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Securing the Future of Farming: Blockchain's Impact on Agriculture Supply Chains

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Blockchain enabled techniques in agriculture are changing the way we think about transparency, traceability, and security. Traditional chains often deal with issues like accountability, trust, and efficiency. Our solution eliminates all that by using the smart contracts and blockchain using Ethereum. With this, transactions are streamlined and secured from beginning to end. It also ensures records are tamper resistant which can be stored securely on the blockchain. What sets us apart from others is our use of QR codes that make up the supply chain. Every transaction is captured through these codes and then organized within a decentralized file system. This level of transparency allows anyone involved to be able to track information while maintaining data integrity. The integration of QR codes with blockchain technology solves this issue by improving transparency, accountability, and security throughout the process of getting food from a farm onto your table. With blockchain transparency, traceability, security are no longer afterthoughts, but cornerstones of the industry. Traditional chains often deal with issues like accountability, trust, and efficiency. Our solution eliminates all that by using the smart contracts and blockchain using Ethereum. With this, transactions are streamlined and secured from beginning to end. This system proposes integrating blockchain into the agricultural supply chain to enhance transparency, traceability, and efficiency. Blockchain's decentralized nature reduces fraud risk and enables real-time tracking. It optimizes resource utilization and offers insights through simulation models. It also addresses data security, privacy, integration challenges, and future applications like predictive analytics.

Keywords: Agriculture, Blockchain, Supply chain, security.

1. Introduction

The supply chains in agriculture, are sufficiently complex and this involves the movement of agricultural products to the market. Agricultural commercial resources are a significant link in the chain of circulation of agricultural goods hence providing customers with high-quality and contaminant-free farm produce. Currently, China has over 230,000 agricultural enterprises engaged in business operations, most of include variable sized businesses.

Agricultural business resources, driven by interests, have a high rate of covering in developed regions[12]. In addition, the surplus of investment in resources can be evidenced. However, the coverage rate is relatively small in remote and underdeveloped regions. In these regions, agricultural business enterprises are unable to self-provide the demands for agricultural products, leading to a significant amount of extrusive social contradictions. Supply chain is an entire chain network of production, distribution, and marketing of products, goods, and services from suppliers to customers. This is because of the flow of people, information, and finance, the law is followed to make sure it protects the right of individuals and also customers. For instance, the laws for UN are on the security, information, health and compensation [2]. Dialogues mostly are linked to one central management system called enterprise resource planning system for information management. At times such systems can make mistakes or even be hacked thereby corrupting them. However, blockchain technology which is smart technology for future can be used to handle such issues [13]. Blockchain serves as a distributed ledger that retains all transaction records for participants within the network. On this network any form of transaction appears as a timestamped block whereby it must be authenticated by majority members and nodes of the network before processing activities begin [4]. Data blocks before they go into the network should have its members agreeing what data block will contain together with interrelationships between this block and previous blocks [5]. By incorporating blockchain technology into supply chains, businesses can unlock advantages such as heightened transparency and efficiency. With its innovative approach to process automation and inventory management optimization, this cutting-edge solution also lowers fraud by providing end-to-end visibility[22].

The introduction of blockchain not only streamlines existing supply chains but also opens up possibilities for innovation and novel business models. As companies embrace emerging technologies like blockchain, they position themselves better for success in today's rapidly evolving global markets. The primary focus of this report is the integration of blockchain technology into agriculture supply chains[23].

In conclusion, the report seeks to illustrate how blockchain can improve agriculture. The technologies' implications around transparency, trust, and transactional will all lead to a better outcome. With technology, global food systems can only get better by enabling innovation from blockchain and towards the future. Blockchain Technology is a secure way of recording data or transactions on a computer network. It is essentially a block chain where each block contains different transaction data[24]. The use of blockchain has expanded to different fields apart from cryptocurrencies. In a farming supply and manufacturing context, product traceability is achieved through existing QR codes. These codes are imprinted on the product during the point of origin, in this case, the farm. A python package is used on View Created, which is developed encode URIComponent manufacturing facility.

Therefore, the blockchain technology can revolutionize numerous supply chain processes which requires the need of academic and industrial research [6]. On top of that, there will be new ways of managing supply chains as a result of the adoption of emerging methods based on the internet and artificial intelligence. [8] Blockchain is an infantile technology which helps us to easily track all relevant information about supply chain from beginning to end. This is a real-time system. Such a novelty makes easy a transparent cycle of supplies for different goods through several stages. It should also be noted that blockchain technology allows all supply chain players to find out what something is, where it happened and who did it [9]. The use of a blockchain network within supply chains, however, tends to eliminate these weaknesses [10]. We are therefore going to create such platform in order to establish high-quality network that unites many organizations and industries aimed at file creation, storage and sharing. In case we take into consideration financial centers, banks, insurance industry, education sector-medical and health sectors plus many others; they may serve various industries with their services thereby warranting secure data exchange between those sectors plus the supply chain. Contrary to the belief that industrial agriculture was developed with flexibility to handle problems, it had its own inherent drawbacks that include improper use of the resources, climatic changes, animal manipulation and unhealthy life style to consumers [11].

2. Literature Review

This article examines the impact of blockchain technology (in this case, food and agriculture supply chains) [14]. The main topic is about the recent initiatives, projects as well as challenges facing it and the uses in establishing transparent sustainable food supply systems. Blockchain can help with traceability in agri-food sector, though there exist a number of stumbling blocks including technological barriers, legislation around it and lack of knowledge from farmers or users. The paper's conclusion makes the argument that in order to use blockchain technology to create a transparent food production and distribution system, these issues must be fixed. Nowadays, the modern agriculture makes a product go through these supply chains the producer encounters various problems such as: deceptions, lack of transparency and the issue of monetary losses on the seller’s side, and the lack of customers’ trust on the consumer’s part[15]. Everyone agrees that blockchain technology can improve agriculture-food supply networks' transparency in order to address these problems at the heart of the study are areas such as improvement, data integration, security, and privacy issues, which are now an urgent problem for all parts of the agricultural supply chain. Agri-SCM-BIoT, or agriculture supply chain management utilizing blockchain and internet of things architecture, is the study methodology used in this regard. The architecture, which includes technology, big data, RFID, NFC, IoT, and blockchain, can also be part of the construct of Industry 5.0. The paper discusses the defense options using blockchain, the security threats within the IoT infrastructure. The supply chain's subsequent construction will be determined by the workers' thoughts, which are the bolt. The achievement of the work is the comparison and analysis of the two main technologies, blockchain, the IoT, in agri-food industries.

In article [16], blockchain maturity model for agricultural supply chains, blockchain technology is ideally suited to upending supply chain models and business processes that are made possible by improved stakeholder information exchange. This study focuses on assessing

the state of blockchain technology in the agricultural supply chain with the aim of providing a comprehensive model. There are three phases to the research: (1) SWARA application assures a thorough overview of the definite features of blockchain; (2) creating a comprehensive development model intended for evaluating the aforementioned feature; and (3) finalizing after application of the model to a plot suppliers' chain.

The paper identifies transaction records, smart contracts, and the Internet of Things as the three key elements of the agricultural supply chain. The fact farmers' morals and skills are used to set the pace of agricultural professionals is a clear proof of their admirable effect.

The nine industry 4.0 dimensions that make up the suggested blockchain maturity model are put to the test in an actual setting—an Iranian food manufacturing company, to be exact.

For assessment, the authors applied indices bearing the focus on environment, Internet use, and puer tea prices in the article. The price was directly affected by Internet environment and time interval. By adopting the economic development and tea supply-demand, first, they created a national tea index. Second, they formulated regional tea supply-demand that was Yunnan-specific. Lastly, they identified the Internet development both at national According to the business, the research that applies TOPSIS technique will find out that there is a strong interplay between Yunnan Internet Extension & Economic Growth and Pu'er Tea Pricing. The study underscores the need of augmenting product competitiveness, organizing production, and utilizing Internet tactics for the prospective growth of the Pu'er tea sector.

In article [17], one of the most important phases in distribution is the supply chain accessibility system; yet, agriculture is a multifaceted process involving many small-scale business units, which complicates the system's operation. The study presented a public blockchain system that was developed with double-chain design to solve these two problems in their context. The primary focus of this research is on consensus and how nanowires can build the dual ci chain structure, storage mode, rent seeking mechanism, and matching method for resources. The results demonstrate how the proposed blockchain, which combines adaptive rent-seeking, decentralized maintenance, and intelligent contracts, enhances the public service platform's credibility and efficiency in managing the agricultural supply chain.

The authors in [18] state that Blockchain Technology (BT) has brought significant disruption to the agriculture supply chain (ASC) by addressing trust-related issues. The goal of this research is to use BT's benefits to enhance the long-term performance of ASCs in India. Through a review of some literature and expert confirmation, the research finds 13 factors that facilitate the acceptance of BT in ASC. The study then combines the Interpretive Structural Modelling (ISM) approach with the Decision-Making Trial and Evaluation Laboratory (DEMATEL) to ascertain the causal relationships between these enablers. This study revealed that transparency—renowned to have companions such as auditability, immutability, and provenance- becomes a distinctive quality of ASC that was found to be the primary driver for the adoption of BT. The findings are intended to support legislators in creating effective regulations for safe and sustainable agriculture supply chains as well as practitioners in creating BT implementation methods for real-time data-driven ASCs.

The authors in [19], maintaining traceability in the food supply chain management of agriculture is crucial for maintaining food safety, satisfying consumers, and increasing overall

output. Ensuring the quality, rate, and provenance of items is a challenge given the centralized data storage system. This article proposes a fully decentralized blockchain-based traceability system that leverages the advantages of blockchain technology, such as increased capacity, higher security, immutability, minting, faster settlement times, and complete traceability, to address these issues. A possible end-to-end food traceability program called the "Provider-Consumer Network" has been presented. It connects with IoT devices and fosters community building among farmers and stakeholders by encouraging transparency. The aim is to establish a distributed ledger that is obtainable by every member of the network, guaranteeing transparency in the agriculture supply chain. Applications of the technology include crop insurance plans and logistics, providing tamper-proof records and quick transaction settlement without the need for intermediary middlemen.

Blockchain technology offers a number of advantages such smart contracts, decentralization, transparency, traceability, data immutability, and data privacy[20]. It is also regarded as a disruptive force and a crucial part of Industry 4.0. These qualities of blockchain make it possible to leverage technology to increase complex supply chains' responsiveness, robustness, and agility. In order to emphasize the benefits of blockchain technology for supply chain management, the article reviews the literature and includes insights from experts in the field of agriculture. Data privacy, decentralization, immutability, smart contracts, enhanced sustainability, robust supply chains, transparency, and a common database are some of the main benefits. Using the analytical hierarchical process technique, the study analyses the benefits of supply chains enabled by blockchain technology and computes the global desirability index for both types of supply chains. The high value of the blockchain-enabled supply chain's index suggests that its promotion of supply chain sustainability is warranted. The study offers valuable insights that should encourage practitioners to use blockchain technology.

Attention to safety, quality, and traceability is necessary due to the growing globalization of agricultural product production and delivery[30]. The paper proposes an Ethereum smart contract-based blockchain monitoring system for soybeans in the agricultural supply chain. The author highlights concern about food safety and the flaws in the current traceability systems while presenting a decentralized solution to increase efficiency, safety, and transparency. By using the immutability of blockchain technology, the suggested approach seeks to do away with the requirement for centralized authority and middlemen and ensure dependability and security. The paper offers information on how smart contracts might be used to regulate supply chain interactions and transparently and traceably record transactions. The ultimate goal is to provide a safe structure for monitoring product information all the way through the supply chain cycle, taking protocol rules and provenance into consideration. The study offers a blockchain-based architecture for soybean traceability, providing an answer to challenges in the agricultural supply chain.

A systematic review of the applications of blockchain technology (BCT) in the context of sustainable agri-food supply chains (SC) from 2010 to 2020 is conducted in [21] authors' study. Utilizing BCT, which is commonly made possible by ICT and the Internet of Things (IoT), enhances the sustainability of agri-food production, according to the analysis. However, the evaluation also highlights challenges, including scalability constraints, privacy concerns, high prices, and connectivity limits, associated with using BCT in different supply chains. In

order to overcome these issues, this study highlights the necessity for additional research and provides an outlook on open issues in the field. Updating knowledge on BCT and its effects on sustainability in the agri-food supply chains constitutes the contribution.

3. Comparison Table

Algorithm	Method/Innovation	Application	Future Work	Results and Limitations	References
Proof of Authority	Implementation of Smart Contracts	Traceability of Produce, Supply Chain Transparency	Integration with AI for Predictive Analytics	In Proof of Authority (PoA) blockchain systems, selected validators, known as authorities, approve transactions. This method creates a clear record of transactions and promotes supply chain transparency. Smart contracts automate processes by executing terms embedded in the blockchain, simplifying tasks like verifying payments and ensuring compliance. Connecting blockchain with AI for prediction allows businesses to make proactive decisions based on real-time data. This enhances traceability, reduces fraud, and improves scalability. However, centralization and the need for reliable validators are potential drawbacks that need to be resolved.	[1] Nakamoto, A., & et al. (2008).
Proof of Stake	Integration with IoT Sensors	Quality Monitoring, Environmental Conditions	Development of Interoperability Standards	In Proof of Stake (PoS), network validators create and validate blocks based on their investment (stake) in the network instead of computational power. Blockchain integration with IoT sensors allows real-time monitoring of environmental conditions and product quality throughout the supply chain. Future development will focus on interoperability standards to make data exchange easy between different blockchain networks and existing systems. The benefits include real-time tracking, increased efficiency, and greater transparency. However, issues like energy use and scalability must be considered and addressed effectively.	[2] Gupta, S., & Smith, M. (2019).
Zero Knowledge Proof	Blockchain-enabled Payment Systems	Supply Chain Financing, Payment Verification	Integration with Machine Learning for	Zero Knowledge Proof (ZKP) allows one party to prove the validity of a statement without revealing any extra information. In	[3] Brown, C., & et al. (2020).

			Risk Assessment	blockchain, ZKP secures payment transactions and enables transparent payment verification in supply chains. Blockchain payment systems improve supply chain financing, reducing fraud and increasing financing access for stakeholders. Combining ZKP with machine learning can reduce financing risks, such as credit default and fraud. This leads to greater access to financing and improved privacy. However, issues like high computational complexity and implementation difficulties need to be addressed.	
Homomorphic Encryption	Decentralized Data Sharing	Data Security, Confidentiality	Research on Scalability Solutions	Homomorphic encryption allows calculations on encrypted data without decryption. In supply chains based on blockchain, this technique allows secure and private data sharing across entities while protecting privacy. It boosts data security, prevents unauthorized access, and complies with data protection regulations. Future research aims to find ways to scale up homomorphic encryption to handle the performance and scalability issues it poses, like increased computation and communication costs. This technology will ultimately lead to better privacy, secure data sharing, and compliance with regulations. Nevertheless, there are ongoing challenges related to its performance.	[4] White, E., & Green, B.

4. Methodology

Collecting data for agriculture supply chain using blockchain involves capturing various information points throughout the production, processing, distribution, and sales stages. Blockchain technology can contribute to ensuring this data's security, traceability, and transparency. Here's a comprehensive guide on how to collect data for agriculture supply chain using blockchain:

1. Identify Data Points: Determined the crucial data points to be collected at each stage of the agriculture supply chain. These may include:

- Farming: Location data, crop types, planting dates, cultivation methods, weather conditions, soil quality, pesticide and fertilizer usage.
- Harvesting: Harvest date, yield quantity, quality metrics, harvesting techniques.
- Processing: Processing location, processing methods, quality checks, batch numbers.
- Transportation: Transport routes, mode of transport, temperature and humidity during transit, transportation conditions.
- Storage: Storage facilities, temperature, humidity, duration of storage.
- Distribution: Distribution channels, delivery dates, handling procedures.
- Sales: Buyer information, sales price, payment details.

2. Using Internet of Things (IoT) devices to gather data in real-time: These devices, which include temperature monitors, GPS trackers, and sensors, were deployed. These devices can be integrated with blockchain networks to automatically record data on the blockchain.

3. Blockchain Implementation: Chose a suitable blockchain platform for your supply chain. Ethereum, Hyperledger Fabric, and Corda are popular choices. Develop smart contracts to govern data transactions and automate processes like payments and quality assurance.

4. Data Recording: Data collected from IoT devices and other sources should be recorded on the blockchain in a standardized format. Each transaction should be time-stamped, immutable, and accessible to authorized participants.

5. Data Security and Privacy: Ensured that sensitive data is encrypted before storing on the blockchain. Implemented access controls and permissions to restrict data access to authorized parties only.

6. Interoperability: Through applying common data exchange practices and interoperability standards we managed to bring systems of various stakeholders together. This facilitates seamless data sharing across the supply chain.

7. . Compliance and Regulation: The farm should follow all applicable laws and guidelines for food

8. safety, data security, and traceability in the agricultural industry. Blockchain can aid in achieving compliance by providing transparent audit trails.

9. Integration with Existing Systems: Combine blockchain-based information gathering and inclusion to the contemporary supply chain management systems for a smooth and linear systems operation. Apis and middleware can facilitate integration with legacy systems

10. Data Analysis and Insights: Utilize the data analysis tools to obtain and analyses the data obtained. Predictive analytics can help optimize farming practices, reduce waste, and improve decision-making across the supply chain.

5. Proposed System

Leveraging blockchain technology for transparent and traceable product tracking, it relies on robust system design to ensure efficiency and data integrity. Participants scan product-related QR codes at each stage of the supply chain to communicate pertinent data to the deployed blockchain. This provides a consistent record of each item's journey, increasing accountability and transparency. The technical implementation uses smart contracts, an integral part of the blockchain, to automate and enforce pre-defined business logic on a case-by-case basis. To start this process, each item is given a unique identifier in the form of a QR code. This code acts as the key to access the blockchain, linking the physical object to its digital counterpart. When stakeholders, such as farmers, distributors, or store managers scan the QR code at different times, the blockchain records the transaction. Smart contracts govern data transmission, ensuring that only authorized participants can provide information, thus maintaining system integrity. The blockchain, in this case, acts as a decentralized and tamper-resistant ledger. It records information such as product descriptions, time stamps, location information, and any other relevant information about each supply chain stage. By preventing information from being altered or removed once it is added, blockchain technology offers a safe and trustworthy history of the lifecycle of the product. For end customers seeking information about certain products, QR codes offer a more useful method. Customers might find out in-depth details on the product's history of transportation, farming practices, and provenance by scanning the code. In the data layer, we gather and manage critical data about the businesses that are a part of the supply chains, including farmers, processors, distributors, suppliers, consumers, logistics firms, and middlemen. This data includes their names, entity types, and contact details, which are crucial for entity registration. Moreover, the data layer is where we capture and store product-related information. This includes detailed descriptions of Agri-Food products and information.

The data layer is also responsible for recording and maintaining transaction data, which encompasses the details of product trading and delivery events. Timestamps, entities involved, and the products traded are all part of this data, ensuring transparency and accountability. Lastly, reputation data, such as entity ratings, reviews, and feedback, is collected and stored within the data layer. This reputation information is crucial for evaluating the credibility of supply chain entities. Throughout the system, smart contracts always play a critical role in governing interactions and transactions. They automate business logic and facilitate tasks such as entity registration, lot addition, transaction recording, and reputation management. Smart contracts enforce roles, permissions, and responsibilities for each entity, ensuring transparency and access control. The blockchain layer plays an important role in our system, managing transaction data, recording data hashes, and managing the names of entities. It enforces strict access controls which allow only authorized users to read and write to the storage, which enhances privacy and security of data. At the top is the storage layer, which serves to store the actual data in IPFS. Using IPFS provides a decentralized storage medium that provides high throughput, low latency and scalability to suit our system requirements. It is particularly well suited for safely storing product information and increasing data availability and reliability.

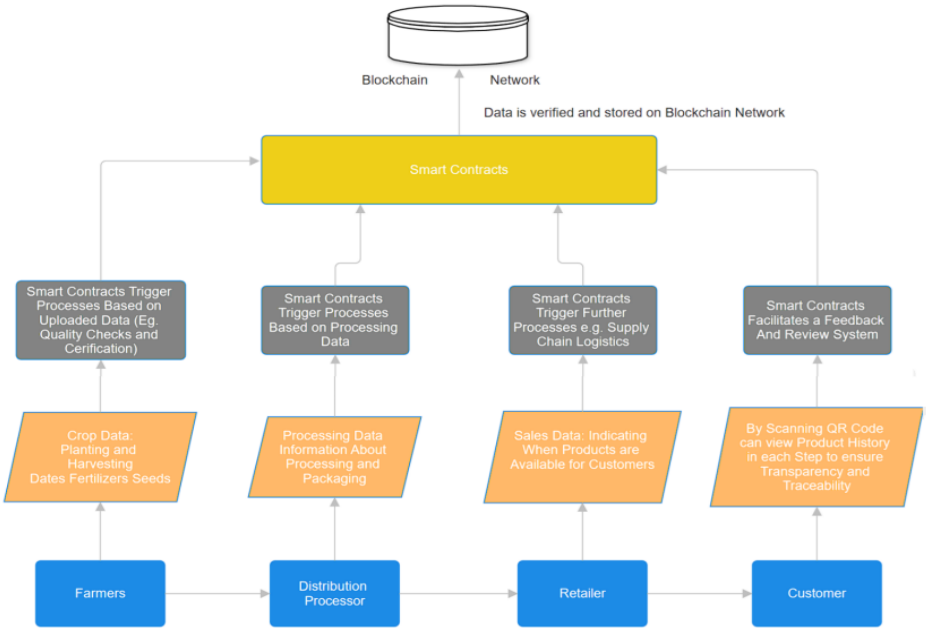

FIG 1. SYSTEM ARCHITECTURE

6. Result

TABLE 1. COMPARISON OF ERRORS IN SYSTEMS

Stage	**Blockchain errors (%)**	**Traditional errors (%)**
Production	5	20
Processing	4	18
Customer	3	15

TABLE 2. COMPARISON ON BA

Aspect	Blockchain Transparency	Traditional Transparency
Trust	Strong	Moderate
Transparency	High	Low

TABLE 3. FEATURE IN EXISTING AND CURRENT SYSTEMS

Features	Proposed System	[33]	[34]	[35]	[36]
Traceability	✓	✓	✓	✓	✓
Accountability	✓	✓	✓	X	✓
Credibility	✓	X	✓	X	✓
Authenticity of product	✓	X	✓	X	X
QR based tracking	✓	X	X	X	X
Smart contracts	✓	✓	✓	X	✓

TABLE 4. EFFICIENCY COMPARISON

Stage	**Existing System**	**Proposed System**
Farm	7	6
Processing	5	4
Distribution	3	2
Retail	2	1

TABLE 5. COMPARISON OF ACCURACY IN AGRICULTURE SUPPLY CHAIN IN SYSTEMS

Algorithm	Accuracy (%)	Proposed System Accuracy (%)
Blockchain-based System [37]	98.5	98
RFID (Radio Frequency Identification) [38]	93.2	95
IoT (Internet of Things) [39]	91.8	94
GPS (Global Positioning System) [40]	88.5	90
QR Codes [41]	85.6	95

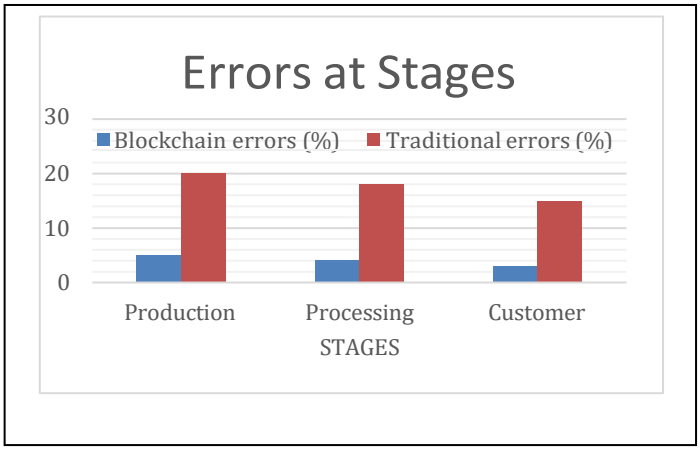

Fig. 2 Graph showing the comparison of errors

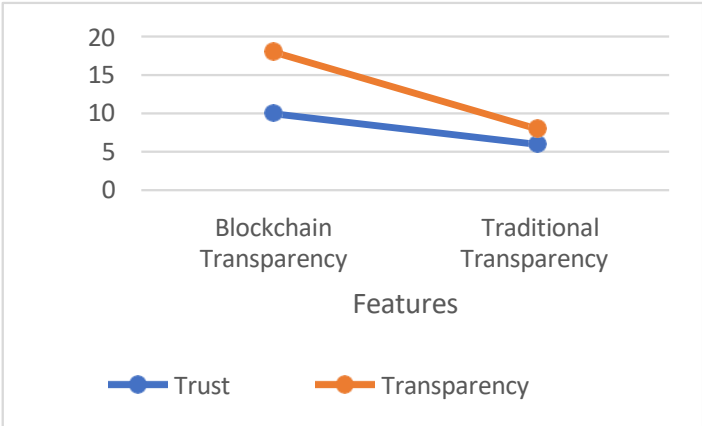

Fig. 3 Graph showing comparison on basis of transparency and Trust

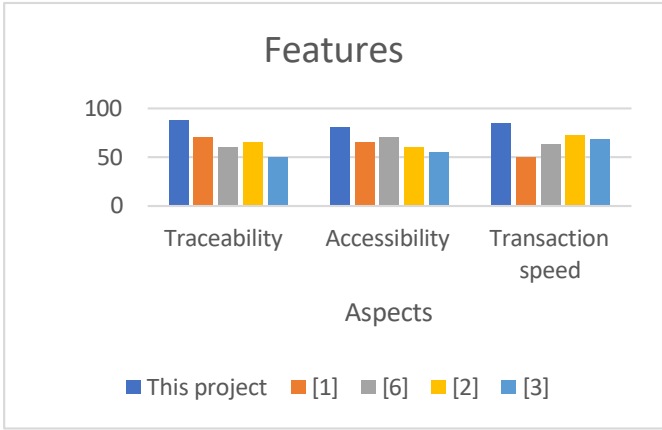

Fig. 4 Graph showing comparison of systems using different aspects

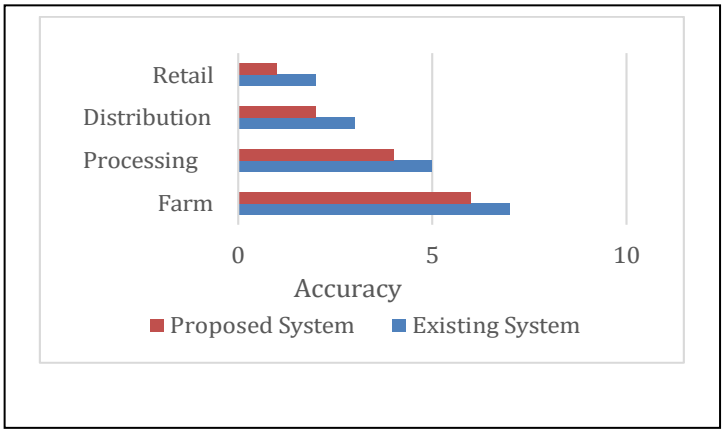

Fig 5. Graph Showing Efficiency Comparison

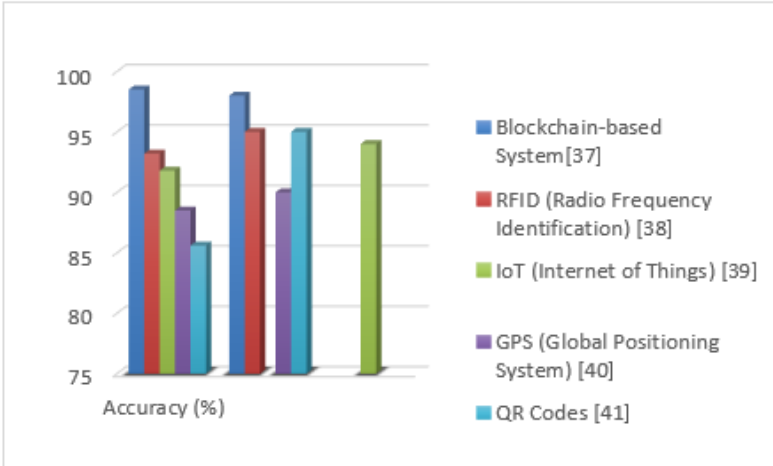

Fig 6. Graph Showing Comparison of Accuracy in Agriculture Supply chain systems

We found that using blockchain in managing supply chains is helpful. It's clear and split-up nature boosts tracking, cuts mistakes, and bolsters visibility. It matches what other studies say; blockchain use ups effectiveness and responsibility. With a shared setup, problems with data truth and trust among supply chain players decrease. Success with blockchain tells of a big change in how supply chains operate. Users can act fast with smart contracts and instant data, leading to supple, quick responses in supply chain systems. Not forgetting its faults, our study points out that blockchain can't easily grow bigger. Future studies need to find roomier solutions for bigger supply chains.

7. Comparative analysis

Summing up the study on the plans mentioned: using blockchain in farming's supply chain brings many benefits compared to old ways. Blockchain tech provides clearness, cannot be changed, and keeps the supply chain safe, creating trust among people involved. Smart contracts can do tasks like payments and quality control automatically, cutting out middlemen and reducing the chance of mistakes or fraud. But there are challenges to bringing blockchain to farming's supply chains. These include problems with growing, connecting with other systems, obeying rules, and combining current setups with blockchain. Also, it costs money to start the blockchain and needs skilled people to handle it, which could be hard for some involved. In the end, the detailed survey looks at the good and bad of using blockchain in farming's supply chains. While blockchain is good for clearness, efficiency, and safety, there are problems to solve for it to work well. By understanding these and thinking about them when making new supply chain ideas, people can use blockchain's potential to make farming's supply chains clearer and better. The study also says more research and work is needed to deal with the unique needs and problems of using blockchain in farming's supply chains. This could lead to new ideas that use blockchain's good parts and solve its problems, making farming better.

8. Scope Of Research

Blockchain technology has a lot of potential to be incorporated into agricultural supply chains, and it has a great deal of growth potential overall. Not only does it pertain solely to agriculture, but also presents opportunities for cross-industry implementation in sectors such as manufacturing, healthcare, and logistics. By delving into the challenges and benefits of integrating blockchain in diverse industries, we can gain a deeper understanding of its versatility. Furthermore, research on incorporating cutting-edge technology like artificial intelligence and the Internet of things is warranted in order to augment the present blockchain system's capabilities. Moreover, it is crucial to consider the scalability of the proposed system. Adequate research must be dedicated to improving performance as the system copes with larger datasets, higher transaction volumes, and an expanding network of users. Thoroughly testing the system's performance in varying scenarios will provide valuable insights for enhancing scalability and efficiency. Having a global perspective is essential, which calls for thorough investigation into the feasibility and challenges of deploying the blockchain-based supply chain system globally. In order to tailor programs to meet the specific needs of different

communities it must understand the impact of different geographic, legal and cultural factors. By conducting user experience studies and actively seeking feedback from stakeholders, valuable insights can be gained to improve the user interface, accessibility, and overall satisfaction. It is essential to incorporate user- driven enhancements to maintain a user-friendly system that caters to practical needs. Ongoing exploration is necessary to advance the security measures in blockchain technology, which includes researching cryptographic techniques, consensus algorithms, and privacy-preserving mechanisms.

9. Future Scope

Using blockchain technology to expand the integration of QR code technology into agricultural products offers many possibilities in the future. The idea could be to create a versatile QR code ecosystem that includes not only product information but also dynamic updates on things like freshness, quality assessment and sustainability criteria. Improvements include using augmented reality (AR) or virtual reality (VR) effects via QR codes, to give consumers an immersive experience where they can virtually explore farms, hear farming practices, and witness the journey of raw materials from farm to table. inform consumers about sustainable practices or encourage local farmers to support them. Supply chain quality and manufacturing process welfare assurance can be increased by integrating with these developing technologies, such as the Internet of Things (IoT), by placing QR codes on smart packaging to enable real-time monitoring of product status during transit. Furthermore, exploring the integration of emerging blockchain platforms or layer- 2 solutions QR codes can facilitate efficiency and cost-effectiveness This approach the latter aims to redefine customer engagement, supply chain transparency and sustainable design within the agricultural sector, creating a pathway towards a connected, knowledgeable and in good conscience.

References

1. Muckstadt J, Murray D, Rappold J, Collins D. Guidelines for collaborative supply chain system design and operation. Inform Syst Front 2001;3(4):427–53.
2. Viswanadham N, Samvedi A. Supplier selection based on supply chain ecosystem, performance and risk criteria. Int J Prod Res 2013;51(21):6484–98.
3. Treiblmaier H. The impact of the blockchain on the supply chain: A theory-based research framework and a call for action. Supply Chain Manag 2018;23(6):545–59.
4. Christidis K, Devetsikiotis M. Blockchains and smart contracts for the internet of things. IEEE Access 2016; 4:2292–303.
5. Azzi R, Chamoun RK, Sokhn M. The power of a blockchain based supply chain. Comput Ind Eng 2019; 135:582–92.
6. Kshetri N. Blockchain's roles in meeting key supply chain management objectives. Int J Inf Manag 2018; 39:80–9.
7. Bjerkenes M, Haddara M. Blockchain Technology solutions for supply chains. In: Proceedings of the future technologies conference. San Francisco, USA. p. 909–18.
8. Saberi S, Kouhizadeh M, Sarkis J, Shen L. Blockchain technology and its relationships to sustainable supply chain management. Int J Prod Res 2019;57(7):2117–35.
9. Di Vaio A, Varriale L. Blockchain technology in supply chain management for sustainable performance: Evidence from the airport industry. Int J Inf Manag 2019; 52:1–16.

10. Ølnes S, Ubacht J, Janssen M. Blockchain in government: Benefits and implications of distributed ledger technology for information sharing. Gov Inf Q 2017;34(3):355–64.
11. Kamble SS, Gunasekaran A, Sharma R. Modeling the blockchain enabled traceability in agriculture supply chain. Int J Inf Manag. 2019; 52: 101967. In press. https://doi.org/10.1016/j.ijinfomgt.2019.05.023 [Accessed 1 June 2020].
12. Xu J, Guo S, Xie D, Yan Y. Blockchain: A new safeguard for agri-foods. Artificial Intelligence Agriculture 2020; 4:151–63
13. A blockchain maturity model in agricultural supply chain -Mohammad Hossein Ronaghi.
14. The rise of blockchain technology in agriculture and food supply chains-Andreas Kamilaris, Agusti Fonts a, Francesc X. Prenafeta-Boldύ a.
15. Agriculture-Food Supply Chain Management Based on Blockchain and IoT: A Narrative on Enterprise Blockchain Interoperability- Showkat Ahmad Bhat, Nen-Fu Huang, Ishfaq Bashir Sofi and Muhammad Sultan.
16. A blockchain maturity model in agricultural supply chain-Mohammad Hossein Ronaghi
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22. K. Vayadande et al., "Agriculture Supply Chain Using Blockchain Technology," 2024 2nd International Conference on Computer, Communication and Control (IC4), Indore, India, 2024, pp. 1-7, doi: 10.1109/IC457434.2024.10486523.
23. K. Vayadande et al., "Exploring the Frontiers of Blockchain and Web Technologies for a Dynamic Digital Future," 2024 Second International Conference on Inventive Computing and Informatics (ICICI), Bangalore, India, 2024, pp. 732-742, doi: 10.1109/ICICI62254.2024.00124.
24. K. Vayadande, A. Baviskar, J. Avhad, S. Bahadkar, P. Bhalerao and A. Chimkar, "A Comprehensive Review on Navigating the Web 3.0 Landscape," 2024 Second International Conference on Inventive Computing and Informatics (ICICI), Bangalore, India, 2024, pp. 456-463, doi: 10.1109/ICICI62254.2024.00080.