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Harvest Link - Blockchain in Agriculture Supply Chain

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ABSTRACT The Agricultural supply chain (ASC) is the backbone of economies around the world, playing a vital role in driving numerous industries and serving as a major stakeholder. The involvement of diverse stakeholders, including farmers, distributors, retailers, and consumers, contributes to the inherent complexity and challenges in managing the supply chain effectively. However, the lack of transparency within the supply chain not only presents challenges but also leads to inefficiencies, wastage, and susceptibility to fraudulent practices. Recognizing these deficiencies, this paper aims to comprehensively address and rectify the shortcomings in the agricultural supply chain. The significance of these issues cannot be overstated, as they have a profound impact on food security, fair trade, and the livelihoods of countless stakeholders. In response to the growing demand for transparency in the sourcing of food products, this paper endeavors to shed light on these critical aspects, fostering improved trust, enhanced accountability, and the assurance of safety and quality in food products for consumers. To effectively tackle the identified deficiencies, the paper proposes the utilization of Blockchain technology as the primary mechanism to establish an immutable ledger for every transaction and product movement, ensuring data integrity and trust without the need for intermediaries. Each stage of the supply chain, from cultivation to distribution, will be recorded in a tamper-proof manner, allowing consumers and stakeholders to effortlessly trace the history of agricultural products. Additionally, the integration of AI is proposed to analyze blockchain data, providing real-time insights and predictions to further enhance transparency. While acknowledging potential barriers such as technical challenges, education, and government policies, this fusion of blockchain and AI stands as a promising technology to create a robust, transparent, and accountable agricultural supply chain. Efforts will be made to address these challenges and foster widespread adoption among farmers and stakeholders, realizing the envisioned positive impact on the agricultural supply chain.

INDEX TERMS Agriculture Supply Chain, Blockchain Technology, Artificial Intelligence, Food Security, Accountability, Predictive Analysis

I. INTRODUCTION

The global agricultural supply chain serves as a foundational pillar for economies worldwide, intricately weaving together various industries and stakeholders, including farmers, distributors, retailers, and consumers. However, the inherent complexity of this network, together with the lack of transparency, presents significant challenges, leading to operational inefficiencies, resource wastage, and susceptibility to fraudulent practices [1]. Considering these deficiencies, this paper endeavors to comprehensively address and rectify the shortcomings within the agricultural supply chain, and acknowledge their profound implications for food security, fair trade, and the livelihoods of countless stakeholders. The pressing need for increased transparency in the sourcing of food products propels our investigation into these critical aspects, aiming to foster improved trust, enhanced accountability, and the assurance of safety and quality in agricultural products for consumers.

In response to these challenges, our research advocates for a transformative approach, by utilizing Blockchain technology as the primary mechanism to establish an immutable ledger for every transaction and product movement in the supply chain [2]. By ensuring data integrity and trust without the need for intermediaries, this Blockchain-based system offers a tamper-proof record of each stage in the supply chain, allowing consumers and stakeholders to effortlessly trace the history of agricultural products from cultivation to distribution. Moreover, we propose the integration of Artificial Intelligence (AI) to analyze Blockchain data, providing real-time insights and predictions to further enhance transparency and decision-making capabilities.

While acknowledging potential barriers such as technical challenges, educational needs, and governmental policies, this fusion of Blockchain and AI stands as a promising technology to create a robust, transparent, and accountable agricultural supply chain [2]. This introduction sets the stage for a comprehensive exploration of our proposed solution, emphasizing its potential impact on

overcoming the challenges and inefficiencies plaguing the agricultural supply chain.

II. RELATED WORKS

A. Blockchain in Agriculture Traceability Systems

The research project thoroughly investigates the potential of blockchain technology in enhancing traceability in the agri-food area, focusing on adoption, traceability, and associated benefits. The evaluation of the literature includes a thorough examination of scientific papers, technical publications, research initiatives, and blockchain-integrated systems in the agriculture supply chain. The authors provide a taxonomy and historical summary of relevant studies, categorizing them based on smart contract usage. Furthermore, the study delves into the definitions, degrees, methods, and benefits of traceability. A complete literature evaluation is included in the process to lay the groundwork for future study. It uses interpretive structural modeling (ISM) and decision-making trial and evaluation laboratory (DEMATEL) approaches to define the supply chain's hierarchical levels and linkages. Experts from several fields contribute to the validation of enablers for blockchain technology adoption. The identified barriers and challenges, which range from accessibility issues and governance concerns to technical challenges and data privacy, highlight the importance of ongoing research and development to overcome obstacles and ensure the successful integration of blockchain technology in agriculture traceability systems [3].

B. A Survey on the Role of IoT in Agriculture for the Implementation of Smart Farming

This survey provides an in-depth analysis of IoT-based smart farming. It emphasizes the potential benefits of IoT in improving crop yields, lowering costs, and increasing efficiency by covering network technology, sensors, data analytics, and applications. The process entails a thorough survey of innovative IoT technologies, data collecting, summarizing, and analyzing the information, framework construction, and assessment of obstacles and opportunities. The inflated cost of implementation, a lack of knowledge among farmers, challenges related to the deployment of IoT devices, security and privacy concerns, hardware and networking challenges, the importance of government policies and regulations, and technological issues are among the barriers and challenges discussed. This essay is an excellent resource for understanding the current environment of IoT-based smart farming, detailing both its potential and the numerous hurdles that must be overcome for its adoption [4].

C. A Blockchain-Based Framework to Make the Rice Crop Supply Chain Transparent and Reliable in Agriculture

This article highlights the importance of rice quality and safety in the agricultural supply chain, and it introduces a blockchain-based framework to improve transparency and dependability. The survey of literature provides a complete overview of blockchain technology's impact on agriculture, with a focus on traceability, supply chain re-engineering, and IoT data allocation methods. The methodology section describes the proposed system's aims, framework architecture, and implementation stages, highlighting its reliance on Ethereum smart contracts and Rice Coin (RC) for transparent supply chain tracking. Although the paper does not specifically provide constraints and challenges, it does identify potential issues in technology acceptance, cost, consistency of data, compatibility, regulatory considerations, and education as being relevant to the effective application of blockchain in the rice supply chain. Addressing these concerns is critical for future endeavors aiming to integrate blockchain technology effectively in the agricultural sector [5].

D. Blockchain-Based Soybean Traceability in Agricultural Supply Chain

The paper provides a thorough overview of the research, citing publications such as M. Chinaka's Ph.D. dissertation and R. Kamath's article on Walmart's usage of blockchain for food traceability. The technique includes system design, architecture, and smart contract algorithms, as well as a complete structure that includes associated literature, a system overview, sequence diagrams, and implementation details. The paper recognizes critical barriers and challenges in implementing blockchain-based traceability, such as scalability issues, governance challenges with multiple stakeholders, the need for robust identity registration, privacy concerns, and adherence to a variety of industry standards and regulations. These issues are highlighted as future work areas, emphasizing the need to address them to improve the effectiveness of blockchain-based traceability systems in agricultural supply chains [6].

E. Agriculture Supply Chain Management Based on Blockchain Architecture and Smart Contracts

A Survey on the Role of IoT in Agriculture for Smart Farming Implementation delves into the technologies that support IoT-based smart farming, including network architecture, layers, topologies, and protocols. It explains how IoT allows for little human engagement in agricultural farm monitoring and maintenance, with a focus on its integration with cloud computing and other important technologies. In conjunction, this paper addresses challenges in agricultural data analytics and proposes a novel blockchain architecture aimed at preserving data integrity and providing secure storage for farmers. Consensus methods, security analysis methodologies, energy and data size testing, platform environment control, smart

contracts, and smart contract tracing and distribution are all part of the architecture. The article emphasizes potential benefits such as increased efficiency and transparency, while also emphasizing the importance of overcoming barriers such as disorganized agricultural data, technical complexity, data security, integration challenges with existing systems, and regulatory considerations for successful blockchain implementation in agricultural supply chain management. The literature review and methodology employed in this paper highlight the existing gaps in blockchain research for agriculture, as well as the thorough evaluation done to provide feasible solutions to these difficulties [7].

F. Blockchain and agricultural supply chains traceability: research trends and future challenges

Blockchain and Agricultural Supply Chain Traceability Research Trends: The researched literature provides a complete overview of current research trends and blockchain technology applications in agriculture. A thorough assessment of scientific publications published up to September 2019 finds that, despite its early stage, blockchain technology in agriculture has seen a spike in scholarly contributions, particularly from China, the United States, and Italy. The research emphasizes blockchain's potential benefits in improving traceability and transparency within agricultural supply networks. However, the lack of real-world case studies casts doubts on the economic and organizational benefits of establishing a blockchain-based platform. The study argues for the gathering, recording, and categorization of proposed approaches to identify research trends, future advancements, and problems. Data collection and analysis using the Scopus database, data selection based on inclusion/exclusion criteria, and a full literature evaluation and discussion are all part of the approach used. VOS viewer is used in the study to see the bibliometric network. In addressing constraints and problems, the article emphasizes the absence of real case studies, ambiguous economic and organizational benefits, the need to improve blockchain credibility and reputation, and the growing nature of the research branch. These findings highlight the importance of additional research, real-world applications, and case studies to fully comprehend and leverage the potential of blockchain technology in agricultural supply chains [8].

G. A blockchain maturity model in the agricultural supply chain

The research has made progress in understanding how blockchain technology can be applied to the agricultural supply chain. It does this by introducing a SWARA maturity model, which sets it apart from studies that only acknowledge the potential of blockchain. The study uses the method to evaluate maturity. Reveals that digital document applications have reached the highest level of maturity focusing on secure record keeping. On the other hand, smart contracts and IoT integration still have room, for improvement. To ensure a practical model agricultural expert were involved in a three-stage methodology that included real-world testing.

By identifying challenges in adopting technology in agriculture such as technical complexity, cost, interoperability, regulatory ambiguity, data privacy concerns, and education needs this research not only highlights these issues but also provides a foundation for overcoming them. The insights gained from this study serve as a catalyst for advancing the use of blockchain in agriculture. Decision-makers and practitioners can benefit from these findings to

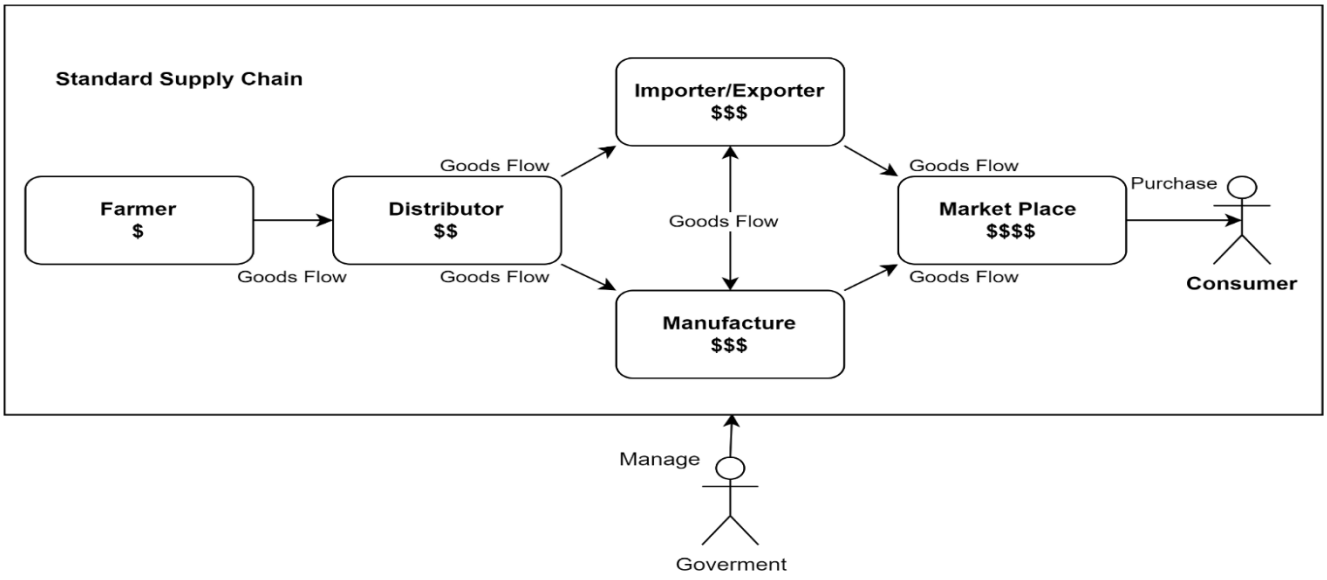

Figure 1 Standard Supply chain

implement technology and unlock its transformative potential, in agricultural practices [9].

III. PROBLEM STATEMENT

In the current agricultural supply chain system, pervasive transparency issues pose significant obstacles, jeopardizing critical aspects of the global food ecosystem. The lack of clear visibility and processing of data within the supply chain gives rise to multifaceted challenges that reverberate across food security, fair trade, and the livelihoods of stakeholders [1].

Key issues stemming from this opacity include:

Limited Consumer Information: Consumers often lack essential details about the origin and quality of the food they consume.

Supply Chain Fraud: Vulnerability to fraud within the food supply chain leads to health hazards and financial losses.

Inefficiencies in the Supply Chain: The complexity of the agri-food supply chain, involving numerous stakeholders, results in operational delays.

Income inequality: originates from the supply chain's complex size and provides opportunities that, regrettably, lead to income inequality. Because of this imbalance, hardworking workers frequently earn less while intermediaries take advantage of the situation.

Food Safety Compliance: Adherence to stringent food safety guidelines in the agri-food sector proves challenging to implement and track [10]. The application of blockchain technology in the food supply chain improves food safety and traceability. It provides a safe way to store and handle data, which makes it easier to develop and apply data-driven innovations for intelligent benchmark crop insurance and smart farming. Additionally, it may reduce transaction costs, improving farmers' access to markets and generating new sources of income [13].

Figure 1 illustrates the journey of crops from the farmer to the final consumer. Initially, the farmer cultivates the crops, but the distributor steps in, taking advantage of their position and selling the produce at an inflated price to either manufacturers or shipping companies. These companies further process the goods, adding to the overall cost of the final product for the consumer. Consequently, the product becomes significantly more expensive than it ideally should be. Throughout this supply chain, the government acts as a third-party regulator, striving to manage and optimize the system efficiently.

However, a notable drawback of this supply chain is its susceptibility to intermediaries who can exploit the system for substantial profits. The lack of seamless information flow exacerbates this vulnerability, creating opportunities for tampering within the supply chain. The ease with which tampered documents can be created adds another layer of risk, allowing individuals to take advantage of the system for their gain.

IV. PROPOSED SOLUTION

Our tailored blockchain solution introduces immutable ledgers that, once created, offer traceability in case of issues, enabling swift identification of responsible parties. This enhances accountability within the agricultural supply chain by establishing a clear link between transactions and their outcomes. The integration

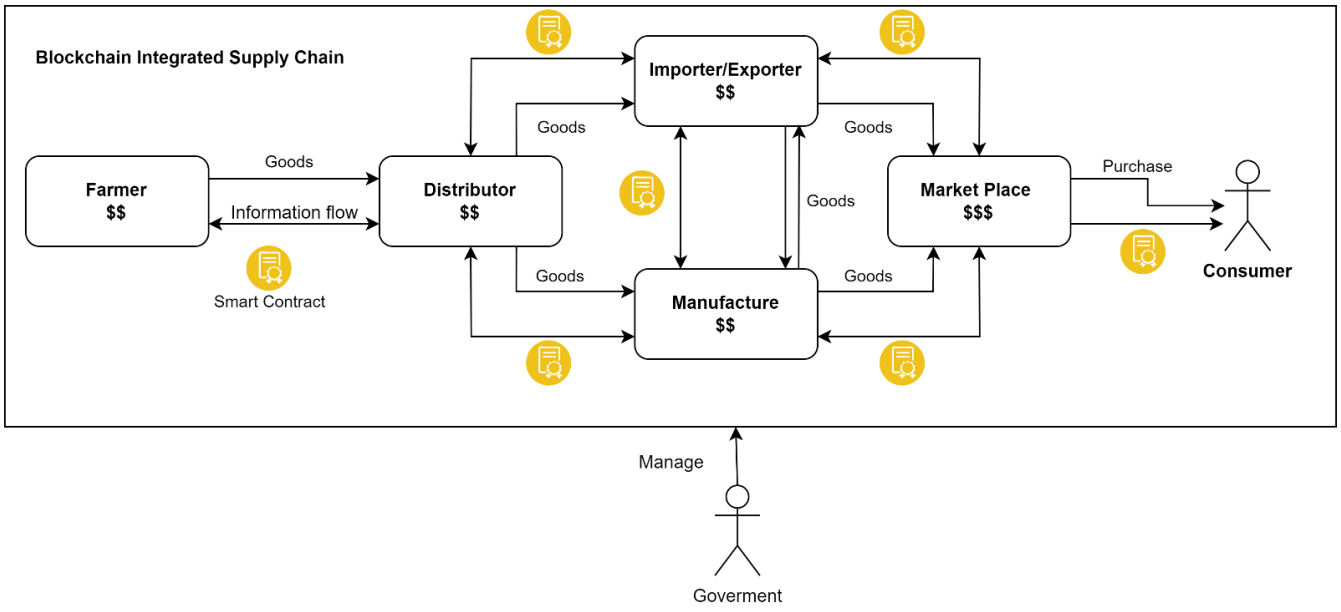

Figure 2 Blockchain Integrated Supply Chain

of AI extends the solution's impact, empowering stakeholders to predict future supply and demand, calculate land area necessities, facilitate farming processes, and enable governmental analyses [2]. By leveraging the data generated from the blockchain, our solution provides an all-around tool for informed decision-making across diverse aspects of the agricultural supply chain.

AI technology is integral to the supply chain framework, offering diverse support across multiple dimensions. Its key contributions encompass precise forecasting, comprehensive tracking, error detection, and continuous monitoring in real time. When integrated with blockchain, AI facilitates automated supply chains and provides stakeholders with access to extensive data for informed decision-making. This integration streamlines operations, enhances warehouse management practices, enables predictive maintenance, and strengthens tracking mechanisms. These advancements ultimately result in heightened efficiency and optimized performance throughout the supply chain [15].

Blockchain technology allows peer-to-peer transactions to take place transparently and without the need for an intermediary like a bank (such as for cryptocurrencies) or a middleman in the agriculture sector. By eliminating the need for a central authority, technology changes the way that trust is granted. Instead of trusting an authority, trust is placed in cryptography and peer-to-peer architecture. It thus helps restore the trust between producers and consumers, which can reduce the transaction costs in the agri-food market [13].

Designed to cater to a wide range of stakeholders regardless of educational background, our solution aims for inclusivity, ensuring a wide range of markets benefits from its influence. This adaptability reflects our commitment to creating a solution that transcends barriers, preventing resistance to accepting change. Acknowledging the diverse user base, aspects of the application demand greater user interaction and understanding. This strategic approach guarantees that users, regardless of their background, can effectively harness the full power of the application [1]. By prioritizing usability, we maximize the solution's effectiveness across different stakeholders.

The proposed solution's focus on inclusivity, accountability, and usability positions it as a versatile
and impactful tool for enhancing transparency in

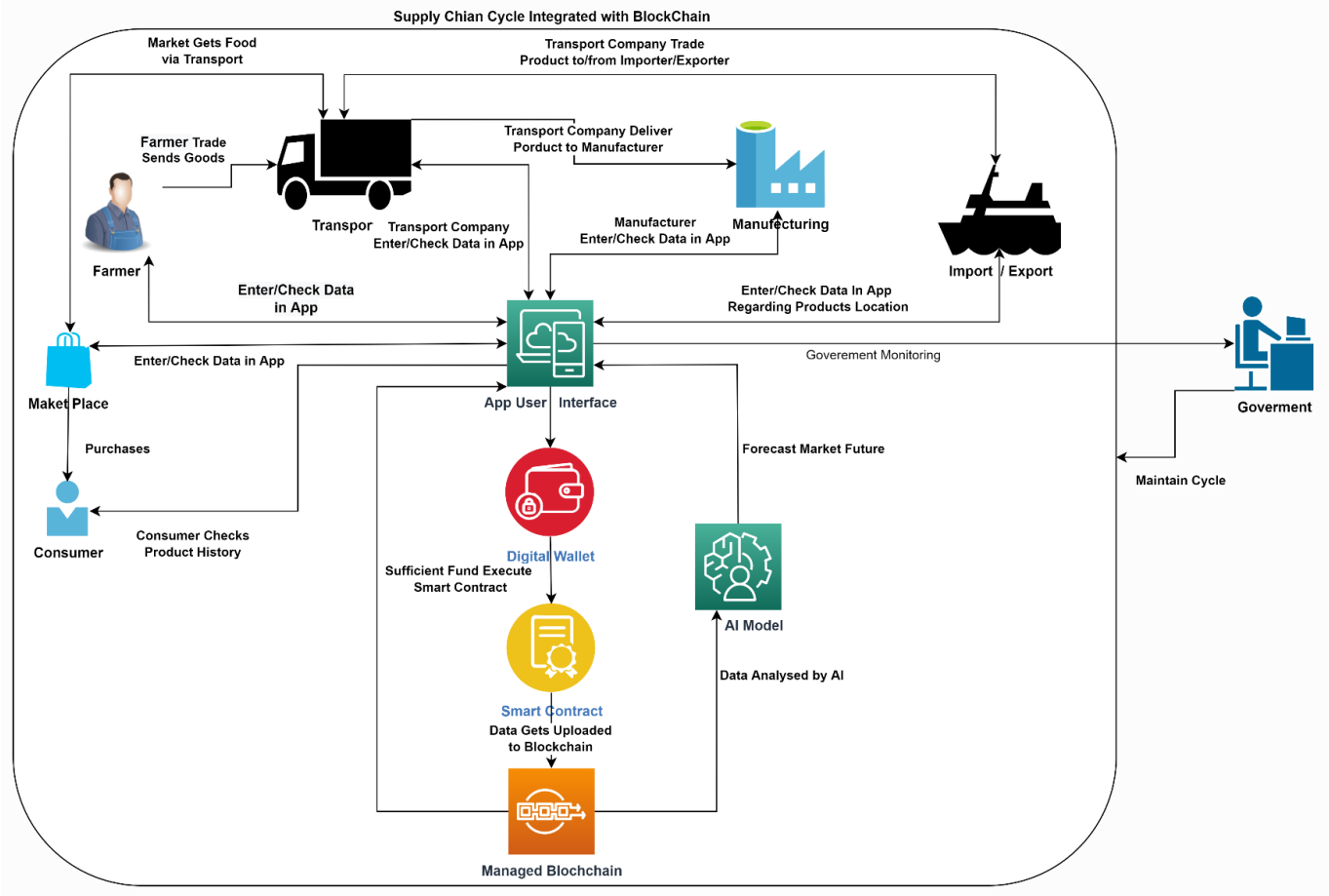

Figure 3 Harvest-Link Architecture Diagram

agricultural supply chains. As we advance, the continuous integration of user feedback and iterative development will further refine and optimize the solution, ensuring its relevance and efficacy in real-world scenarios [1].

Because the parties can deal even when they do not trust one another, we refer to the blockchain as enabling trustless networks [11]. Ethereum is the blockchain that we will utilize for our overall solution. There are a number of advantages to using Ethereum, but the most important one is that it offers the Ethereum Virtual Machine (EVM). It makes decentralized apps and intricate smart contracts possible to implement. Smart contracts, which are self-executing contracts with the terms of the agreement directly put into code, are intended to be executed by the EVM. The EVM's built-in safeguards against unwanted access and guarantees for the blockchain's integrity make it an ideal platform for the safe execution of smart contracts [12].

Figure 2 demonstrates how blockchain improves collaboration among all parties. The primary distinction from the standard practice is the seamless exchange of information and the public's ability to trust it. Customers will be able to trace the origin of their goods, and farmers will be able to see what the market will bear and sell directly to the highest bidder, cutting out the intermediary. People can purchase products at a lower cost thanks to this shift, which also makes things more equitable and reduces wasteful spending.

The utilization of blockchain technology in the supply chain offers a dependable information source to all parties involved. The information gathered from transactions helps businesses develop and succeed by enabling them to make informed decisions.

The proposed framework for the Harvest-Link project is shown in Figure 3. It describes in detail how the application tracks the movement of goods from a farmer to a factory, import/export, and transportation. This produces an irreversible record, guaranteeing reliable information and a trustworthy source.

The farmer lists goods for sale on the application to start the process, as seen in the diagram. When the highest bidder secures the goods, a smart contract that documents the transaction information is automatically executed. Once the deal is finalized, the buyer or farmer can schedule transportation, which is also promoted on the app, and the highest bidder wins. The smart contract is once more automatically carried out after the transport company accepts it. From the farmer to the customer, all stakeholders are involved in this stage of transit. Manufacturers can choose to transport their products to other nations for sale, or they can deliver them straight to market.

All of this is coordinated by the Harvest-Link application, which meticulously logs user's account statuses. As an observer, the government concentrates on this, which helps them examine the market more broadly and prepare for the future of the economy more effectively. By doing away with intermediaries, this platform helps businesses increase their cash flow and profitability.

One of the key benefits for the customer is having access to comprehensive data. When making purchases, customers can scan things to discover all their historical information kept on the blockchain, including information on the farmer who grew the product's base, the type of fertilizers used, when it was harvested, and other crucial details. By being transparent, companies give their customers the information they want to know about the goods they purchase.

Preliminary mitigation strategies are essential to address the potential risks associated with blockchain adoption in the organic food industry. Non-compliance with regulatory standards may result in legal repercussions and reputational harm, necessitating continuous monitoring, legal consultation, and auditing to ensure compliance. Additionally, fraudulent data entry poses a threat to blockchain integrity, emphasizing the importance of implementing strict verification processes and utilizing smart contracts for prevention [14]. Furthermore, thorough risk assessment and mitigation planning are crucial, particularly concerning data integrity, scalability, and privacy [14].

V. HARVEST-LINK VS STANDARD SUPPLY CHAIN

Table I
Harvest-Link vs Standard Supply Chain

Sr	Issues	Harvest-Link	Standard Supply Chain
1	Transparency	✓	✗
2	Record	✓	✗
3	Digital Currency	✓	✗
4	Intermediaries	✗	✓
5	Faster Transaction	✓	✗
6	Product History	✓	✗

Table II
Role of Stakeholder in Harvest-Link

Sr	Stakeholder	Functionality
1	**Farmer**	List items for sale on Harvest-Link application.
		Participate in bid transactions for their goods.
		Arrange transportation for sold goods.
2	**Government**	Oversee the Harvest-Link platform as a regulatory body

		Analyze market trends and data for broader economic planning
3	**Shipping**	Monitor and optimize shipping processes
		Ensure proper storage conditions during transportation
		Track cargo conditions using IoT in shipping
4	**Transport**	Participate in bid transactions for transportation services
		Execute transportation contracts automatically through smart contracts
		Set routes to take for transportation
5	**Manufacturer**	Receive raw materials from farmers or transport companies
		Send manufactured goods directly to the marketplace or export to different countries
6	**Consumer**	Scan products for detailed information on their history and origin
		Benefit from lower product costs due to a streamlined supply chain
		Make informed purchasing decisions based on transparent blockchain data

VI. **FUTURE WORKS**

Although Harvest-Link is a software platform initially, it can transform to include hardware readings as well as digital readings. This has several advantages, from obtaining new raw data for historical records to facilitating real-time decision-making abilities.

IoT in Farming: Farmers can continuously monitor their fields thanks to the integration of IoT in hardware, which makes crop production more effective. This includes information about the pH, water content, and best dates to sow and harvest the soil.

IoT in Transportation: Ensuring the safe delivery of goods in transportation frequently depends on fulfilling certain requirements. Real-time information on the condition of transportation vessels is periodically provided using IoT technology. As more data is gathered over time, this information can be extremely helpful in calculating the ideal conditions needed for different forms of transportation, including the amount of fuel needed and the most efficient routes.

IoT in Manufacturing: By integrating IoT into manufacturing procedures, industrial equipment may be better monitored and controlled. Initiative-taking maintenance plans, decreased downtime, and more efficiency might result from this.

IoT in Shipping: IoT devices can be used in the shipping sector to monitor and optimize many areas of the shipping process. This entails monitoring cargo conditions, making sure storage temperatures are appropriate, and planning shipping routes based on real-time data to maximize overall shipping process dependability and efficiency.

VII. **CONCLUSION**

In conclusion, our paper addresses the critical challenges within the global agriculture supply chain, emphasizing the complexity arising from various stakeholders and the resultant lack of transparency. The issues, ranging from operational inefficiency to fraudulent activities, have profound implications for food security, fair trade, and the well-being of stakeholders worldwide. As consumer demands for transparency in food sourcing rise, our paper plays a pivotal role in shedding light on these crucial aspects, aiming to rebuild trust, strengthen accountability, and ensure the safety and quality of food.

Our proposed solution, combining tailored blockchain technology and AI integration, offers a transformative approach to enhance transparency and efficiency in the agricultural supply chain. The introduction of immutable ledgers ensures traceability, holding accountable parties responsible in case of issues, thereby fostering a heightened sense of accountability. The integration of AI extends the solution's impact, empowering stakeholders with predictive capabilities and informed decision-making across diverse aspects of the supply chain.

Designed for both literate and illiterate stakeholders, our solution prioritizes inclusivity, ensuring a wide range of markets can benefit from its influence. The strategic emphasis on user interaction and understanding guarantees effective utilization across diverse backgrounds, maximizing the solution's potential.

As we move forward, continuous refinement through future user feedback and iterative development will optimize the solution's relevance and efficacy in real-world scenarios Our vision of progress and security for all stakeholders in the agricultural supply chain remains steadfast, and the proposed solution stands as a versatile and impactful tool for ushering in a new era of transparency and accountability.

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