

Blockchain based Solution to Implement Supply Chain Management in Indian Agriculture

¹Harsh Singh, ²Harshit Kumar Gupta, ³Jinesh Jain, ⁴K R Mamatha

^{1,2,3}Student, ⁴professor

Department of Information science and engineering
B.M.S.College of Engineering, Bangalore.

Abstract- For the past few years, the market has changed a lot and it has become dynamic and demanding which has put the market into a competitive environment. The supply chain plays a crucial role to adapt the business to the dynamic environment as it is very reliant on collaboration integration as well as flexibility. The applications related to the supply chain have gotten the attention of many business owners and to improve the flow control of the supply chain many specialized applications are implemented. One of the most important new technological applications in the supply chain is blockchain technology which has garnered the attention of many business owners as it can be quickly adapted to dynamic market conditions and in the business environment. One upon reading this will get to know about the effect of blockchain technology utilization on this field. The results of the research paper recommend that companies invest in blockchain technology so that the supply chain becomes more transparent, flexible, and secure. There is no doubt in the fact that blockchain technology plays an important role in developing trust with the stakeholder of the supply chain. In the end, the research paper has also given some considerations on the implications that are positive as well as the potential of the blockchain in the field of collaboration and integration.

INTRODUCTION

Most global companies have always faced challenges in supply chain management. The company has always devoted a lot of resources which leads to various inefficiencies and to figuring out cost reduction. With the approach of blockchain technology, companies have thought of thinking forward. This technology could help in the evolution of the supply chain. According to analysts, blockchain technology can enhance the contemporary structure of the supply chain by enhancing supply chain efficiency, trust as well as transparency [1]. Moreover, the future of the supply chain is blockchain solutions according to many supply chain leaders. The survey performed by PwC in 2019 has revealed that more than 24% of the industrial manufacturing industry is looking to implement blockchain technology in supply chain management [2]. The 2020 survey of Deloitte global blockchain reveals that more than 55% of the senior executive, as well as practitioners, looked up to blockchain as their top priority [3]. Moreover, blockchain is not a new internet infrastructure but it's extremely new in the field of supply chain networks that offer the future of business.

Definition of blockchain: It is known to be a string of encrypted data blocks where the blocks have the information that is the data, and the information is locked so that whoever has the key can access the information [6]. The chain contains many files linked with one another and each of the files includes information such as a timestamp that speaks about when the data is created and the historical information about the blocks in the blockchain [7]. All the blocks together are known as the blockchain.

Blockchain infrastructure: Blockchain can only be accessed over a computer, laptop, server connected to the internet. All the devices when connected are known as nodes of the blockchain. Blockchain is stored by the nodes and permission is given to certain users that will be discussed in the study of blockchain in the supply chain [8]. A ledger is created when the blockchain is stored across the nodes which are recognized as a system where the data is stored and is shared across various sites, countries, or institutions [6]. Traditional databases are used to contrast the distributed ledger where the digital data is enclosed in a centralized location and in blockchain, the nodes store identical data.

Adding to the blockchain: To add data to the block of the blockchain, it is required to send a node out a transition request with the data that is added to other nodes of the network of the blockchain for the creation of the block [7]. It is necessary to agree to the addition of the new block to the blockchain before the block is added to the chain. At the time of the validation of the new block, the node must confirm that the block is correctly formatted and there is no duplicate transaction in the block [9]. Once the block is validated, an encrypted block is added to the blockchain and in the blockchain network; it is stored by the other nodes. Due to the encryption nature of the blockchain and

distributed ledger format, the data on the blockchain is not hackable and thus there is a lot of trust and confidence in the data that is stored on the blockchain [10].

Research Objective: The purpose of the research is to discuss blockchain technology and how it can help logistic companies. Blockchain technology is a new technology, and most people are not familiar with this innovation however the paper has helped the readers to know about the introduction of blockchain technology and how it can help in supply chain management.

Research Questions: How can technology help to find a solution to some of the supply chain challenges?

Research Motivation: In the field of the supply chain, there are a lot of products that deliver to the customer that comprises independent farms. Because of these reasons, the business fails to compete as isolated companies, but they are also a part of the huge supply chain network [11]. Moreover, the companies are also encountering uncertainty challenges because of the globalization and high expectation of the customer. There is also a huge market competition and complex supply chain that demands cooperation across the supply chains. Supply chains are fragmented because of internal competition and limited information exchange. Apart from this, these constraints also have a huge influence on business performance and give rise to challenges and high operation costs and capacity storage that can be easily resolved by blockchain technology [12].

Research Gap: Blockchain technology offers a lot of benefits but it's not a comprehensive solution in the supply chain management field. There are many problems with blockchain-based technology and other related technologies.

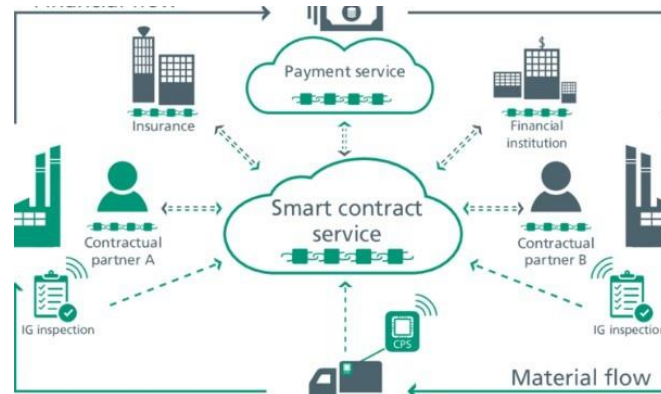


FIG. 1(Material Flow Diagram)

ANALYTICS

1) Blockchain Technology definition and its boundaries: It has been discussed above that blockchain is a distributed ledger database that consists of records or transactions or various digital incidents that are executed by the participants. Some articles have been published to a clarification on blockchain technology and how it works in the recent past [14]. Cryptocurrencies are one of the most popular examples of blockchain technology has been also named Bitcoin. Apart from these cryptocurrencies, there are also human implications of this blockchain such as supply chain, financial services, and manufacturing. This research paper has focused on the implementation of blockchain in supply chain management rather than concluding the technical mechanism of the blockchain technologies [15]. The paper has not talked about blockchain technology's key aspects like the protocols, algorithm, wallet signature and hash function.

2) Supply chain management definition and its boundaries: The definition of supply chain management is not the same for all others; however, according to [16], supply chain management is a process of handling the entire integrative flow of materials ranging from a raw material supplier to production warehousing and transportation to the users. There are various methods involved in supply chain management and it is important to identify its boundaries [12]. In this research paper, all the supply chain activities ranging from supply to manufacturing, distribution and the activities related to customers has been discussed. Apart from this, supply chain management also discusses the management of the entire chain in the study.

3) Blockchain-based supply chain: There is uncertainty about the adoption of blockchain, globally as well as logistically [17]. The reason is the immaturity of blockchain, and it is looking to transform the SC activities by helping enhance as well as accountability. According to [18], transparency is a crucial factor in the traceability level.

However, [19] has come up with 3 types of transparency in an SC. They are a range of transparency products, transparency, and participation transparency. Thus to implement blockchain-based SCs, it is necessary to analyze the SC transparency factor and to correlate it with the opportunity as well as list perspective analysis so that it could help in assessing the mystery gains or losses. To understand blockchain technology in the supply chain, it is necessary to consider interdisciplinary investigation so that theories can be built and designed for blockchain technology [20]. Moreover, the firms can be benefited from blockchain-based social sustainability and responsibility to extend visibility and assure due diligence. It has been found that there is a lack of experience in understanding and knowledge about blockchain technology and there is also a labour skill gap with this technology that is required to be fixed. Moreover, according to [17], blockchain technology for technology and business needs to be addressed properly because there is a lot of expectation from this technology that can lead to the field adoption of this technology in the industry.

Blockchain technology can assist in achieving the seven objectives of SCM: their cost, quality, speed, dependency, risk reduction, sustainability as well as flexibility [21]. [21] has discussed blockchain as a capability to break down data silos and provide one data source in digitization with the help of real-time data control that is required for all trusted partners in the network. With the help of blockchain trust and security can easily be enhanced and apart from this, there also exist business values that would help in building trust with the help of blockchain by improving efficiency, reputation, and responsiveness [17]. It can be easily concluded that the blockchain has a huge impact on the performance of the supply chain however when it comes to operation management, the blockchain provides a lot of advantages over the existing systems. According to [22], enterprise resource planning, radio frequency identification, and the blockchain are regarded as complementary technologies and it is extremely important to analyze their best combination so that we can maximize effect and impact. According to [20], there are four barriers to blockchain development-enabled SCs are interested-organizational organizational, technical as well as external variables. There is no doubt that despite these barriers, blockchain technology is extremely useful as the driver of digitization in the SC [20].and development in these areas continue to push the boundaries of what is achievable and drive improvements in their real-world applications.

4) Blockchain Technology and supply chain transparency: As shown in Fig 4 and 5 the field of the supply chain, blockchain plays a crucial role in solving two major issues based on transparency, traceability, and irreversibility of transaction data. The two major issues of the supply chain are the difficulty and inadequacy in moving and claiming responsibility because of the insufficient information transparency and the inferior product quality that is not easy to be eliminated because of the multi-zone and long-term characteristics of the logistics [23]. For better tracking and reporting, blockchain plays a crucial role it also allows for better transparency in logistics. Moreover, the company can be benefited by improving the delivery timeline [24]. The wide distribution of supply leads to an increased risk of mismatch conflict and inconsistency related to the old fashion supply chain. To eradicate this issue, blockchain can play a crucial role and the implementation of GPS-based vehicle tracking can be useful by integrating it with blockchain technology. Moreover, blockchain technology is also a good option for logistics as there is the involvement of vehicle location tracking to reduce cost and increase efficiency [17]. In the field of manufacturing, blockchain technology offers a lot of potential by assuring security transparency as well as stability that has no central data storage Technology [2]. Blockchain technology can prove to be better than traditional centralized solutions by offering promising results in the organization and economic criteria.

5) Blockchain Technology and supply chain flexibility: The present supply chain functions are in a more complex and uncertain business environment than before. Customer expectation is very high because of the product diversity and the short Product life cycles. All these domains require flexibility in the supply chain and if the supply chain is flexible then the company and its supply structure are required to adapt to the changes in the environment [25]. Flexibility in the supply chain is defined as the ability to meet and react to a wide customer base to gain a competitive advantage against competitor. There is no doubt in the fact that the business has experienced a highly ambitious situation because of continuous change [26]. The government can make use of flexibility so that it can adapt and respond quickly to the massive change of the absence of good information. In the supply chain, it is necessary to create a

FIG. 2

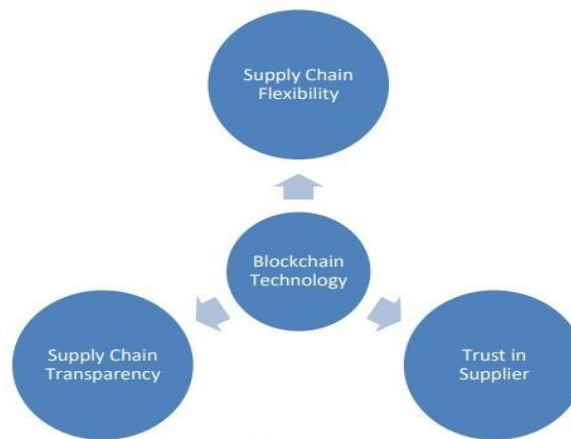


Fig. 1. Blockchain Utilization in Supply Chain [22].

flexible one so that the company can achieve a sustainable competitive advantage in the present environment that calls for dynamism, uncertainty, and unpredictability. Moreover, if there is a flexible supply chain then the company can be assured of an improved delivery process and the product can be easily transported to the market in the required quantities [27]. Moreover, the improved supply chain can help in handling the challenges of the environment because business transactions are becoming much more volatile and global. When an organization can properly respond to and adapt to disruption and demand then it can achieve flexibility across the total supply chain against the competitor to cater to the customer need. To achieve flexibility in internal and external supply chains, it is necessary to focus on rapid economic and technological development [25]. Companies that have a flexible supply chain will find it easy to respond faster in situations that are not certain. Moreover, a flexible supply change can also enhance the company's ability in presenting the product and services clearly and effectively to the customer and meet their needs [27]. One of the most suitable technologies for achieving flexibility is blockchain technology by facilitates tracking and tracing in the various stages of production. The implementation of blockchain technology in the supply chain lies at specific contact points [28]. Blockchain technology will allow the organization to control data security for all the supplies in transactions. Apart from this it can also enhance the visibility of the supply chain and offer real-time data sharing on the network. Therefore, the blockchain can assist in supply chain flexibility strategies by meeting the various numbers of stakeholders that are affected due to an outage [29]. The technology can also integrate the various supply chain processes and can enhance production and management which would result in a more realistic supply and inventory management. Another advantage of using blockchain technology in the supply chain system is that it can offer the design-related documents that are to be shared and used [24]. All these factors will help the organization to improve decision-making throughout the supply chain as the various documents can be easily provided to all the participants.

SYSTEM REQUIREMENT SPECIFICATIONS

The system should include robust user authentication mechanisms to ensure that only authorized personnel can access and modify information within the blockchain-based supply chain platform. Different user roles, such as farmers, distributors, retailers, and administrators, should be defined with specific access privileges. The system must record all relevant transactions in the agricultural supply chain, capturing details such as product origin, cultivation practices, transportation, and sale. Transactions recorded on the blockchain should undergo validation processes to ensure accuracy and consistency, maintaining the integrity of the supply chain data. Implement a traceability feature that allows stakeholders to track the journey of agricultural products from the farm to the market. Integrate smart contracts to automate payment processes, ensuring that farmers receive fair compensation based on predefined criteria. Smart contracts should execute transparently, securely, and promptly, reducing the risk of delayed payments and promoting financial stability for farmers. Provide tools for stakeholders to manage inventory efficiently, with real-time updates on product availability, demand forecasts, and production schedules. The system should help minimize wastage, optimize storage, and streamline logistics through accurate inventory information.

TECHNICAL IMPLEMENTATION

Transparency and Traceability: Blockchain's distributed and immutable ledger ensures transparency and traceability in the supply chain. Each transaction or event, such as the production, shipment, or receipt of goods, is recorded in a secure and unchangeable manner. This transparency helps in building trust among participants, as everyone in the supply chain can access a single version of the truth. It enables stakeholders to trace the origin of products, verify authenticity, and ensure compliance with regulations. **Smart Contracts:** Smart contracts, self-executing agreements

with the terms directly written into code, play a vital role in automating and streamlining supply chain processes. They enable predefined conditions to trigger automatic actions, such as releasing payments upon delivery confirmation or adjusting inventory levels based on real-time demand data. Smart contracts reduce the need for intermediaries, minimize errors, and enhance efficiency in contract execution. Inventory Management: Blockchain facilitates real-time visibility into inventory levels across the entire supply chain. With a decentralized and shared ledger, participants can access accurate and up-to-date information about the availability of raw materials, work-in-progress, and finished goods. This transparency helps in optimizing inventory levels, reducing carrying costs, and preventing stockouts or overstock situations. Supply Chain Finance: Blockchain technology can streamline supply chain finance by providing a secure and transparent platform for managing financial transactions. Smart contracts can automate payment processes, ensuring timely and accurate settlements between parties. This reduces the risk of fraud, enhances financial visibility, and improves the overall liquidity of the supply chain. Counterfeit Prevention: The immutability of blockchain records helps combat counterfeiting by providing a secure and unforgeable record of a product's journey through the supply chain. This transparency allows consumers and businesses to verify the authenticity of products, ensuring that they are not purchasing counterfeit or substandard goods. This is particularly important in industries where product quality and safety are critical, such as pharmaceuticals and food. Risk Management and Resilience: Blockchain enhances supply chain resilience by providing a decentralized and redundant system. In the event of a disruption or failure in one part of the supply chain, the distributed nature of blockchain ensures that other nodes can continue to operate. This decentralized approach reduces the risk of a single point of failure, making the supply chain more robust and capable of withstanding unforeseen challenges such as natural disasters or geopolitical issues. Additionally, blockchain's real-time data visibility helps in identifying and mitigating risks promptly.

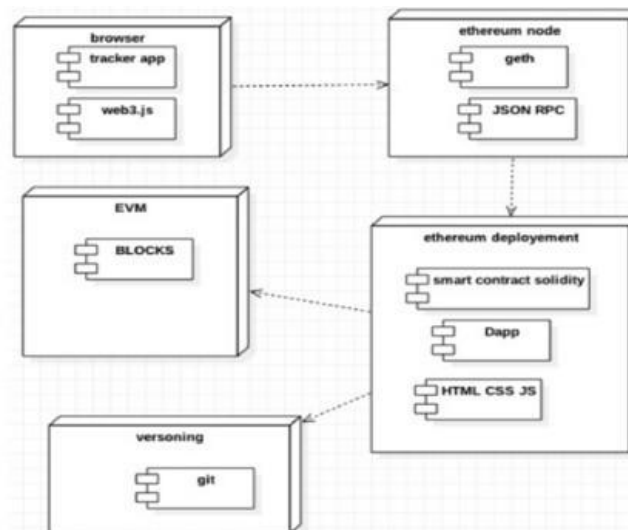


FIG. 3(Blockchain network)SMART CONTRACTS

Smart contracts are pieces of program code based on business process logic to process the transaction based covering compliances and settlement of a contract between involved stakeholders. The term Smart contract was first presented by Nick Szabo in 1994. Blockchain has used the concept of smart contract to eliminate the need of intermediaries in the business processes. The blockchain allows integration of complex rules in the form of smart contracts and transactions can be validated using multiple signature protocols using digital signatures of involved stakeholders.

A distributed application (dApp) is an interesting implementation of smart contracts that stores data and enforces multiple smart contracts on a blockchain. Conventional practices involved in Simple smart contracts require people to sign the transactions; these repetitive actions can be programmed into smart contracts and can facilitate smooth processing of real-time payments, without any manual intervention using autonomous agents. Some autonomous agents could be programmed to make intelligent decisions based on various decision parameters and they could adapt to the state of the system and act accordingly. For example, the system knows that your account balance in prepaid mobile accounts is exhausted and hence can thereby initiate a recharge immediately. These advancements not only support individual farmers in making data-driven decisions but also contribute to a more resilient and adaptable agricultural system. As the technology becomes more accessible, even small-scale farmers can leverage these tools to improve. Small-scale farmers often struggle to access markets and obtain fair compensation for their products. Blockchain can create direct links between farmers and buyers, reducing the need for intermediaries and allowing farmers to receive a more

significant share of the revenue. This direct connection can also open new opportunities for farmers to access global

markets and negotiate better terms.

BLOCKCHAIN USE CASE SELECTION AND DESIGN PROCESS

Blockchain use case selection involves many decisions based on following criteria and NITI Ayog has published a blockchain use case selection framework:

- Is there a compelling business case to reduce intermediaries?
- Are Multiple Stakeholders Involved?
- Are we working with digital assets instead of physical Assets?
- Do multiple parties require shared write access?
- Do we require high performance and rapid transactions?
- Do we intend to store non-transactional data as part of your solution?
- Do we need to rely on trusted parties for compliance reasons?
- Do we have a robust Tokenomics Model?
- Do we need the ability to control functionality?
- Should transactions be public?

Blockchain-based systems are developed in a step by step process. The whole procedure requires a clear understanding of business processes and compliance requirements of the use case to facilitate decision making.

The procedure starts with a question on whether to decentralize trust (authority) – or not. A blockchain is more suitable where no single trusted authority is mandatory and the reliable authority can be distributed or partially distributed. If the trust authority can be distributed then rules and specifications regarding trust authority needs to be identified. Otherwise blockchain is not applicable and systems can be built using traditional databases. Given the restrictions of blockchains, critical concern is configuration of computation and data storage between on-chain and off-chain components. It all depends on business requirements and volume of transactions for a use case to decide about storage and computation infrastructure required for blockchain application. A thorough assessment of workload and capacity requirements needs to be done. Capacity planning is required to estimate storage and computation for a use case.

FEATURES OF BLOCKCHAIN

Features of Blockchain Technology BigchainDB doesn't enhance, rather, it builds upon blockchain technology. It adds blockchain characteristics like decentralized control, immutability and the transfer of digital assets by starting with a big data distributed database.

- **Decentralization:** It means there is no single point of control and failure. A federation of voting nodes constitute a P2P network and works through decentralized control. Supply Chain Management in Agriculture Using Blockchain and IoT 229
- **Immutability:** It means it is more than only tamper-resistant. Data once stored can't be deleted or changed.
- **Query:** any MongoDB query can be written and run to search the contents of all stored transactions, assets, metadata.

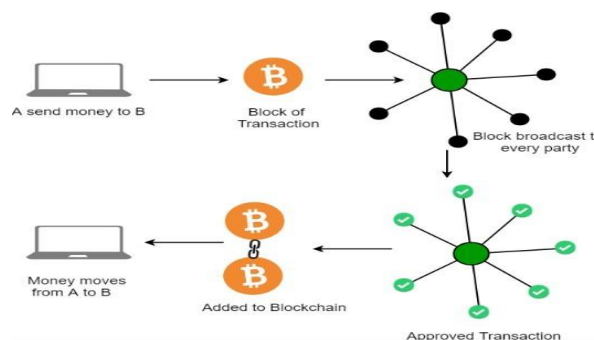


FIG. 4(TRANSACTION MODEL) HARDWARE AND SOFTWARE DETAILS

High-Performance Servers: CPU: Multi-core processors (e.g., Intel Xeon, AMD EPYC) with high clock speeds. This is crucial for efficient data processing and model training. RAM: At least 32GB, preferably more, to handle large datasets and in memory computations without bottlenecks. Storage: High- capacity SSDs for quick data access and processing. GPUs: High-end GPUs (e.g., NVIDIA Tesla, AMD Radeon Instinct) for deep learning tasks. Network Infrastructure: High- bandwidth and low-latency network setup for real-time data collection and processing. This is crucial for streaming data from APIs and Discord. Set up blockchain nodes to participate in the blockchain network, considering factors such as CPU performance, RAM, and storage for each node .

Operating Systems: Server OS: Linux distributions (e.g., Ubuntu, CentOS) for server environments. Development OS: Windows, macOS, or Linux, depending on the developers' preference and tools used. **Programming Languages and Frameworks:** Python: Primary language for machine learning, data processing, and backend development. JavaScript/TypeScript: For developing interactive front-ends, particularly if using web technologies. **Frameworks:** TensorFlow or PyTorch for machine learning models. Flask or Django for API development and server-side logic. React or Angular for frontend development if not using Streamlit. Solidity and Metamask for building smart contracts.

Data Storage and Management: SQL Databases: PostgreSQL or MySQL for structured data storage. NoSQL Databases: MongoDB or Cassandra for unstructured data like logs or chat data from Discord. **APIs and Integration Tools:** Financial data APIs (e.g., Alpha Vantage, Yahoo Finance API) for realtime stock data. Discord API for data collection from Discord bots. Integration tools and libraries for connecting various data sources and APIs. **Web Server and Application Deployment:** Web server software like Apache or Nginx if deploying a custom frontend. Deployment tools like Docker for containerization and Kubernetes for orchestration if deploying on a large scale. **Development and Collaboration.**

IMPLEMENTATION IN SUPPLY CHAIN

Blockchain adoption is gaining huge momentum as industry is evolving at a fast pace. Many startups have initiated use cases and there is significant rise in investments in blockchain projects as well specially across diverse sectors such as supply chain [50] and financial industry has been the prime sector for blockchain adoption. There are many use cases that can apply Blockchain technology for making processes more efficient and effective. With the rise in digitization and process automation organizations need to maintain a competitive advantage by adopting technological enhancements across their process that decrease Turnaround time to address speed to market and the ability to rapidly navigate changing business environments. Supply chains have huge scope for blockchain adoption and involve complex operations and transactions having product variety, global sourcing of components with strong emphasis on efficiency and effectiveness. Supply chains systems involve interaction of multiple stakeholders and participants across various business processes like manufacturing, freight and logistics, financial, sales and distribution. These systems may involve interaction with government entities and several third-party service providers. There is a requirement of a robust system to ensure quick and effective coordination with multiple stakeholders like freight forwarder, customs broker, banks and so on). Supply chains can be significantly transformed by using smart contracts to facilitate trust with the blockchain system and to ensure operations with minimal human intervention. Supply chain management is to integrate all the supply chain operations that span all movement and storage of raw materials, work-in-process inventory and finished goods from the point-of-origin to the point-of-consumption. The critical challenge is to find the best supply chain configuration such that operations can be performed in an efficient and responsive way.

COMPARISON WITH OTHER METHODS

Traditional Supply Chain Management: Traditional supply chain management methods have long been the backbone of business operations. These systems involve centralized control and are often characterized by manual record-keeping, leading to potential errors and delays. While they are familiar to industry professionals and have lower initial implementation costs, they lack real-time visibility and are susceptible to issues like data manipulation and fraud. Blockchain, in contrast, offers a decentralized and tamper-resistant ledger, addressing these shortcomings and providing enhanced transparency and traceability throughout the supply chain.

Centralized Database Systems: Centralized database systems have been employed for managing supply chain data efficiently. These systems offer quick data retrieval and are suitable for smaller supply chain networks. However, they are vulnerable to single points of failure and often lack the transparency required in modern supply chains. Blockchain's decentralized nature eliminates the risks associated with a single point of failure, ensuring greater resilience. The immutability of blockchain records also guarantees data integrity, making it a more secure option compared to centralized databases. **Internet of Things (IoT):** The Internet of Things (IoT) has revolutionized supply chain management by providing real-time monitoring and data collection capabilities. While IoT enhances visibility and decision-making based on live data, it also raises concerns related to security and data overload. Blockchain can address these concerns by providing a secure and transparent framework for recording and verifying IoT data. The combination of blockchain and IoT ensures the integrity of the data collected, enhancing security and trust in the information exchanged within the supply chain. **RFID Technology:**

RFID technology is widely used for efficient product tracking and quick identification within the supply chain. However, it comes with challenges such as costs associated with RFID tags, limited data storage capacity, and potential vulnerabilities to data manipulation. Integrating blockchain with RFID can mitigate these challenges by

creating an immutable and secure record of the data collected. Blockchain ensures the integrity of the information stored, providing a reliable and tamper-resistant history of product movements throughout the supply chain. Machine Learning and Predictive Analytics: Machine learning and predictive analytics contribute to supply chain optimization by providing data-driven insights for demand forecasting and inventory management. While these technologies offer significant advantages, they also come with complexities in implementation and dependencies on the quality and relevance of data. Blockchain can enhance the trustworthiness of the data used by machine learning algorithms by providing a secure and transparent ledger for storing historical records.

This combination improves decision-making accuracy and builds confidence in the insights generated. Blockchain and Smart Contracts: Blockchain's incorporation of smart contracts automates and streamlines various supply chain processes. Traditional methods often involve manual intervention for tasks such as contract execution and payment processing, leading to delays and errors. Smart contracts, based on blockchain, enable self-executing agreements with predefined conditions, automating these processes. This reduces the need for intermediaries, minimizes errors, and accelerates the overall efficiency of contract execution within the supply chain. Cross-Organizational Collaboration: Traditional supply chain methods and centralized databases may face challenges when it comes to cross-organizational collaboration. Sharing sensitive information across different entities requires trust and transparency.

Blockchain's decentralized and distributed ledger allows for secure and transparent collaboration among various stakeholders in the supply chain. Each participant retains control over their data, while the blockchain ensures the integrity and immutability of shared information, fostering a more collaborative and trustworthy ecosystem. Scalability and Adoption Challenges: While blockchain technology offers numerous benefits, it also faces challenges related to scalability and widespread adoption. Traditional methods, being well-established, may initially seem more scalable due to their familiarity and existing infrastructure. However, ongoing advancements in blockchain protocols and increased awareness are addressing these challenges. As scalability solutions and standardization efforts progress, blockchain's potential for revolutionizing supply chain management becomes more achievable, promising a future where its advantages can be harnessed on a broader scale.



FIG. 5(Advantages)APPLICATIONS

Blockchain technology has found applications across various industries, and supply chain management is one area where its impact has been particularly significant. Here are some key applications of blockchain in supply chain management: Provenance Tracking and Traceability: Blockchain provides an immutable and transparent ledger, allowing for the tracking and traceability of products throughout the entire supply chain. This is especially crucial in industries like food and pharmaceuticals, where knowing the origin and journey of products is essential for compliance, quality control, and consumer safety. Blockchain ensures that each transaction or movement of goods is recorded and cannot be altered, providing a reliable provenance trail. Anti-Counterfeiting Measures: The tamper-resistant nature of blockchain helps in preventing counterfeiting by ensuring the authenticity of products. By recording every step of a product's journey on the blockchain, stakeholders can verify its legitimacy, reducing the risk of counterfeit goods entering the supply chain.

This is particularly relevant in industries such as luxury goods, electronics, and pharmaceuticals. Streamlining Supply Chain Processes: Blockchain's smart contracts automate various supply chain processes, from order processing to payment settlement. This automation reduces the need for intermediaries, minimizes errors, and accelerates transaction times. Smart contracts can be programmed to execute predefined actions when specific conditions are met, improving the overall efficiency of supply chain operations.

Inventory Management and Demand Forecasting: Blockchain enhances real-time visibility into inventory levels by providing a decentralized and shared ledger. This visibility is crucial for optimizing inventory levels, reducing carrying costs, and preventing stockouts or overstock situations. Additionally, by integrating with other technologies such as IoT devices and sensors, blockchain facilitates more accurate demand forecasting through the analysis of real-time data. **Supply Chain Finance:** Blockchain facilitates secure and transparent supply chain finance by automating payment processes through smart contracts. These contracts can be programmed to trigger payments upon the completion of predefined milestones or the delivery of goods. This not only accelerates payment cycles but also reduces the risk of fraud and disputes in financial transactions between different parties in the supply chain. **Cross-Border Transactions and Global Trade:**

Blockchain simplifies and secures cross-border transactions by providing a decentralized and trustworthy platform. Smart contracts can automate the documentation and compliance processes involved in international trade, reducing paperwork and delays. This is particularly beneficial in optimizing customs clearance procedures and ensuring compliance with regulations in different countries. **Collaborative Supply Chains:** Blockchain facilitates collaboration among multiple stakeholders in a supply chain network. Each participant retains control over their data, but the shared ledger ensures transparency and trust. This collaborative approach improves communication, reduces disputes, and enhances overall efficiency in multi-party supply chain ecosystems. **Waste Reduction and Sustainability:** The transparency provided by blockchain enables companies to monitor and optimize their supply chain processes, leading to reduced waste and increased sustainability.

By identifying inefficiencies and areas for improvement, organizations can make data-driven decisions that contribute to environmental and economic sustainability. **Cold Chain Management:** In industries where temperature control is critical, such as pharmaceuticals and perishable goods, blockchain ensures the integrity of the cold chain. By recording temperature and environmental conditions at each stage of transportation and storage, stakeholders can verify that products have been handled according to the required specifications, maintaining quality and compliance. **Quality Assurance and Compliance:** Blockchain provides a secure and unchangeable record of product information, ensuring compliance with quality standards and regulations. This is crucial in industries where adherence to specific standards is mandatory, such as healthcare, aerospace, and automotive. Blockchain helps in automating the documentation and verification processes, reducing the risk of non-compliance. These applications highlight the versatility and transformative potential of blockchain in supply chain management, offering solutions to long-standing challenges and contributing to increased efficiency, transparency.

RESULTS AND CONCLUSIONS

The integration of blockchain technology into supply chain management has yielded noteworthy results, fundamentally transforming traditional practices and addressing longstanding challenges. One key outcome is the significant enhancement of transparency and traceability throughout the supply chain. The immutable and decentralized nature of blockchain enables a transparent and tamper-resistant record of every transaction and movement of goods. This has proven invaluable in industries where provenance tracking is critical, such as food and pharmaceuticals, ensuring adherence to quality standards, compliance, and consumer safety.

Blockchain technology offers significant potential to revolutionize agriculture by enhancing transparency, traceability, and trust across the supply chain. It can improve food safety, reduce fraud, and promote sustainability by allowing stakeholders to track the journey of agricultural products from farm to table. This traceability helps consumers make informed decisions, supports fair trade practices, and enables efficient recall procedures in case of contamination or other issues.

Furthermore, blockchain can streamline processes, reduce costs, and facilitate the adoption of smart contracts for automated transactions. It empowers small-scale farmers by giving them direct access to markets and reducing the role of intermediaries, thereby increasing their profitability.

However, to realize these benefits, several challenges must be addressed, including scalability, interoperability with existing systems, regulatory compliance, and ensuring the technology is accessible and affordable to all stakeholders, especially small-scale farmers. Collaboration among industry players, government agencies, and technology providers is crucial to create standards and frameworks that promote adoption while maintaining the integrity and security of the blockchain ecosystem.

In conclusion, blockchain in agriculture has the potential to create a more transparent, efficient, and equitable industry. Its successful implementation will require a concerted effort to overcome technical and logistical challenges,

but the benefits for consumers, farmers, and the environment are significant. As blockchain technology matures and integrates with other emerging technologies like IoT and AI, its impact on agriculture is likely to grow, leading to a more sustainable and resilient food system.

Blockchain technology has the potential to transform agriculture by enhancing transparency, traceability, and trust throughout the supply chain. It can boost food safety, reduce fraud, and encourage sustainable practices by allowing stakeholders to track products from farm to table. Consumers gain the ability to verify the origins and certifications of their food, leading to increased trust and the empowerment to make informed choices. This transparency also supports sustainability and fair trade practices, allowing for quicker recall procedures in case of contamination or other issues.

Blockchain can streamline agricultural processes, reducing costs and automating transactions through smart contracts. This efficiency benefits everyone, from producers to consumers, by eliminating unnecessary intermediaries and reducing waste. Small-scale farmers, in particular, can connect directly with markets, enhancing their profitability and market reach.

However, several challenges must be addressed for widespread adoption. Scalability, interoperability with existing systems, regulatory compliance, and equitable access to technology are among the key hurdles. Addressing these requires collaboration among industry stakeholders, technology providers, and governments to create standards that ensure security and accessibility.



FIG. 6(Blockchain awareness graph)

Despite these challenges, blockchain technology's potential to transform agriculture is significant. As it matures and integrates with other technologies like IoT and AI, blockchain's role in creating a more efficient, sustainable, and equitable agricultural industry is likely to grow, benefiting both producers and consumers.

In addition to its benefits in transparency and efficiency, blockchain can also foster innovation in agriculture. By combining blockchain with Internet of Things (IoT) devices and artificial intelligence (AI), farmers can collect real-time data on crop growth, soil conditions, and weather patterns. This data, when securely recorded on the blockchain, can be shared among stakeholders to optimize agricultural practices and predict crop yields.

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