iJRASET
International Journal For Research in Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 13 **Issue:** III **Month of publication:** March 2025

DOI: https://doi.org/10.22214/ijraset.2025.67778

www.ijraset.com

Call: 08813907089 | E-mail ID: ijraset@gmail.com

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 13 Issue III Mar 2025- Available at www.ijraset.com

Blockchain-Enabled Supply Chains: A New Era of Trust and Accountability

Agam Kumar Singh, Anush Shinde, Avinash Awasthi
Department of Computer Science and Engineering Malviya National Institute of Technology, Jaipur, India

Abstract: ***Blockchain technology presents an innovative solution to tackle essential challenges in supply chain management and logistics, such as the requirement for enhanced transparency, traceability, and security in various sectors. By establishing a secure and tamper-proof decentralized ledger, blockchain allows participants in a supply chain—including suppliers, manufacturers, distributors, and retailers—to exchange data in real- time with confirmed accuracy. This ability builds trust among participants since every phase of the supply chain is permanently documented, decreasing chances for fraud, mistakes, and inefficiencies. A traceability system utilizing blockchain secures product origin by providing an immutable path to it, from its source to its ultimate endpoint. This degree of secure traceability is especially advantageous in sectors like food, pharmaceuticals, and luxury items, where the authenticity and safety of products are crucial. The use of blockchain in various supply chains, including food and agriculture, pharmaceuticals, retail, and auto- motive, shows diverse applications customized to meet the specific requirements of each industry. [8] Logistics functions are further improved by smart contracts, which streamline transactional procedures like customs clearance, freight tracking, and payment settlements, consequently minimizing manual involvement and operational expenses.***

I. INTRODUCTION

In today's globalized economy, supply chain management has become increasingly complex as companies often rely on networks that span multiple countries, involve multiple stakeholders, and operate across a wide range of sectors. These complex supply chains face challenges such as lack of transparency, inefficient product tracking, vulnerability to fraud, and data security issues. Traditional systems have proven inadequate to address these challenges because they are often characterized by siloed databases and manual record- keeping, and do not provide real-time, reliable, or immutable data access to all participants. Thus, consumers, businesses, and regulators are calling for a more transparent, reliable, and efficient approach to managing global supply chains.

Blockchain technology offers an innovative solution to these problems by enabling a decentralized, secure and immutable record of transactions and product movements throughout the supply chain. Unlike traditional databases controlled by a central authority, blockchain operates on a distributed ledger system where data is verified by consensus, ensuring the accuracy and security of the information exchanged between participants. This capability addresses critical issues of trust and traceability, allowing companies to verify the authenticity and source of goods at every stage of the supply chain.

Additionally, blockchain increases transparency by giving all stakeholders access to real-time data on the location, quality, and condition of a product, which is critical for industries such as food, pharmaceuticals, and luxury goods, where security and authenticity are paramount. Through smart contracts—self-executing contracts with predefined conditions—blockchain also streamlines administrative tasks, such as customs clearance and payment settlements, reducing de- lays, errors, and costs associated with manual processing.

In this context, blockchain emerges as a powerful tool for transforming supply chain management, making it more efficient, transparent, and secure. In this paper, we investigate the process and advantages of integration of blockchain technology to supply chains, how to take up the key industries, improve operation efficiency, and have more elasticity with the basics of chain networks.

II. A REGULAR SUPPLY CHAIN

The conventional method of transferring products, services, and information from suppliers to customers via a number of interrelated phases is known as a normal supply chain. The acquisition of raw materials, manufacture, distribution, warehousing, and delivery to the final consumer are usually included in these phases. Every step entails a variety of tasks and participants who work together to guarantee that goods fulfill customer needs and arrive at their destination quickly. [5]

Information is shared between stakeholders in a typical supply chain, and the movement of commodities is frequently linear. Several intermediaries may be involved in this arrange- ment, each of whom is in charge of overseeing a distinct sup- ply chain section, frequently using disparate and occasionally incompatible record-keeping systems.A supply chain consists of several interconnected stages each having their role to perform . Below given are the stages generally used for a supply chain:

A. Sourcing and Procurement

Purchasing component and raw materials required for production is the focus of sourcing and procurement stage. Business finders, suppliers and contract negotiators who can deliver materials in required quantity, quality and price range comes under this stage only.

B. Manufacturing and Production

Turning raw materials or components into completed goods comes after procuring the materials. This can involve a number of procedures, including as packaging, quality control, fabri- cation, and assembly. Goods manufactured to specifications and prepared for the subsequent stage of the supply chain are guaranteed by effective production procedures.

C. Warehousing and Storage

After being produced, goods are frequently moved to ware- houses or other storage facilities where they are kept until they are delivered. This phase is crucial for inventory control, product security, and getting goods ready for delivery. By balancing supply and demand, warehousing enables businesses to guarantee that goods are available when needed.

D. Distribution and Logistics

Moving items from warehouses to different distribution sites, including retail locations or straight to customers, is the main focus of the distribution and logistics stage. In order to reduce expenses and delivery times, it entails managing carriers, organizing and coordinating modes of transportation (such as trucks, trains, ships, or airplanes), and streamlining routes.

E. Retail and Sales

Products enter the market and are made available for customers to buy during the retail stage. E-commerce sites, physical shopfronts, and other sales channels can all be used for this. In order to satisfy client requests and link items with end users, retailers are essential.

F. Order Fulfillment and Delivery

Order fulfillment entails selecting and packing products, processing customer orders, and organizing delivery. The product is delivered to the customer at this final physical stage of the supply chain. Last-mile delivery, in which goods are delivered straight to customers' doors, is a component of e- commerce and direct-to-consumer business models.

G. Customer service and Support

The goal of this post-purchase phase is to help clients who might have some queries, require product assistance, or wish to return goods. Good customer service can increase loyalty and satisfaction, which feeds back into decisions about distribution, manufacturing, and sourcing in the future.

H. Return and Reverse logistics

The handling of returned goods is the focus of reverse logistics. Product returns, repairs, recycling, and disposal might all fall under this category. Reducing waste, getting value back from returned goods, and preserving a satisfying customer experience all depend on efficient reverse logistics. [4]

III. CURRENT SCENARIO OF BLOCKCHAIN USAGE IN SUPPLY CHAIN

The blockchain supply chain market is projected to develop at a compound annual growth rate (CAGR) of 49.87 percent from 2024 to 2029, from an estimated USD 0.84 billion in 2024 to USD 6.31 billion by 2029. Two key drivers of market expansion are the increasing need for supply chain transparency and the surge in demand for increased supply chain transaction security. Blockchain technology's increased automation and elimination of middlemen in supply chain management would create opportunities for market expansion.

A. Block Supply chain Market Trends

1) The blockchain supply chain market share is dominated by the retail sector. Retail players' increased adoption of it to optimise their supply chain operations is expected to keep it at the top. Additionally, blockchain allows supply chain partners to know the location of their products and guarantees quality, product safety, dependability, and authenticity. These factors propel the blockchain market's expansion in the retail sector.

2) The primary driver of blockchain market expansion in the retail sector is the rise in demand for smart contracts and transparent transactions. Both online and offline transactions can benefit from the automation of payment procedures made possible by smart contracts. By elimi- nating the merchant (middleman), who charges extra for transaction authentication, it can save businesses time and money.

3) The retail sector is expected to lead the blockchain supply chain market due to the growing use of supply chain optimisation by retail operators. For example, according to a survey conducted by Eyefortransport Ltd. (left), the majority of expenditures were allocated to learning about the technology; of those surveyed, 38.2 percent of retailers, brands and manufacturers, and 55.3 percent of logistics service providers reported spending money on blockchain in the supply chain domain.

4) Walmart recently used blockchain technology to track seafood in Andhra Pradesh, India, and it intends to use this technique to increase food traceability globally. Offering a fully-managed service that makes it simple to build and administer scalable blockchain networks in retail using open-source frameworks, Amazon Web Services (AWS) is where the company first introduced its blockchain solutions.

5) In addition, the International Labour Organisation esti- mates that over 25 million individuals worldwide—47 percent of whom are in the Asia-Pacific area alone—work in and out of supply chains under forced labour circum- stances. Coca-Cola and the U.S. Department of State have chosen to employ blockchain technology to enforce labour rights along the supply chain and guarantee ethical working conditions for their products.

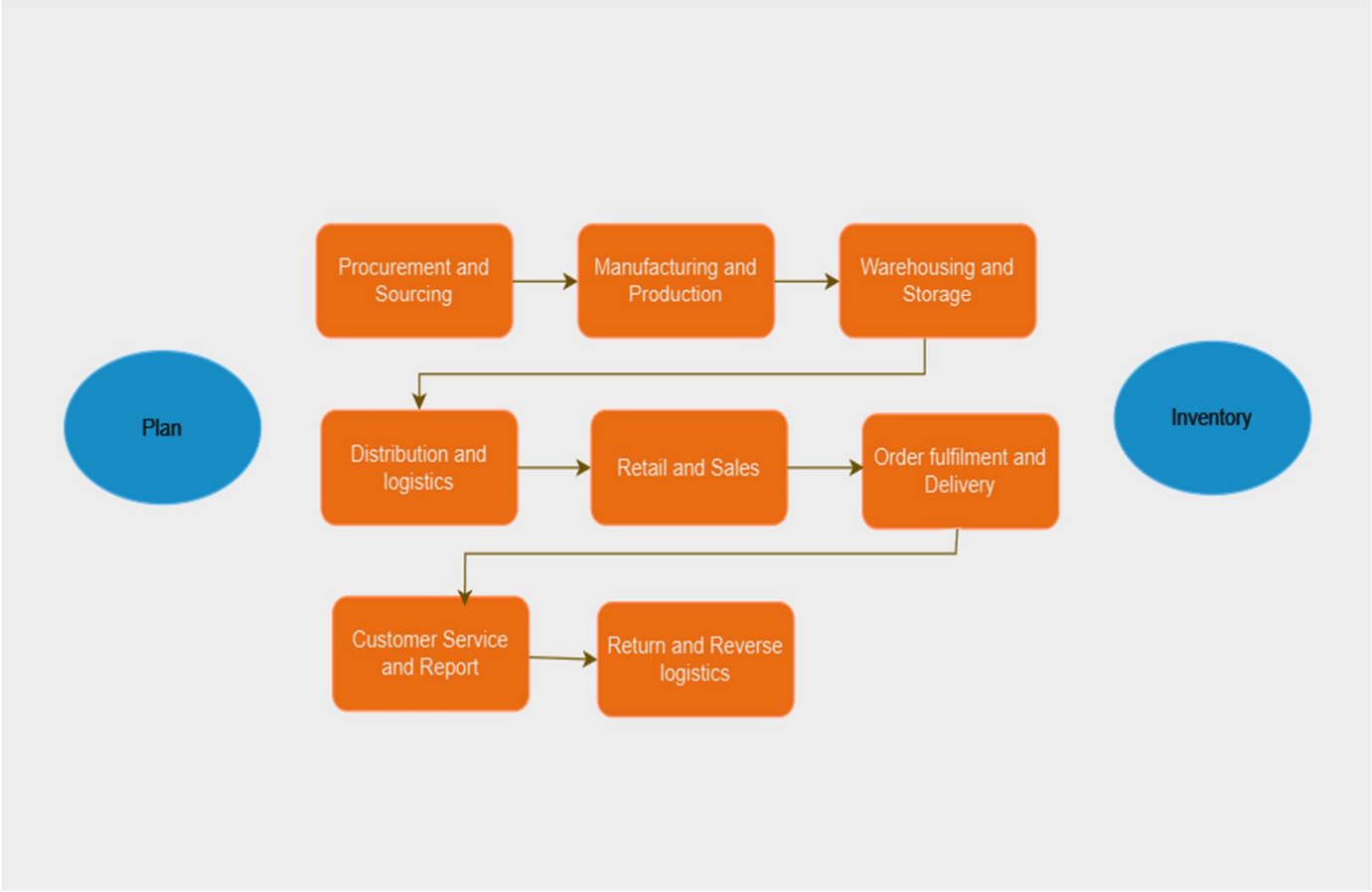


Fig. 1. Various Stages in a supply chain.

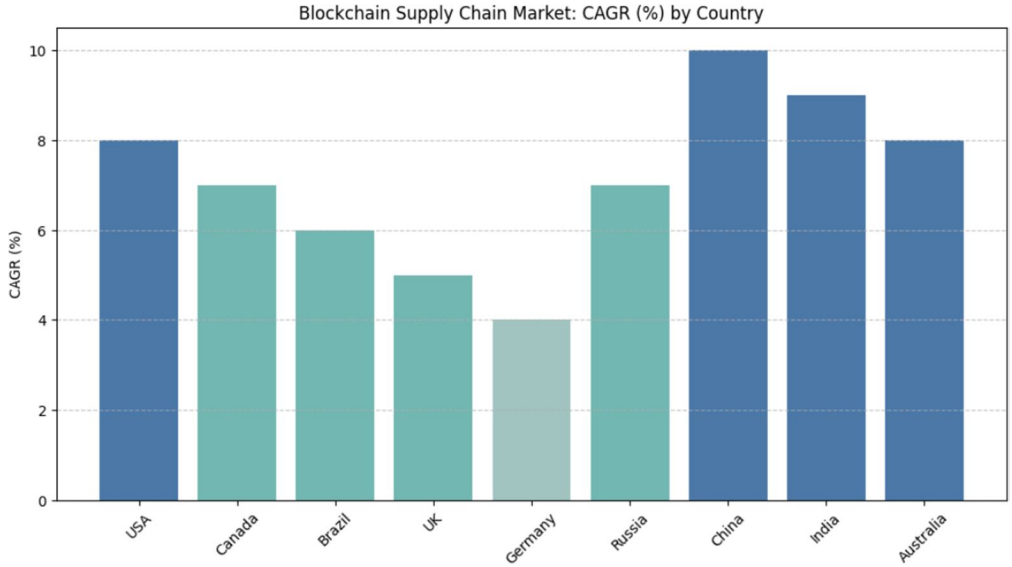


Fig. 2. Blockchain Supply chain market:Market CAGR(percent),By Region,Global(sourcec:www.mordorintelligence.com)

B. Block Supply chain market Analysis

1) Two key drivers of market expansion are the increasing need for supply chain transparency and the surge in demand for increased supply chain transaction security. Blockchain technology's increased automation and elimi- nation of middlemen in supply chain management would create opportunities for market expansion.

2) Due to the growing use of blockchain platforms to optimise supply chain operations, the platform compo- nent segment is expected to continue to dominate the blockchain supply chain market as a whole.

3) When blockchain reaches a position where it can provide value, progressive businesses intend to invest. Blockchain hasn't yet fully benefited applications outside of food and medicine, though. According to Kenco Group, only 6 percent of supply chain executives view blockchain as a top priority

4) Additionally, blockchain technology is being used by healthcare service providers to continuously monitor and manage healthcare items from production to distribution. Additionally, pharmaceutical firms can reduce illicit ac- tivities including the creation of hazardous pharmaceu- ticals illegally, counterfeiting, and inappropriate stock control by utilising blockchain supply chain capabilities.

5) The COVID-19 pandemic increased demand for eCom-merce. Artificial intelligence (AI) and machine learning (ML) propelled business innovation strategies during a pandemic, hastening the adoption of blockchain supply chain solutions by SMEs.

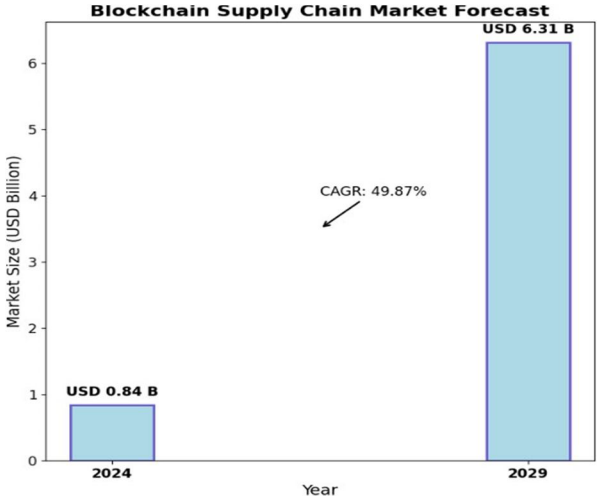


Fig. 3. Blockchain Supply chain market:Market Size

ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 13 Issue III Mar 2025- Available at www.ijraset.com

IV. PROPOSED BLOCKCHAIN ARCHITECTURE FOR SUPPLY CHAIN

This section suggests a blockchain architecture for improv- ing supply chain management that combines essential elements to provide efficiency, security, and transparency at different supply chain phases. Businesses may more easily manage, validate, and secure supply chain data from beginning to end using this architecture's comprehensive and secure system for managing intricate, multi-tiered supply chains using the blockchain. [6]

A. Flow Summary and Components

- Participants in the Supply Chain: The blockchain network facilitates communication between all parties, including manufacturers, distributors, retailers, suppliers, and cus- tomers. The blockchain layers, which record and handle all activities, are linked to these entities.
- Layers of the blockchain:
  - Data Layer: Holds information on product origin, movement, and compliance status in the supply chain.
  - Network Layer: Enables nodes to communicate with one another.
  - Consensus Layer: Verifies transactions; for quicker, more energy-efficient validations, it makes use of effective procedures like Proof of Authority (PoA).
  - Smart Contract Layer:The supply chain's smart con- tract layer automates contracts for payments, com- pliance checks, and other requirements.
  - Application Layer: Offers tools and interfaces for supply chain participants to communicate with the blockchain
- Data Security and Privacy: Contains privacy strategies (such as zero-knowledge proofs) and encryption tech- niques to guarantee that private information is safe- guarded and distributed only to confirmed participants.
- Distributed ledger:Also known as on-chain storage, is a safe distributed ledger that only authorised nodes can access. It contains an unchangeable record of important transactions and metadata.
- Off-Chain Data Storage (e.g., IPFS): To lower blockchain storage overhead, data is stored off-chain for assets that contain a lot of data, like product certifications, contracts, and pictures. With connections to off-chain files, only necessary metadata is kept on-chain.
- Smart Contracts: Make it possible to automate processes like product verification, payments, and customs paper- work. Smart contracts can incorporate quality control and compliance checks to guarantee that all transactions adhere to predetermined guidelines.
- Interoperability Layer: Facilitates smooth data sharing be- tween supply chains using different blockchain platforms by enabling connectivity between several blockchains. Through APIs, this layer can also communicate with outside data sources.
- Regulatory bodies: Authorised nodes give regulatory bod- ies real-time access to data, allowing for audits and com- pliance verification without compromising data privacy.
- Real-time access to supply chain data, including infor- mation on product status, shipment, and quality, is made possible via analytical dashboards and user interfaces.
- Machine Learning for Demand Forecasting: Machine learning models can forecast demand trends using past supply chain data that is recorded on the blockchain, which helps with waste reduction and inventory optimi- sation.
- Predictive analytics: Assists in decision-making and elim- inates bottlenecks by forecasting inventory levels and shipment schedules.

B. Workflow Example

- Raw Materials: Suppliers enter pertinent information about raw materials, including compliance and place of origin, onto the blockchain. [2]
- Manufacturing: A verified product history is created by recording manufacturing data (such as production date and batch numbers) when materials are turned into com- pleted goods.
- Distribution and Logistics: Blockchain ensures trans- parency and provides information for addressing delays or bottlenecks by tracking items via logistics with real- time location updates.

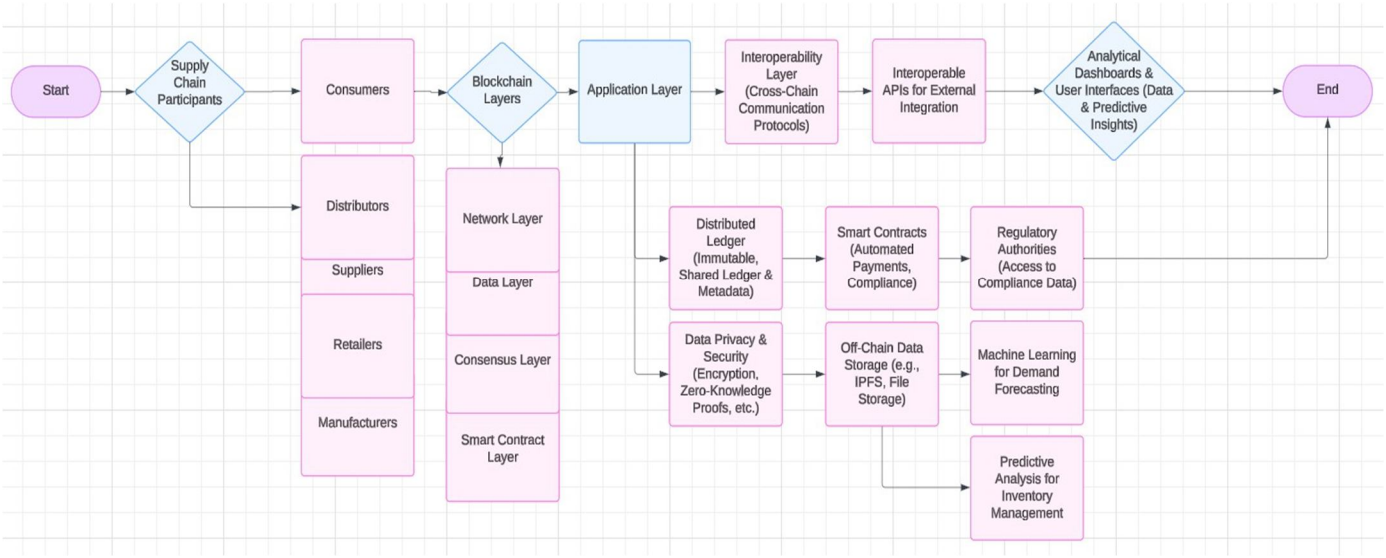


Fig. 4. Proposed method for Blockchain usage for Supply Chain.

- Retailer and End User: To confirm authenticity, quality, and compliance, retailers and customers can view product history and certifications. [3]

V. CHALLENGES ON INTEGRATION OF BLOCKCHAIN WITH A SUPPLY CHAIN

1) Complexity and Fragmentation: Because global supply chains are diverse and contain several players, systems, and procedures, integrating blockchain into supply chain management can be challenging. It can be difficult to integrate blockchain technology and guarantee interoper- ability across many platforms.

2) Lack of Transparency: Stakeholder resistance and reluc- tance to share data publicly make transparency difficult, despite blockchain's disruptive potential.You must estab- lish trust in these matters by showcasing the advantages of transparency, such as enhanced traceability, decreased fraud, and increased efficiency.

3) Inefficiencies and Delays: Manual procedures, extra pa- perwork, and a lack of real-time information are common causes of inefficiencies and delays in traditional supply chains. Furthermore, re-engineering these procedures is necessary to use blockchain for supply chain manage- ment, which may cause disruptions and encounter oppo- sition.

4) Security Concerns: Despite the security of blockchain technology, implementation flaws such as faulty code, inadequate key management, and insecure interfaces can occur.Blockchain supply chain solution providers adhere to best practices, which include secure coding standards, frequent audits, encryption, and stringent testing.

VI. CONCLUSION AND FUTURE SCOPE

The suggested blockchain architecture for supply chain management provides a thorough framework that improves security, traceability, and transparency at different supply chain phases. This architecture maintains data security and integrity while facilitating effective and automated interac- tions between various stakeholders, including manufacturers, distributors, suppliers, and regulators, through the integra- tion of smart contracts, permissioned blockchain networks, and privacy-preserving measures. Important elements like off- chain storage, distributed ledgers, and real-time data analyt- ics give stakeholders reliable information, which improves operations, reduces delays, and boosts customer confidence. All things considered, this design tackles fundamental supply chain issues and offers a strong basis for attaining end-to-end accountability and visibility.

Blockchain technology in supply chain management has enormous potential for development and broad use:

1) Improved compatibility: Cross-platform compatibility will become more and more necessary as more supply chains implement blockchain. Smoother interactions will be made possible by efforts to standardize protocols and create bridges across various blockchains, particularly in international trade where several blockchain systems coexist.

2) Integration of Artificial Intelligence (AI): AI-powered analytics can improve predictive insights even further by providing more accurate supply chain resilience, inven- tory optimization, and demand forecasting. Businesses may predict market demands and reduce them by using machine learning algorithms to find trends in data stored on blockchains.

3) IOT integration: [1]Real-time data from smart sensors throughout the supply chain can be obtained by integrat- ing the Internet of Things (IoT) with blockchain. This would increase supply chain responsiveness and lower operational risks by improving shipment tracking, moni- toring product conditions, and triggering smart contracts based on sensor data.

4) Better Scalability Solutions: There is still room for in- novation in the architecture's scalability. Future advance- ments in Layer 2 scaling techniques, like state channels or sidechains, may speed up and lower the cost of the blockchain network, enabling it to process more transac- tions.

5) Sustainability Tracking: By guaranteeing raw material tracking and confirming adherence to environmental reg- ulations, blockchain can assist sustainability initiatives. Customers may feel more assured about the ethical sourcing of goods as a result, and businesses may be able to satisfy customer and regulatory demands for sustainability.

6) Improved Compliance and Regulatory Tools: The archi- tecture may be extended to incorporate more sophis- ticated compliance tools when regulatory requirements change, enabling smooth transition to new regulations in sectors including logistics, food safety, and pharmaceuti- cals.

7) Automation via Smart Contracts: Smart Contracts can be used to enforce restrictions or criteria fulfillment to various operations like validating orders, releasing pay- ments , initiating shipments ,etc thus increasing precision and effectiveness and helps reducing fraud and chance of human mistakes. [7]

In conclusion, blockchain technology has the potential to revolutionize supply chain management in the future and open the door to more intelligent, robust, and sustainable supply networks globally.

REFERENCES

[1] Xiuying Chen, Sheng Liu*, Wentao Zhu and Qingzhu Li, "Transition to the Intelligent Services Ecosystem: Integration of Block Chain and Inter- net of Things in Supply Chain Management" ,2020 IEEE International Conference on Artificial Intelligence and Computer Applications.

[2] Shweta Pethe, Amit P.Sahu , Priyadarshani Keshtty, Indrajeet Gajbhiye, "Analysis of Agricultural and Food Supply Chain Utilizing Block chain,IoT and Lightweight Cluster Head Technology" ,2024 ICICET

[3] Mohammed Musthafa Sheriff and D.John Aravindhar, "Integrated Blockchain-Based Agri-Food Traceability and Deep Learning for Profit- Optimized Supply Chain Management in Agri-Food Supply Chains," 2024 Fourth International Conference on Advances in Electrical, Com- puting, Communication and Sustainable Technologies (ICAECT).

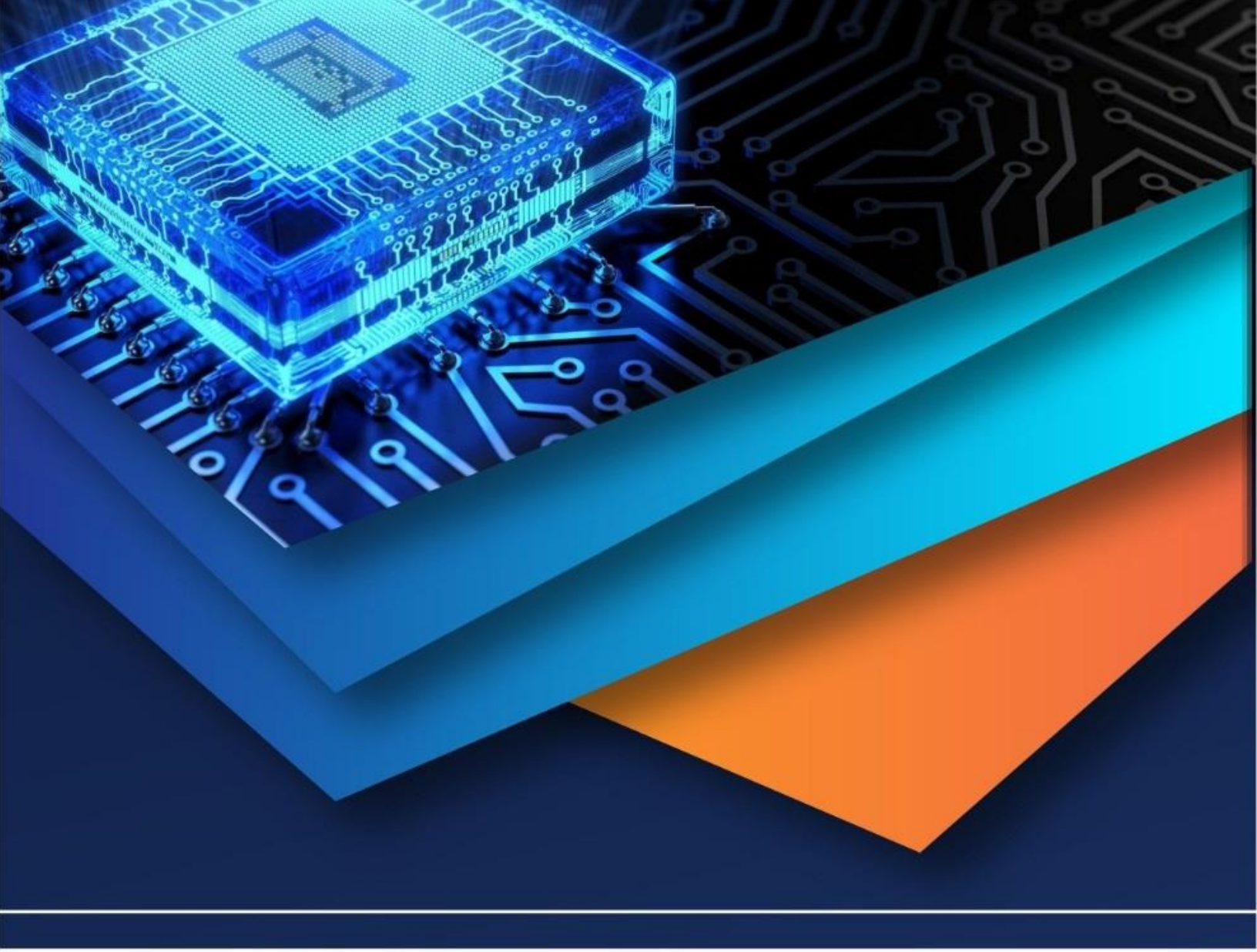
[4] A Rajeshwar Rao,Dr. Monika Saxena,Dr. Konda Hari Krishna,Anandhi R J,B Pravallika,Amit Dutt "Secured traceability System using Block chain Technology in Supply Chain Management," 2023 10th IEEE Uttar Pradesh Section International Conference on Electrical, Electronics and Computer Engineering (UPCON).

[5] D Sathya, S Nithyaroopa ,D jagdeesan, I Jeena Jacob "Blockchain Technology for Food supply chains," 2021 Third ICICV.

[6] Aakash Bhalla, kartikeya Ranjan, Kuldeep pPatidar, and Kiran M, "A Bidirectional Blockchain Architecture for Supply Chain Management ",2024 IEEE International Conference on Electronics, Computing and Communication Technologies (CONECCT)

[7] Luu The Vinh,Dr. Madhu Arora,Parveen Roja M,Saurabh Singh,Subham Kushwaha , Dr. Ameya Madhukar Rane," Exploring the Potential of Block chain Technology in Supply Chain Management".

[8] Harshit Singh and Pooja Dehraj ,,"A Study on Importance of Blockchain Technology in Logistics Supply Chain Management",IEEE Xplore Part Number: CFP22K25-ART; ISBN: 978-1-6654-1028-1.



10.22214/IJRASET

45.98

IMPACT FACTOR: 7.129

IMPACT FACTOR: 7.429

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY