



Improving Availability in Supply Chain Management Using Blockchain Technology

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Abstract : Supply chain availability is critical for businesses to ensure seamless operations, reduce disruptions, and meet customer demands efficiently. However, traditional supply chains face challenges such as inefficiencies, lack of transparency, and reliance on intermediaries. Blockchain technology has emerged as a transformative solution, enabling real-time tracking, automating procurement, and enhancing supply chain visibility. This paper explores how blockchain improves availability in supply chain management through decentralized ledgers, smart contracts, and integration with IoT and AI. The study highlights real-world applications and discusses potential challenges and future prospects.

IndexTerms - Blockchain, Supply Chain Management, Availability, Transparency, Decentralization, Traceability, Smart Contracts.

I. INTRODUCTION

Need for Blockchain in Supply Chain Management

Traditional supply chain management (SCM) relies heavily on centralized systems, paper-based documentation, and multiple intermediaries, which result in inefficiencies and delays. The lack of real-time visibility, coupled with data silos between stakeholders, leads to high operational costs, shipment delays, and susceptibility to fraud. Blockchain technology addresses these issues by offering a decentralized, secure, and transparent system where all participants can access real-time data and verify transactions independently, reducing reliance on intermediaries and improving operational efficiency.

Need for Enhancing Availability in SCM

Availability in supply chains ensures that raw materials, components, and finished goods are consistently accessible to meet demand. However, factors such as supplier failures, logistical disruptions, inaccurate demand forecasting, and inventory mismanagement often result in shortages or excess stock. Enhancing availability in SCM helps businesses reduce lead times, minimize financial losses, and improve customer satisfaction. By improving availability, companies can maintain steady production flows, reduce wastage, and ensure optimal inventory levels without over-reliance on emergency stock replenishment.

Need for Blockchain to Improve Availability

Blockchain enhances availability in SCM by providing a real-time, tamper-proof ledger of transactions, ensuring that stakeholders have accurate inventory and logistics data. Smart contracts automate procurement and restocking processes, reducing human error and inefficiencies. Additionally, blockchain integration with IoT enables real-time tracking of goods in transit, allowing businesses to anticipate delays and take proactive measures. Through its decentralized structure, blockchain reduces dependencies on single points of failure, ensuring supply chain resilience and uninterrupted availability of critical goods.

1.1. DEFINITION AND PURPOSE

Availability in Supply chain Management: Availability in Supply Chain Management (SCM) refers to the ability to ensure that raw materials, components, and finished goods are consistently accessible to meet production and consumer demand. It encompasses factors such as inventory management, supplier reliability, and logistical efficiency to minimize disruptions and shortages.

Blockchain Definition: Blockchain is a decentralized digital ledger that records transactions across multiple computers, ensuring data integrity, transparency, and security. Each transaction is verified by network participants, making it nearly impossible to alter or delete past records.

Purpose: The purpose of blockchain in SCM is to enhance traceability, automate contract execution, improve data security, and eliminate inefficiencies by providing a trusted, distributed system that enables real-time collaboration among all supply chain stakeholders. Blockchain is a decentralized digital ledger that records transactions across multiple computers, ensuring data integrity, transparency, and security. Each transaction is verified by network participants, making it nearly impossible to alter or delete past records.

1.2. Types of Availabilities in SCM

1. **Product Availability:** Ensuring that raw materials, components, and finished goods are readily available to meet production and consumer demand.
2. **Supplier Availability:** Having reliable access to diverse suppliers to prevent disruptions due to vendor failures or delays.
3. **Logistical Availability:** Ensuring seamless transportation and warehousing operations to prevent delays and bottlenecks in distribution.
4. **Inventory Availability:** Maintaining optimal stock levels to prevent both shortages and overstocking.
5. **Information Availability:** Ensuring real-time data access across all supply chain partners to enhance decision-making and efficiency.

1.3. Core Components and Technologies

Blockchain technology consists of several fundamental components that enhance availability in supply chain management. These include:

1. **Decentralized Ledger:** A distributed and immutable record of all transactions, ensuring real-time visibility and reducing reliance on central authorities.
2. **Smart Contracts:** Self-executing agreements that automate procurement, supplier payments, and inventory replenishment, minimizing delays.
3. **Consensus Mechanisms:** Validation protocols such as Proof of Work (PoW) and Proof of Stake (PoS) ensure security and trust among participants.
4. **Cryptographic Security:** Encryption techniques safeguard data integrity, preventing unauthorized modifications or tampering.
5. **Integration with IoT and AI:** IoT devices enable real-time monitoring of supply chain activities, while AI-powered analytics optimize forecasting and decision-making.

1.4. Key Features and Advantages

Blockchain provides key features that significantly improve availability in supply chain management:

1. **Transparency:** A decentralized ledger ensures that all participants have access to accurate, real-time data, reducing discrepancies and enhancing coordination.
2. **Immutability:** Once recorded, blockchain transactions cannot be altered, preventing fraud and ensuring product authenticity.
3. **Automation:** Smart contracts replace manual processes, expediting procurement, payments, and contract execution, reducing lead times and human errors.
4. **Security:** Cryptographic security mechanisms protect supply chain data from cyber threats and unauthorized access.
5. **Interoperability:** Blockchain can seamlessly integrate with existing enterprise systems (ERP, IoT, AI), enhancing supply chain efficiency and predictive analytics.

1.5. Use Cases and Applications

Blockchain technology is transforming various industries by improving supply chain availability. Key use cases include:

1. **Pharmaceutical Supply Chains:** Blockchain ensures authenticity and prevents counterfeit drugs from entering the market by providing traceability from manufacturer to consumer.
2. **Food Safety and Traceability:** Retailers such as Walmart use blockchain to track food products, ensuring freshness, reducing contamination risks, and enhancing recall efficiency.
3. **Luxury Goods Authentication:** Brands like LVMH leverage blockchain to verify product authenticity, combating counterfeiting and increasing consumer trust.
4. **Automotive Industry:** Companies like Tesla utilize blockchain to monitor ethically sourced raw materials, ensuring regulatory compliance and sustainability.
5. **Logistics and Shipping:** Platforms like TradeLens improve customs processing, reduce paperwork, and enhance real-time cargo tracking to avoid delays and bottlenecks.

II. LITERATURE REVIEW

2.1. Overview of Existing Research on SCM

Existing research on Supply Chain Management (SCM) highlights the importance of efficiency, transparency, and resilience in maintaining seamless global trade operations. Traditional SCM systems often face challenges such as data silos, manual inefficiencies, and lack of real-time visibility, leading to disruptions and increased costs.

Key Studies and Contributions:

1. **Christopher (2016)** emphasized the role of agility and flexibility in SCM, stating that traditional supply chains are vulnerable to demand fluctuations and logistical inefficiencies.
2. **Mentzer et al. (2001)** defined SCM as an integrated approach to managing material and information flows across the supply chain network to improve performance and customer satisfaction.
3. **Ivanov & Dolgui (2020)** examined supply chain resilience in the wake of global disruptions, such as the COVID-19 pandemic, highlighting the need for improved visibility and risk mitigation strategies.
4. **Tang & Musa (2011)** analyzed supply chain risk management techniques, discussing how digitalization and automation can enhance supply chain robustness.
5. **Hald & Kinra (2019)** explored the impact of digital transformation in supply chains, emphasizing how new technologies like IoT and AI contribute to supply chain efficiency but also present integration challenges.

These studies collectively underline the growing necessity for technological advancements, such as blockchain, to overcome SCM inefficiencies and enhance availability, traceability, and responsiveness.

2.2. Blockchain Applications in SCM

The application of blockchain in supply chain management has been widely researched, with a focus on improving transparency, automation, and security. Various studies have demonstrated blockchain's potential to enhance supply chain efficiency by reducing fraud, improving traceability, and optimizing logistics.

Key Studies and Contributions:

1. **Casino et al. (2019)** conducted a systematic review of blockchain-based supply chains, concluding that blockchain enhances traceability and reduces counterfeit risks in industries such as pharmaceuticals and luxury goods.
2. **Kamble et al. (2020)** analyzed blockchain's role in improving supply chain efficiency by automating procurement and payment systems through smart contracts, reducing delays and transaction costs.
3. **Queiroz et al. (2019)** reviewed blockchain adoption in logistics and highlighted its benefits in minimizing paperwork, enhancing real-time tracking, and reducing bottlenecks in global trade.
4. **Saberi et al. (2019)** examined blockchain's impact on sustainable supply chains, demonstrating how it can improve compliance with environmental and ethical sourcing regulations.
5. **Tian (2017)** investigated blockchain's role in food supply chains, showing how it enables real-time tracking of perishable goods to enhance food safety and reduce waste.

These studies collectively support blockchain's transformative impact on supply chains, particularly in improving availability by ensuring real-time monitoring, automated contract execution, and fraud prevention. Blockchain has been studied for its role in improving traceability, reducing fraud, and automating contract execution. Several studies highlight blockchain's potential to improve transparency and accountability.

2.3. Gaps in the Literature

While extensive research has been conducted on blockchain's role in supply chain management, significant gaps remain, particularly regarding its impact on availability. Most existing studies focus on blockchain's potential benefits, but few provide empirical evidence on its real-world effectiveness in minimizing supply chain disruptions and improving inventory flow.

Identified Gaps and Research Contributions:

1. **Limited Empirical Studies:** Many studies (Casino et al., 2019; Kamble et al., 2020) discuss blockchain's advantages theoretically but lack data-driven evaluations of its impact on supply chain availability. Our research aims to fill this gap by analyzing case studies and pilot implementations.
2. **Lack of Focus on Smart Contract Integration:** While smart contracts are recognized for automating procurement and inventory management (Queiroz et al., 2019), there is limited research on their efficiency in dynamic supply chain environments. Our study examines how smart contracts streamline operations and reduce stockouts.
3. **Blockchain Scalability and Adoption Challenges:** Saberi et al. (2019) highlight blockchain's role in sustainability, but research on large-scale adoption barriers remains scarce. Our study investigates scalability issues and proposes solutions for seamless blockchain implementation.

4. Absence of Comparative Analysis with Traditional Systems: Most research does not compare blockchain-based supply chains with traditional centralized systems. We aim to provide a comparative analysis to demonstrate blockchain's effectiveness in enhancing availability.

By addressing these gaps, our study contributes new insights into how blockchain technology can practically enhance supply chain availability, offering data-driven recommendations for implementation. While research discusses blockchain's theoretical benefits, there is limited empirical evidence on its impact on availability. This study aims to bridge this gap.

III. METHODOLOGY

3.1. Research Design

This study employs a mixed-method research design, integrating both qualitative and quantitative approaches to provide a comprehensive analysis of blockchain's impact on supply chain availability. The research involves case studies, surveys, and blockchain implementation assessments to evaluate improvements in supply chain transparency, efficiency, and automation.

- 1. Qualitative Approach:** Case studies from industries such as pharmaceuticals, food supply chains, and automotive manufacturing are analyzed to understand blockchain's effectiveness in real-world supply chain operations.
- 2. Quantitative Approach:** Data from surveys and blockchain-based tracking systems are collected and statistically analyzed to measure reductions in supply chain disruptions, improvements in order fulfillment times, and inventory optimization.
- 3. Comparative Analysis:** Blockchain-enhanced supply chains are compared with traditional SCM models to assess relative improvements in availability, security, and efficiency.

Data collection includes industry reports, academic literature, and expert interviews, while data analysis employs statistical tools such as regression models and time-series analysis to measure blockchain's effectiveness in reducing supply chain disruptions. This study employs a mixed-method research design, integrating both qualitative and quantitative approaches to provide a comprehensive analysis of blockchain's impact on supply chain availability. The research involves case studies, surveys, and blockchain implementation assessments to evaluate improvements in supply chain transparency, efficiency, and automation.

3.2. System Architecture

The proposed system architecture for blockchain-based supply chain management consists of several layers, each designed to improve availability by enhancing transparency, security, and automation. Below are the core components:

1. Data Layer:

- a. Stores immutable transaction records on a decentralized blockchain ledger, ensuring transparency and traceability.
- b. Provides a tamper-proof record of inventory movement, reducing data manipulation risks.
- c. Ensures real-time synchronization across multiple supply chain stakeholders.

2. Network Layer:

- a. Facilitates secure peer-to-peer communication among supply chain participants, reducing the need for intermediaries.
- b. Uses consensus mechanisms such as Proof of Work (PoW) or Proof of Stake (PoS) to validate transactions.
- c. Enhances supply chain resilience by distributing transaction records across multiple nodes.

3. Smart Contract Layer:

- a. Automates procurement, inventory restocking, and payment processing using predefined contract conditions.
- b. Reduces delays caused by manual approvals and human intervention.
- c. Provides automated dispute resolution and contract enforcement mechanisms.

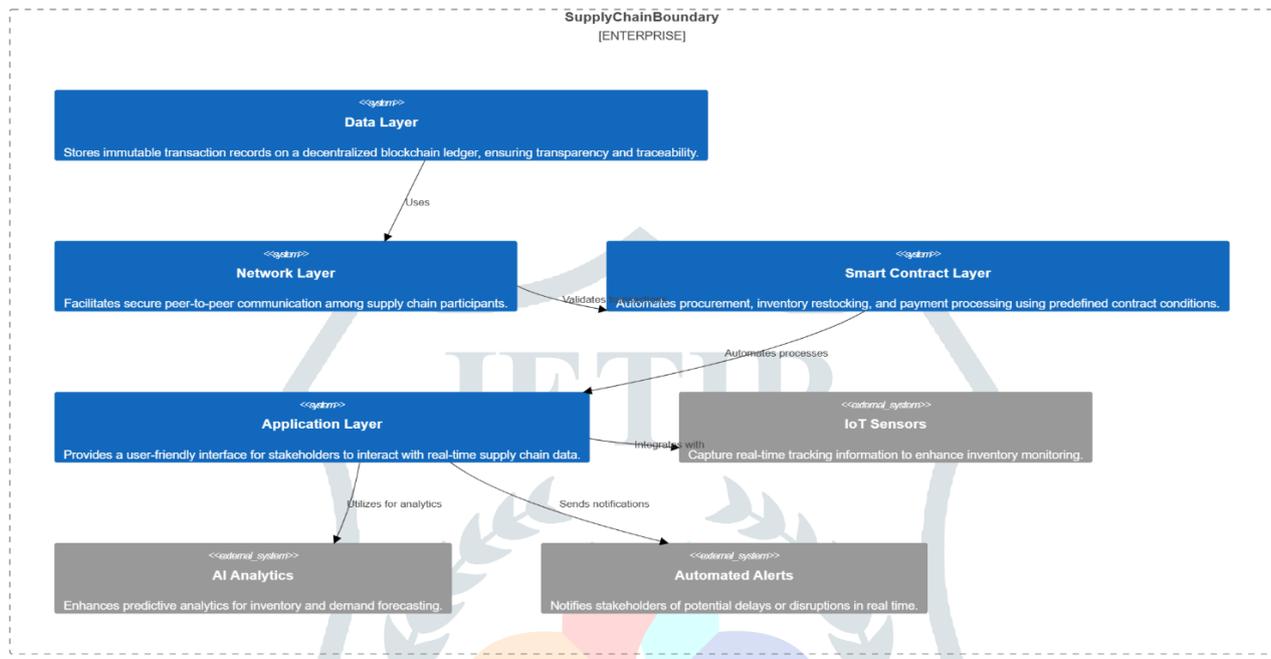
4. Application Layer:

- a. Provides a user-friendly interface for suppliers, manufacturers, logistics providers, and consumers to interact with real-time supply chain data.
- b. Offers dashboards, alerts, and tracking functionalities to ensure seamless operations.
- c. Integrates with enterprise resource planning (ERP) systems to streamline supply chain management.

5. Integration with IoT and AI:

- a. **IoT Sensors:** Capture real-time tracking information, such as temperature, humidity, and location, to enhance inventory monitoring.
- b. **AI Analytics:** Enhances predictive analytics for inventory and demand forecasting, optimizing supply chain decision-making.
- c. **Automated Alerts:** Notifies stakeholders of potential delays, disruptions, or quality control issues in real time.

This architecture ensures enhanced availability by reducing delays, eliminating bottlenecks, and improving decision-making in supply chain operations. By leveraging blockchain's decentralized and immutable nature, the proposed system provides a more secure, transparent, and efficient supply chain network.



system architecture diagram for blockchain-based supply chain management

IV. BLOCKCHAIN TECHNOLOGY IN SUPPLY CHAIN MANAGEMENT

4.1. Overview of Blockchain Technology

Blockchain technology is a decentralized, distributed ledger system that records transactions securely and transparently. Unlike traditional databases controlled by a single authority, blockchain operates on a peer-to-peer network, where all participants have access to the same transaction history. This technology eliminates the need for intermediaries, reduces fraud, and enhances trust among supply chain partners.

Blockchain consists of blocks of data that are cryptographically linked and immutable, meaning that once a transaction is recorded, it cannot be altered or deleted. The decentralized nature of blockchain enhances security, reduces data manipulation, and ensures greater transparency in supply chain management.

Key Features of Blockchain

1. **Decentralization:** Instead of relying on a single authority, blockchain distributes data across multiple nodes, preventing single points of failure and reducing reliance on intermediaries.
2. **Immutability:** Transactions recorded on a blockchain cannot be modified or deleted, ensuring data integrity and preventing fraud.
3. **Transparency:** Every participant in the supply chain network can access a synchronized ledger, reducing information asymmetry and improving traceability.
4. **Security:** Blockchain employs cryptographic algorithms to secure data, reducing cyber threats and unauthorized access.
5. **Smart Contracts:** Self-executing contracts automate and enforce agreements between supply chain stakeholders, reducing manual intervention and errors.
6. **Interoperability:** Blockchain systems can integrate with IoT, AI, and ERP solutions to improve real-time tracking, predictive analytics, and supply chain efficiency.

By leveraging these features, blockchain enhances supply chain management by improving product traceability, automating transactions, and reducing operational inefficiencies.

4.2. Applications of Blockchain in SCM

Blockchain technology is transforming supply chain management by addressing inefficiencies, improving traceability, and automating processes. Various industries have adopted blockchain to enhance supply chain availability, security, and efficiency.

Key Applications:

- 1. Inventory Tracking and Management:** Blockchain enables real-time tracking of goods, ensuring accurate inventory levels and reducing stockouts. Companies like Walmart use blockchain to track perishable goods, improving food safety and minimizing waste.
- 2. Procurement and Supplier Verification:** Smart contracts automate procurement processes, reducing human errors and transaction times. Blockchain-based supplier verification ensures that only authenticated and compliant vendors are engaged, reducing fraud and improving reliability.
- 3. Logistics and Transportation Optimization:** Blockchain provides real-time updates on shipment status, ensuring that goods are transported efficiently. The integration of IoT with blockchain enhances logistics tracking by recording temperature, humidity, and location data for sensitive shipments.
- 4. Anti-Counterfeiting and Product Authentication:** Industries such as pharmaceuticals and luxury goods use blockchain to prevent counterfeiting by assigning unique digital identities to products. Everledger's blockchain platform verifies the authenticity of diamonds, preventing fraud in the jewelry industry.
- 5. Sustainable and Ethical Sourcing:** Blockchain ensures ethical sourcing of raw materials by providing an immutable record of transactions. Companies in the automotive and electronics sectors track conflict-free minerals to ensure responsible sourcing.
- 6. Automated Payments and Trade Finance:** Decentralized finance (DeFi) and blockchain-based smart contracts enable automated, secure, and transparent transactions, reducing delays and eliminating intermediaries in international trade.

4.3. Challenges and Limitations

Despite its numerous advantages, blockchain adoption in supply chain management faces several challenges and limitations:

- 1. Scalability Issues:** Public blockchains, such as Bitcoin and Ethereum, have limited transaction processing speeds, making them inefficient for high-volume supply chain operations. Hybrid or private blockchains may offer better scalability but require additional infrastructure.
- 2. High Implementation Costs:** The initial cost of integrating blockchain technology, including software development, hardware setup, and employee training, can be substantial. Many small and medium enterprises (SMEs) struggle to afford blockchain adoption.
- 3. Regulatory Uncertainty:** The lack of standardized regulations for blockchain in supply chains creates legal challenges, especially in cross-border trade. Different jurisdictions have varying rules on data security, smart contracts, and digital transactions.
- 4. Interoperability Challenges:** Many supply chain networks use different legacy systems and enterprise resource planning (ERP) solutions, making blockchain integration complex. Establishing industry-wide standards is crucial for seamless adoption.
- 5. Energy Consumption Concerns:** Some blockchain networks, particularly those using Proof of Work (PoW) consensus mechanisms, require significant computational power and energy. Sustainable alternatives, such as Proof of Stake (PoS) or permissioned blockchains, can mitigate this issue.
- 6. Adoption Resistance:** Companies accustomed to traditional supply chain management methods may resist transitioning to blockchain-based solutions due to a lack of expertise and concerns over data security and transparency.

Overcoming these challenges requires continued research, investment in scalable solutions, regulatory collaboration, and education on blockchain benefits for supply chain management.

V. IMPROVING AVAILABILITY IN SUPPLY CHAIN USING BLOCKCHAIN

5.1. Definition of Availability in SCM

Availability in Supply Chain Management (SCM) refers to the ability to ensure that raw materials, components, and finished goods are consistently accessible to meet demand without disruption. It encompasses various aspects, including inventory management, supplier reliability, production capacity, and logistics efficiency. A well-managed supply chain ensures that goods are delivered on time, minimizing downtime, reducing operational bottlenecks, and enhancing customer satisfaction.

Ensuring availability requires strategic planning, effective demand forecasting, and robust supplier networks. Traditional supply chains often face challenges such as delays due to poor inventory tracking, supplier inconsistencies, and inefficient logistics management. The integration of digital technologies, such as blockchain, artificial intelligence (AI), and the Internet of Things (IoT), provides new opportunities to enhance availability by improving visibility, automation, and real-time tracking.

A lack of availability in supply chains can lead to significant business losses, including production halts, increased costs due to emergency sourcing, and reputational damage. Companies invest heavily in supply chain resilience strategies to mitigate these risks and maintain seamless operations. Blockchain technology has emerged as a promising solution to enhance availability by ensuring transparency, enabling automated decision-making, and securing transactions through decentralized ledgers. In the following sections, we explore the challenges in ensuring availability and the role of blockchain in addressing these issues.

5.2. Current Challenges in Ensuring Availability

Ensuring availability in supply chain management involves maintaining a seamless flow of materials and products to meet demand. However, traditional supply chains face multiple challenges that lead to inefficiencies, delays, and increased costs. Some of the key challenges include:

1. **Supply-Demand Mismatches:** Inaccurate demand forecasting and poor inventory management often result in either overstocking or stockouts, leading to financial losses and customer dissatisfaction.
2. **Inventory Inaccuracies:** Traditional inventory tracking systems rely on manual data entry, which increases the chances of errors, misplacements, and discrepancies in stock levels.
3. **Supplier Unreliability:** Dependence on a limited number of suppliers can cause delays if a supplier fails to deliver on time due to disruptions such as natural disasters, political instability, or financial issues.
4. **Logistical Delays and Inefficiencies:** Poor coordination between transportation providers, customs authorities, and warehousing facilities can cause delays in shipments, leading to supply chain bottlenecks.
5. **Lack of Real-Time Visibility:** Traditional supply chain systems lack real-time tracking, making it difficult for companies to identify potential disruptions early and take corrective measures.
6. **Fraud and Counterfeit Goods:** The presence of counterfeit products in the supply chain affects product quality, increases legal risks, and leads to reputational damage for companies.
7. **Regulatory Compliance Issues:** Meeting international trade regulations and compliance requirements can be challenging due to complex documentation processes and inconsistent regulatory frameworks across different regions.

5.3. Role of Blockchain in Enhancing Availability

Blockchain technology addresses many of the challenges in ensuring supply chain availability by providing transparency, automation, and enhanced security. The following ways illustrate how blockchain improves supply chain availability:

1. **Real-Time Data and Visibility:** Blockchain provides a decentralized, immutable ledger where all supply chain participants have access to real-time inventory and logistics data. This prevents information silos and enables proactive decision-making to avoid stockouts and production halts.
2. **Automated Inventory Replenishment:** Smart contracts automate procurement and restocking processes based on predefined conditions. When inventory reaches a critical level, a smart contract can automatically trigger reorders, reducing human errors and delays.
3. **Supplier Verification and Reliability:** Blockchain enables supplier credential tracking and certification, ensuring that only verified and compliant suppliers are involved in the supply chain. This reduces disruptions caused by unreliable vendors and mitigates risks related to fraudulent suppliers.
4. **Logistics Optimization:** By integrating blockchain with IoT devices, supply chain managers can track shipments in real-time, ensuring on-time deliveries and reducing the impact of transportation delays. Blockchain secures transportation data, preventing manipulation and fraud.
5. **Fraud Prevention and Product Authentication:** Blockchain assigns unique digital identities to goods, preventing counterfeit products from entering the supply chain. This ensures that only genuine, high-quality products are available for consumers.

6. **Regulatory Compliance and Documentation Efficiency:** Blockchain automates compliance reporting and record-keeping, reducing bureaucratic delays in international trade. Smart contracts enforce regulatory requirements, ensuring that all transactions and shipments meet legal standards.

5.4. Case Studies of Blockchain Improving Availability

Blockchain technology has been successfully implemented in various industries to enhance supply chain availability, increase transparency, and reduce inefficiencies. The following case studies highlight real-world examples of how blockchain has improved availability in supply chain management:

Case Study 1: Walmart's Blockchain Food Traceability System

Walmart, in collaboration with IBM, has implemented a blockchain-based food traceability system to enhance supply chain transparency and food safety. The system, built on IBM's Food Trust blockchain platform, enables Walmart to track the origin of food products in real time, ensuring faster recall processes and reducing foodborne illness risks.

Impact on Availability:

1. **Real-Time Tracking:** Walmart reduced the time required to trace the source of contaminated food from 7 days to 2.2 seconds, ensuring faster response times during food recalls.
2. **Improved Inventory Management:** The blockchain system allows suppliers and retailers to have real-time access to inventory levels, preventing stock shortages and overstocking.
3. **Enhanced Supplier Collaboration:** All supply chain participants, including farmers, processors, distributors, and retailers, have a shared and tamper-proof record of transactions, reducing disputes and delays.

By leveraging blockchain, Walmart has improved supply chain availability by ensuring food products are consistently available in stores while minimizing losses due to spoilage and contamination.

Case Study 2: IBM and Maersk's TradeLens Shipping Platform

IBM and Maersk developed TradeLens, a blockchain-based shipping and logistics platform designed to digitize global trade and improve supply chain efficiency. The platform provides real-time visibility into cargo movements, automates document processing, and enhances communication between shippers, carriers, and customs authorities.

Impact on Availability:

1. **Reduction in Shipping Delays:** TradeLens has streamlined documentation processes, reducing shipping delays by 40% and improving overall supply chain efficiency.
2. **Enhanced Transparency:** The blockchain ledger ensures that all stakeholders have real-time access to shipment data, reducing the risk of lost or delayed goods.
3. **Secure and Automated Transactions:** TradeLens uses smart contracts to automate customs clearance and payments, reducing manual processing times and minimizing the risk of fraud.

By integrating blockchain technology, TradeLens has significantly improved the availability of goods in international trade by minimizing inefficiencies, reducing costs, and ensuring timely deliveries.

VI. CONCLUSION

Blockchain technology presents a transformative solution for supply chain management by providing secure, immutable, and transparent transaction records. Its ability to automate procurement, track goods in real time, and ensure supplier reliability significantly enhances supply chain availability. While challenges such as scalability, regulatory concerns, and implementation costs persist, continued innovation and adoption of hybrid blockchain models can mitigate these issues. As industries increasingly recognize blockchain's potential, its integration into supply chain management is expected to drive efficiency, reduce risks, and create more resilient global trade networks.

6.1. Summary of the Research

This study examines the role of blockchain technology in improving availability in supply chain management by enhancing transparency, automation, and efficiency. Traditional supply chains face numerous challenges, including supply-demand mismatches, inventory inaccuracies, logistical inefficiencies, and fraud. The research highlights blockchain's ability to overcome these challenges through decentralized ledgers, real-time tracking, smart contracts, and integration with IoT and AI. Case studies, such as Walmart's blockchain food traceability system and IBM and Maersk's TradeLens platform, demonstrate the tangible benefits of blockchain in reducing disruptions and improving supply chain resilience.

6.2. Key Contributions Table

The following table summarizes key research contributions related to blockchain applications and supply chain management, highlighting major insights and methodologies used in previous studies.

Sr. No.	Author	Paper	Major Takeaways	Methodology
1	Christopher (2016)	<i>Agility and Flexibility in Supply Chain Management</i>	Traditional supply chains are vulnerable to demand fluctuations and inefficiencies.	Conceptual Study
2	Mentzer et al. (2001)	<i>Defining Supply Chain Management and Its</i>	SCM integrates material and information flow to enhance	Theoretical Analysis
3	Ivanov & Dolgui (2020)	<i>Supply Chain Resilience During Global Disruptions</i>	Highlighted the role of visibility and risk mitigation strategies in supply chains.	Empirical Analysis
4	Tang & Musa (2011)	<i>Risk Management in Supply Chains</i>	Explored how digitalization and automation enhance supply chain resilience.	Case Study & Review
5	Hald & Kinra (2019)	<i>Digital Transformation in Supply Chains</i>	IoT and AI improve efficiency but pose integration challenges.	Systematic Literature Review
6	Casino et al. (2019)	<i>Blockchain-Based Supply Chains</i>	Blockchain improves traceability and reduces counterfeit risks.	Systematic Review
7	Kamble et al. (2020)	<i>Blockchain and Smart Contracts in SCM</i>	Blockchain enhances procurement and payments, reducing transaction costs.	Empirical & Theoretical Analysis
8	Queiroz et al. (2019)	<i>Blockchain Adoption in Logistics</i>	Blockchain minimizes paperwork, enhances tracking, and reduces trade bottlenecks.	Review & Qualitative Study
9	Saberi et al. (2019)	<i>Sustainability and Blockchain in Supply Chains</i>	Blockchain helps ensure compliance with ethical and environmental standards.	Case Study
10	Tian (2017)	<i>Food Safety and Blockchain Technology</i>	Real-time tracking of perishable goods improves food safety and reduces waste.	Empirical Case Study

6.3. Practical Implications

Blockchain technology offers significant practical benefits for supply chain management by enhancing transparency, security, and automation. One of the most critical implications is the improvement in **real-time tracking and inventory visibility**, which ensures supply chain availability. Companies can access decentralized ledgers that provide up-to-date data on shipments, inventory levels, and supplier transactions. This reduces delays and stockouts, leading to improved efficiency and customer satisfaction.

Another key implication is the use of **smart contracts** to automate procurement and payment processes. By eliminating manual intervention and reducing paperwork, businesses can streamline operations, reduce costs, and minimize errors in supply chain transactions. Smart contracts also enhance trust among stakeholders by ensuring that agreements are executed automatically when predefined conditions are met, reducing disputes and fraud.

Moreover, blockchain's **enhanced security features** mitigate risks associated with data breaches and counterfeit goods. Immutable transaction records make it nearly impossible to alter supply chain data, ensuring product authenticity and regulatory compliance. This is particularly beneficial in industries such as pharmaceuticals, food safety, and luxury goods, where product traceability is crucial.

And, blockchain adoption promotes **supply chain resilience** by diversifying supplier networks and reducing dependency on centralized entities. Companies can implement blockchain-based solutions to enhance risk management strategies, ensuring that disruptions—whether due to geopolitical issues, pandemics, or natural disasters—do not significantly impact supply chain operations. As blockchain technology continues to evolve, its integration with AI and IoT will further optimize supply chain processes, making global trade more reliable, sustainable, and efficient.

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