the movement of goods from one point to another. The enormous amount of data generated by these activities and the complexities arising from different aspect of operations pose a valid challenge of scalability and implementation of Blockchain within the waybilling operations, given that significant budget has to go into the set up the blockchain systems and the poor infrastructure in Nigeria generally. Lack of power for instance, poses a major consideration in efforts of management to scale the blockchain system in administration of waybilling operations. No doubt the integration of blockchain technology offers numerous advantages, including enhanced immutability and decentralization. However, the scalability of this integration remains a hurdle in the process of full adoption of blockchain that must be addressed to ensure its widespread adoption and effective deployment.

- As the number of transactions and participants in a blockchain network increases, so will also will the amount of data generated and the size of the distributed ledger grows rapidly. Efficient data storage and retrieval mechanisms are crucial for ensuring the scalability of blockchain-based waybilling systems.
- Poor power situation in Nigeria poses a significant challenge to the widespread adoption and scalability of blockchain applications. According to a report by the Nigerian Electricity Regulatory Commission (NERC), as of 2020, Nigeria's average power supply stood at just about 3,500 megawatts, significantly below the country's actual demand, leading to significant power deficits.
- Ensuring interoperability and seamless integration between different blockchain networks or platforms used by stakeholders is a significant challenge.
- Compliance with existing regulations, such as data privacy laws, industry specific regulations and legal framework, is crucial for the scalable implementation of blockchain-based waybilling solutions.

Ways to Overcome the Challenges

To address these hurdles, the following solutions and strategies are proposed:

- Offloading computationally intensive tasks to support network and storing non-critical data off the network can alleviate the burden of storage on the main blockchain network.
- Firms wishing to adopt the blockchain technology in achieving efficiency in waybilling operations must seek alternative power generation.
- Developing interoperability frameworks and standards, such as Blockchain-based Service Network (BSN) can facilitate seamless communication and data exchange between different blockchain networks.
- Fostering collaboration among stakeholders, standardization bodies, and regulatory authorities can accelerate the development and deployment of blockchain solutions for waybilling systems.

Conclusion

The integration of blockchain technology into waybilling systems for manufacturing firms presents a breakthrough opportunity. By leveraging the inherent advantages of blockchain, such as decentralization, immutability, and smart contracts, manufacturers can streamline their logistics operations, enhance transparency, and foster trust among stakeholders. The decentralized nature of

blockchain eliminates the need for a central authority, reducing the risk of data manipulation and single points of failure. Additionally, the immutability of blockchain records ensures the integrity of waybilling data, preventing tampering and promoting accountability throughout the supply chain. Smart contracts can automate various processes, such as verification, payment, and enforcement of contractual agreements, streamlining operations and minimizing human intervention. However, it is crucial to acknowledge and address the scalability challenges associated with implementing blockchain-based waybilling systems. Data storage and management are significant concerns as the volume of transactions and participants in the blockchain network increases. Efficient data storage and retrieval mechanisms must be developed to ensure the scalability and performance of the system. Power management is another critical challenge, particularly in regions with unreliable or limited power supply. Implementing blockchain-based waybilling systems may require significant investments in alternative power sources or energy-efficient computing solutions.

Recommendations

By embracing blockchain technology and addressing the associated challenges, manufacturing firms and indeed Nigeria can unlock new levels of efficiency, transparency, and trust in their waybilling operations, ultimately strengthening their competitive advantage and contributing to the state and national economic growth. Below are some recommendations to foster the wide spread acceptance and adoption of blockchain in waybilling system within manufacturing firms:

- Encouraging collaboration among manufacturing firms, logistics providers, technology partners, and relevant regulatory bodies is essential for developing scalable and interoperable blockchain solutions. This collective approach can facilitate the establishment of industry standards, address legal and regulatory challenges, and promote the widespread adoption of blockchain in waybilling systems.
- Before full-scale implementation, it is advisable for manufacturing firms to initiate pilot projects and proof-of-concept trials. These controlled experiments can help identify potential bottlenecks, assess the feasibility of blockchain integration, and refine the implementation strategies based on real-world scenarios.

Direction for Further Research

As blockchain technology continues to evolve and gain traction in various industries, new research opportunities will undoubtedly emerge, contributing to the advancement and optimization of blockchain-based waybilling systems for manufacturing firms. Underlisted are some potential areas for further research related to blockchain-based waybilling systems for manufacturing firms:

- Developing standardized frameworks and protocols to enable seamless integration and interoperability between different blockchain networks is essential for widespread adoption. Research in this area can focus on developing industry-specific standards, communication protocols, and application programming interfaces (APIs) to facilitate data exchange and collaboration among stakeholders.
- As the volume of transactions and the number of participants in a blockchain network increase, scalability becomes a significant challenge. Further research can explore innovative solutions such as sharding, off-chain computations, and layer-2 scaling techniques to improve the throughput and efficiency of blockchain-based data handling and management systems.
- Conduct research on leveraging blockchain for establishing product provenance and authenticity throughout the supply chain. This could be particularly relevant for industries dealing with counterfeit products, such as pharmaceuticals, luxury goods, and high-value components.

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