Enhancing Supply Chain Transparency and Efficiency Through Innovative Blockchain Solutions for Optimal Operations Management

Shamrao Parashram Ghodake[1], Vishal M. Tidake[2], Sanjit Singh[3], Elangovan Muniyandy[4], Mohit[5]*, Lakshmana Phaneendra Maguluri[6], John T Mesia Dhas[7]

Assistant Professor, Department of MBA, Sanjivani College of Engineering, Savitribai Phule Pune University, Pune, India[1]
Associate Professor, Department of MBA, Sanjivani College of Engineering, Savitribai Phule Pune University, Pune, India[2]
Assistant Professor, Department of MBA, Sanjivani College of Engineering, Savitribai Phule Pune University, Pune, India[3]
Department of Biosciences, Saveetha School of Engineering, Saveetha Institute of Medical and Technical Sciences, Chennai, India[4]
Applied Science Research Center, Applied Science Private University, Amman, Jordan[4]
Research Scholar, Institute of Management Studies and Research, Maharshi Dayanand University, Rohtak, India[5]
Associate Professor, Department of Computer Science and Engineering, Koneru Lakshmaiah Education Foundation, Vaddeswaram, Guntur, Andhra Pradesh, India[6]
Associate Professor, Department of Computer Science and Engineering, School of Computing, Vel Tech Rangarajan Dr. Sagunthala R&D Institute of Science and Technology, Vel Nagar, Chennai, Tamil Nadu, India[7]

***Abstract*—Blockchain technology holds the potential to revolutionize supply chain management by ensuring transparency, efficiency, and security. This paper presents a detailed examination of blockchain's implementation in supply chain systems, focusing on safeguarding confidential information and preserving supply chain integrity. The method involves extracting 'sales order' data from Walmart's transactional database, which is then encrypted using AES algorithms to protect sensitive details such as client names and geographical information. Utilizing Ethereum's decentralized architecture, smart contracts are employed to manage transactions, encryption, decryption, and access rights. The Ethereum P2P network also aids in data validation and asset preservation, enhancing the system's reliability. Comparative analysis shows that the proposed encryption method, with encryption and decryption times of 2.8 and 3.2 seconds, outperforms traditional methods like RSA and ABE. Implemented in Python, this blockchain-based technique offers a robust, nearly infallible solution that can be applied to various supply chain practices, including Asset Management (AM), Enterprise Asset Management (EAM), and Supply Chain Management (SCM), addressing contemporary challenges and enhancing operational efficiency.**

Keywords*—Blockchain; supply chain management; advanced encryption standard; Ethereum blockchain; data storage

I. Introduction

Fundamentally, a blockchain is a distributed ledger system that statistics transactions on a network of linked nodes in a secure and permanent manner [1]. Blockchain networks function in a decentralized fashion, with every member maintaining a replica of the ledger, in comparison to normal centralized databases, in which facts garage and validation are controlled by using a unmarried authority. The decentralized layout minimizes the possibility of facts modification or illegal get admission to, removes unmarried points of failure, and maintains transparency and robustness. Furthermore, tamper-obvious and immutable, transactions registered on a blockchain are timestamped and cryptographically related [2]. The capability of blockchain technology to allow transactions among individuals without the requirement for middlemen like banks or financial groups is certainly one of its number one characteristic. Blockchain networks offer automatic and accept as true with less transactions between events through the use of smart contracts, which can be agreements that execute themselves with predetermined guidelines and conditions [3]. When certain circumstances are happy, smart contracts run routinely, simplifying operations, reducing prices, and eliminating the want for middlemen. This function of blockchain era has considerable ramifications for sectors like banking, actual property, healthcare, and deliver chain management, where safe and powerful peer-to-peer transactions are vital [4].

Blockchain generation probably clear up lengthy-status problems with transparency, duty, and self-associated with global deliver chains, it has attracted a whole lot of interest in the area of deliver chain management. Blockchain era basically affords a dispersed network of participants with a decentralized, unchangeable ledger to file transactions. This dispensed ledger makes it viable to file all transactions, transportation of commodities, and adjustments in possession in the supply chain ecosystem in a transparent and secure way, that's essential for deliver chain management [5]. Blockchain makes it feasible for all authorized events to access a unmarried source of reality, making an allowance for instant insight into the movement of commodities from the procurement of raw materials to the final customer [6]. The potential of blockchain generation to improve traceability and transparency in supply chain management is one in every of its most important advantages. Businesses may additionally gain a thorough know-how in their deliver chains, which includes the sources of substances

*Corresponding Author.

required for the method for manufacturing, and the motion of products thru exclusive phases of manufacturing and distribution, through documenting each transaction on a blockchain [7]. Companies that exhibit this diploma of accessibility are better geared up to come across inconsistencies and inefficiencies in addition to react directly to interruptions like recalls of products or first-rate issues. Furthermore, customers can also have by no means-before-seen transparency into the origination and authenticity of merchandise way to blockchain-primarily based deliver chain solutions, for you to boost their self-assurance in corporations [8].

The potential of blockchain era to reduce the opportunity of deception, imitations, and illegal statistics revisions is every other essential benefit for supply chain control. Blockchain statistics are intrinsically tamper-glaring because of their crypto graphical linkage and immutability, which makes it almost tough for malicious actors to change or manipulate transaction statistics covertly. This characteristic of blockchain era is especially useful in sectors like medicines, expensive items, and hospitality, in which product integrity and authenticity are crucial [9]. Additionally, deliver chain techniques is probably automated and streamlined using blockchain technology, increasing productivity and decreasing fees. Automating procedures like processing payments, agreement regulation, and inventory control is possible with clever contracts that are self-executing agreements with predetermined phrases and situations. Blockchain-primarily based clever contracts can decrease transaction prices, remove mistakes, and quicken business enterprise operations by means of getting rid of the want for middlemen and human interaction [10].

There are several blessings to integrating encryption strategies with blockchain generation in supply chain control, from improving facts protection and confidentiality to maintaining the validity and integrity of transaction records [10]. Sensitive statistics, like product specs, fee facts, and patron names, is saved on the blockchain and requires encryption to be secure. Businesses can also enhance the complete safety postures of the deliver chain atmosphere through stopping unwanted get admission to and information breaches through encrypting information before it's far stored at the blockchain [11]. Maintaining confidentiality of records is one of the essential advantages of using encryption strategies in blockchain-based totally deliver chain management [12]. The increasing frequency of statistics breaches and privacy issues in modern digital environment has made it important for corporations running in deliver chains to shield sensitive data. Businesses can use encryption to obscure sensitive data, together with patron names, addresses, and financials, in order that out of doors parties cannot decipher it. This no longer only promotes consider and self-assurance amongst customers, along with purchasers, companions, and regulators, however also aids in complying with information privateness rules like the CCPA and GDPR [13].

Furthermore, by way of protecting records from undesirable changes or tampering efforts, encryption improves the authenticity and integrity of statistics recorded at the blockchain. Each transaction document is given a man or woman fingerprint or virtual signature through cryptographic hashing strategies like SHA-256. These are subsequently encrypted and recorded at the blockchain [14]. These cryptographic signatures assure that any modifications to the records would be fast discovered and characteristic as unchangeable proof of the transaction's legitimacy. Consequently, deliver chain answers primarily based on blockchain and bolstered via encryption methods provide data which are auditable and proof against manipulation, selling accountability and transparency across the deliver chain. Reducing the chance of fraud and counterfeiting is a first-rate gain of incorporating encryption into blockchain-based totally deliver chain management [15]. For each object within the deliver chain, businesses may additionally produce virtual fingerprints which can be verifiable and impervious to tampering via encrypting product identifiers like serial numbers, QR codes, or RFID tags. Stakeholders may also then safely log these encrypted identities at the blockchain, allowing them to affirm the legitimacy and beginning of goods at each step of the supply chain technique. This reduces the danger of fraud and illegal diversion while also assisting groups in monitoring and tracing gadgets with unmatched precision, which in flip enables save you from the boom of counterfeit goods [16].

The key contributions of the proposed system are given as follows:

- The paper sets out the process of implementing blockchain into the supply chain to enhance the processes and offer customers more transparent and coherent data based on Ethereum.
- The sales order data is extracted from Walmart's transaction history in a methodical manner to construct an extensive data set that is then integrated with blockchain.
- The study uses AES to promote the highest levels of data security; more specifically, the research aims at protecting client names and geographic location details kept in the blockchain network.
- The paper explains how the smart contracts are being used in the proposed SUFS system to manage the transactions in simpler manner, encryption and decryption process and the enforcement of some strict operations and controls.
- The above solution is implemented in Python language with an aim of having a strong, reliable and effective blockchain supply chain management ecosystem that meets supply chain operation in the current world.

The following portions of the chapter are organized as follows. Section II includes an overview of the literature on blockchain technology in supply chain management. The problem statement for the study is presented in Section III. Section IV covers the recommended approach for blockchain technology in supply chain management. Section V compares the method's efficacy to previous techniques, and the performance measures are displayed, along with an explanation of the results. Section VI describes the conclusion.

II. Related Work

Although the food supply chain is one of the areas that blockchain technology has the potential to revolutionize, its deployment is fraught with difficulties. The purpose of this study is to determine and examine the obstacles preventing blockchain from being implemented in food supply chains. After a comprehensive analysis of the literature, 16 main hurdles are found and, with the help of specialists, are further divided into four groups. Then, these obstacles are ranked using the best-worst technique. The results show that organizational and technological limitations are major hindrances to the application of blockchain technology in the food supply chain. To tackle these obstacles, supply chain cooperation must be promoted, blockchain technology must be developed through development and research, and technical proficiency must be increased. However, there are drawbacks, such as the potential for bias in expert judgment and the tendency to overlook specific obstacles throughout the literature review procedure. Despite these drawbacks, the research advances knowledge of how blockchain is being applied in the supply chain and provides policymakers with recommendations on how to remove obstacles and ensure its adoption, especially in emerging economies [17].

The findings advocate that customers apprehend blockchain traceability as especially treasured whilst managing neighbourhood meals assets, leading to extended agree with and pleasant attitudes toward sharing stories [18]. However, on the deliver aspect, regardless of spotting the blessings of blockchain adoption, along with advanced accept as true with, suppliers express reluctance due to inner organizational demanding situations and issues concerning records sharing. While the study provides valuable insights from both consumer and provider perspectives, it's difficult to identify the limitations. These encompass potential biases in player responses and the scope of the examination, which won't absolutely capture all complexities related to blockchain integration in the meals supply chain.

Through a literature assessment and grey Delphi approach, ten CSFs have been identified and analysed, presenting treasured insights for FSC stakeholders [19]. However, it is vital to acknowledge certain barriers on this study. Firstly, the scope of the observation won't encompass all possible CSFs relevant to each FSC context, doubtlessly restricting the generalizability of the findings. Additionally, the gray Delphi method is based on professional critiques, which can also introduce biases or forget about certain perspectives. Furthermore, the gray DEMATEL evaluation affords insights into the significance and causal relationships amongst CSFs however might not capture all nuances of complicated interactions in the FSC ecosystem. However, similar research and practical implementation are had to completely apprehend and address the challenges related to B-IoT adoption in diverse FSC settings [19].

III. Problem Statement

The limitations encompass capability oversights in identifying obstacles, biases in participant responses, and scope constraints that won't absolutely capture the complexities of blockchain integration [17]. To address these obstacles and contribute to ongoing discussions, our look at goals to endorse a novel method for reinforcing traceability and transparency inside the meals deliver chain the usage of blockchain generation. Utilising a mixed-approach method that blends qualitative information and experiments, the aim is to better recognize consumer sentiments on blockchain-enabled traceability and pinpoint manageable answers for providers to recover from adoption hurdles. The recommended technique in the long run seeks to shut the space among theoretical knowledge and real-international software, establishing up the possibility for a supply chain that adopts blockchain era more efficaciously and sustainably.

The limitations of the literatures are given in Table I.

TABLE I. Limitations of Literature

Source	Limitation	How to Overcome
[17]	Expert judgment may be biased, and experts may fail to identify certain challenges because they do not think of them as significant barriers to success.	To minimize bias and omissions, employ pluralism of voices from various experts and compare conclusions to current research, implementing empirical evidence.
[18]	Convincing of suppliers may be hampered by internal organizational issues and inclusive of data sharing.	There is a need to develop and ensure the sharing of data through blockchain with the goal of rebuilding trust in sharing data between organizations.
[19]	There are biases in Gray Delphi method and the relationships between CSFs can be complex, detailed, subtleties may not be identified.	Number different studies and use both qualitative and quantitative research to focus on a broader range of factors affecting FSC.

IV. Proposed Blockchain Integration in Supply Chain Management

The technique employed in this examine initiates with the meticulous collection of critical sales order information sourced from Walmart's tremendous transaction facts, encapsulating pivotal details along with order ID, dates, customer identity, and complete product statistics. Following this initial section, robust information encryption strategies, specially leveraging the AES algorithm, are judiciously applied to make stronger the safety of touchy facts which includes customer identities and geographical records, thereby safeguarding privateness and confidentiality in the course of the complete deliver chain manner. Subsequent to the encryption system, a meticulous crafting of blockchain architecture ensues, harnessing the robust skills of the Ethereum blockchain renowned for its decentralized framework and sensible agreement functionalities, thereby fortifying the transparency and resilience of the supply chain infrastructure. Integral to this system is the strategic improvement of smart contracts designed to orchestrate seamless transactions, data encryption/decryption methods, and stringent access manipulate mechanisms in the blockchain community, thereby imposing predefined policies and authorizations pivotal for ensuring supply chain integrity. The implementation phase entails the configuration of nodes meticulously, fostering an environment conducive to strong facts garage, validation, and get admission to manipulate, capitalizing on the inherently fault-tolerant and resilient structure inherent within Ethereum's peer-to-peer community infrastructure. Post-integration, the encrypted sales order data seamlessly will become part of the blockchain network fabric, with each transaction meticulously tracked and securely saved throughout distributed nodes, as a consequence ensuring redundancy, records integrity, and utmost confidentiality paramount to the sanctity of deliver chain operations. The incorporation of rigorous access control mechanisms and stringent authentication protocols further fortifies the safety and privateness paradigm, ensuring that simplest duly legal employees are endowed with decryption keys or privileged get entry to, as a result fostering a fortified ecosystem bolstered via current blockchain era. Fig. 1 shows the Overall Architecture of the Proposed System.

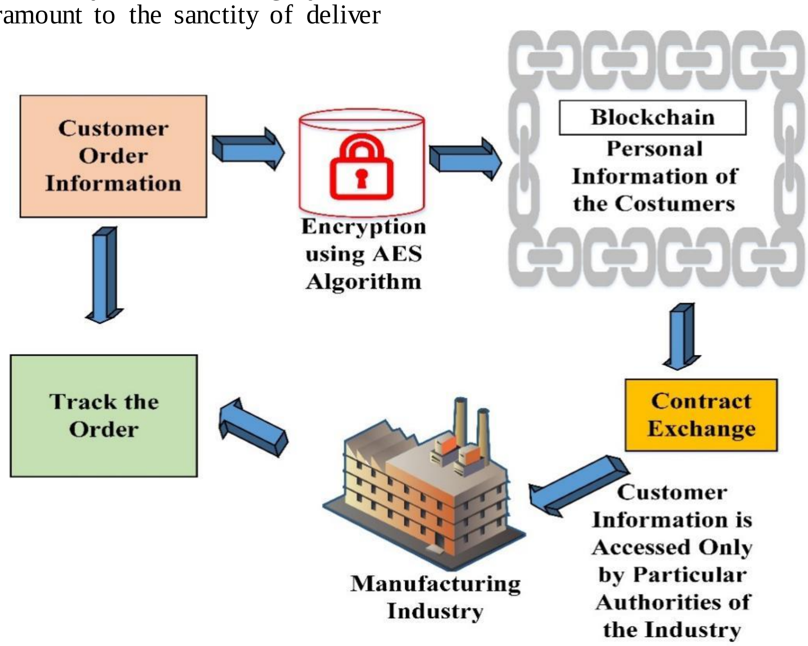

Fig. 1. Overall architecture of the proposed system.

A. Data Collection

The dataset being shared includes giant income order statistics that were extracted from Walmart's extensive transaction statistics. It consists of all of the vital statistics, which include the order ID, the dates of the order and shipping, the consumer's identity, geographical data (United States, city, and nation), and specified product facts (call, type). Every access inside the dataset corresponds to a distinct income transaction, imparting a wealth of facts this is crucial for interpreting the complex dynamics of the supply chain and purchaser interactions within the retail environment. Furthermore, this observation targets to shed mild on the interesting opportunities of blockchain era in enhancing accountability, effectiveness, and safety all through the numerous delivery chain tiers via the prism of Walmart's transactional facts [20].

B. Data Encryption with AES Algorithm

In the context of deliver chain management, information encryption is critical for making certain the safety and privacy of personal records. AES uses a symmetrical key for decryption in addition to encryption, working with constant-length facts blocks. Blocks of plaintext statistics, typically 128 bits in size, are fed into the AES algorithm and converted thru a chain of encryption rounds. In order to efficiently obscure the original information, these rounds entail crucial enlargement, alternative, diversifications, and mixing operations achieved in a selected order. The initiation of the encryption key, which controls how plaintext blocks are converted into ciphertext, starts offevolved the encryption system. Every encryption spherical makes use of a different key thanks to the key growth process, which turns the initial encryption key into a series of spherical keys.

Sensitive facts fields in our dataset, along with consumer names and region records, are encrypted earlier than being recorded inside the blockchain. For example, the AES technique is used to transform the customer's name area, that's represented as a string of letters, into ciphertext. In a comparable vein, location facts that includes the nation, city, and country is encrypted to shield against manipulation or illegal get admission to. The observation makes certain that only those with authorization possessing the decryption key might also decode the encrypted records by way of encrypting those critical regions. Depending on the required level of security, a random encryption key with a period of 128, 192, or 256 bits is generated as a part of the encryption method. The plaintext statistics blocks are in the end encrypted the use of this encryption key and the AES method. The resultant ciphertext, which incorporates place statistics and encrypted consumer names, is then accurately saved on the blockchain, defensive personal records from malevolent use or illegal get admission to.

C. Implementation of Blockchain Design

A thorough technique is required whilst designing and deploying a blockchain infrastructure which addresses the need to store encrypted customer records and income order records. The look at chooses the Ethereum blockchain for this have a look at because of its adaptability, balance, and wealthy clever agreement capabilities. Each of the interconnecting blocks that make up our blockchain shape consists of encrypted sales order statistics alongside associated records. Transparency, immutability, and decentralization are upheld through the shape, ensuring the security and integrity of records this is saved. Within the blockchain network, clever contracts are essential to the coordination of transactions, statistics encryption/decryption processes, and get entry to control structures. By automating the enforcement of present norms and regulations, these self-executing contracts reduce the want for 542 and improve the productiveness of operations. Smart contracts are cautiously crafted within our Ethereum-based blockchain to govern every side of the supply chain management technique, which includes order processing, privateness protection, and get entry to control. Smart contracts provide for the steady garage of encrypted data, the validation of transactions, and the enforcement of access privileges in accordance with pre-installed tips and authorizations.

The setup of nodes for storage of records, confirmation, and get entry to manipulate is an essential step in the blockchain community implementation technique. Because of Ethereum's decentralized structure, fault tolerance and resilience are extended as coordinated variations of the blockchain are maintained through nodes at some stage in the network. Nodes are in charge of distributing sparkling blocks around the community, carrying out smart contracts, and verifying transactions. Nodes reach a consensus on the legitimacy of transactions and the inclusion of latest blocks to the blockchain using consensus strategies like Proof of Work (PoW) or Proof of Stake (PoS). The blockchain network's typical security is progressed and the opportunity of remoted factors of failure is reduced in step with this disbursed consensus approach. Robust cryptographic techniques, like AES, are used to first encrypt patron facts and sales order information. After that, the generated ciphertext is blanketed into transaction payloads and despatched to the Ethereum community to be blanketed in blocks. In order to assure that best the ones people with the essential decryption keys may get right of entry to and decode the encrypted information, smart contracts are in charge of approving and finishing these transactions. Furthermore, clever contracts' integrated get entry to manage mechanisms enforce rights and permissions, prohibiting unauthorized events from gaining access to or altering touchy statistics. Fig. 2 shows the Blockchain Implementation Architecture.

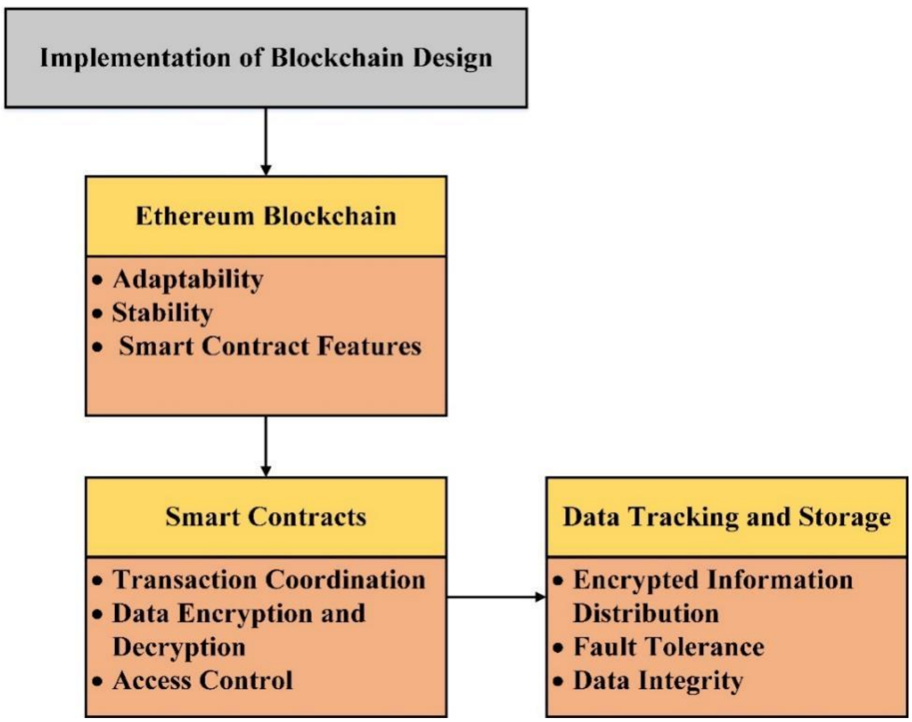

Fig. 2. Blockchain implementation architecture.

The structure of the blockchain network makes positive that encrypted data is dispersed throughout several nodes, improving fault tolerance and redundancy. Every node keeps an encrypted replica of the blockchain, which makes retrieval of records and validation less difficult. Data integrity is maintained the usage of cryptographic hashing techniques, which permit nodes to verify the consistency of information stored. Moreover, the blockchain's immutability guarantees that encrypted statistics cannot be changed or tampered with as soon as it's miles saved, making sure the integrity and validity of client and sales order facts. Implementing Ethereum-based clever contracts involves setting up positive capabilities and common sense inside the agreement code to handle information encryption and decryption methods. Encrypted statistics and decryption keys from structures or users with permission are despatched to clever contracts as enter parameters. By the usage of decryption methods to free up the facts that has been encrypted, those contracts make certain that best individuals with permission may view the plaintext information. Smart agreement-included get right of entry to control techniques put into effect authentication and authorization requirements, limiting unwanted usage of confidential facts. Solidity, the Turing-entire programming language utilized by Ethereum, lets in developers to include complex encryption and decryption good judgment into smart contracts, ensuring robust protection protocols for the duration of the blockchain network.

Ethereum has a peer-to-peer community design wherein nodes are configured for records storage and validation, with every node keeping an archive of the blockchain ledger. Nodes ensure that everybody at the community is in settlement on the blockchain's contemporary popularity through validating transactions and carrying out smart contracts. Nodes can upload extra blocks to the blockchain with the aid of together deciding on the authenticity of transactions the use of strategies like PoW or PoS. The blockchain community's protection and resilience are improved by way of this decentralized validation manner, which reduces the opportunity of malicious attempts or single points of failure. The blockchain community's get entry to manage structures impose authentication and authorization requirements to control get admission to encrypted statistics. Access manipulates common sense incorporated in smart contracts establishes roles, credentials, and verification protocols, making sure that touchy facts might also handiest be accessed by legal individuals or systems. Cryptographic signatures, digital credentials, and multi-factor authentication protocols are examples of authentication structures that provide strong safety against undesirable entry. The blockchain network strictly controls access to records by enforcing access control policies within smart contracts, enhancing security and privacy.

D. Data Tracking and Storage

For income order records to be integrated with the blockchain community, the blockchain platform and the cutting-edge facts assets need to create a continuing interplay. Before being despatched to the blockchain network, the sales order data which incorporates the order ID, order date, shipping date, consumer records, product facts, and sales metrics is encrypted making use of sturdy cryptographic techniques like AES. Every sales order transaction is precisely documented at the blockchain as a brand-new block, with the encrypted statistics payloads appropriately saved interior. By the usage of this approach, the blockchain operates as an unchangeable ledger, making it viable to follow income order transactions transparently and without interference throughout the supply chain. Within the blockchain community, the encrypted purchase order facts is correctly stored throughout dispersed nodes, guaranteeing statistics integrity, redundancy, and secrecy. Because each node in the community incorporates an exact replica of the blockchain ledger, tolerance to failure and resilience are increased. Nodes use consensus techniques to determine among themselves whether or not additional transactions and blocks are valid, ensuring that simplest encrypted and authenticated statistics gets uploaded to the blockchain. This distributed storage layout spreads the encrypted statistics over several nodes, decreasing the opportunity of data loss or modification by using hostile parties. The observe guarantees the integrity and protection of sales order records on the safe, decentralized blockchain community by using following nice practices for blockchain facts garage and encryption.

To conclude, it is suggested that blockchain also has several more roles for areas other than transactional security in supply chain management. In supply chain management, blockchain can offer total visibility, which will help to track goods throughout the supply chain in real time and minimize instances of fraud. It can also make the stock control more efficient as it can provide an uninterrupted and secure record of the stock level and any movements of products thus minimizing on errors, excessive stocking, and running out of stock. In procurement, smart contracts can enable automation of the procurement processes by ordering more stocks and or restocking whenever certain conditions are met. Also in the vendor relationships blockchain technology underlines the improved trust and cooperation through recording all the interactions, contracts, and payments in the ledger avoiding conflicts. In the same manner, blockchain can also help provide an unalterable method of logging quality checks and certifications for compliance purposes to improve business relations with vendors. In conclusion, the use of blockchain can potentially enhance the functional supply chain areas by automating and enhancing the security and verification of supply chain activities.

V. Results and Discussion

In this section, the end result and discussion of the proposed model are given. The method commences with complete information collection from Walmart's transaction information, taking pictures important sales order details like order ID, dates, customer statistics, and product specifics, forming the muse for blockchain integration in supply chain control. Following data acquisition, robust encryption strategies, significantly leveraging AES, are implemented to protect sensitive data such as consumer identities and geographical information, ensuring privacy at some point in the supply chain procedure. Integral to this system is the development of smart contracts orchestrating transactions, encryption/decryption approaches, and get right of entry to controls, enforcing predefined policies to preserve supply chain integrity. Implementation involves configuring nodes to facilitate sturdy facts garage, validation, and access control inside Ethereum's fault-tolerant peer-to-peer network infrastructure. Post-integration, encrypted income order facts seamlessly integrates into the blockchain, with each transaction meticulously tracked and securely saved across dispensed nodes, ensuring redundancy, integrity, and confidentiality. The incorporation of stringent get admission to control mechanisms and authentication protocols similarly fortifies safety and privacy, proscribing get right of entry to to authorized employees and bolstering the atmosphere's resilience.

TABLE II. Memory Usage

Algorithm	Memory Used (mb)
ABE [21]	0.107
RSA [22]	0.186
Proposed AES	0.0088

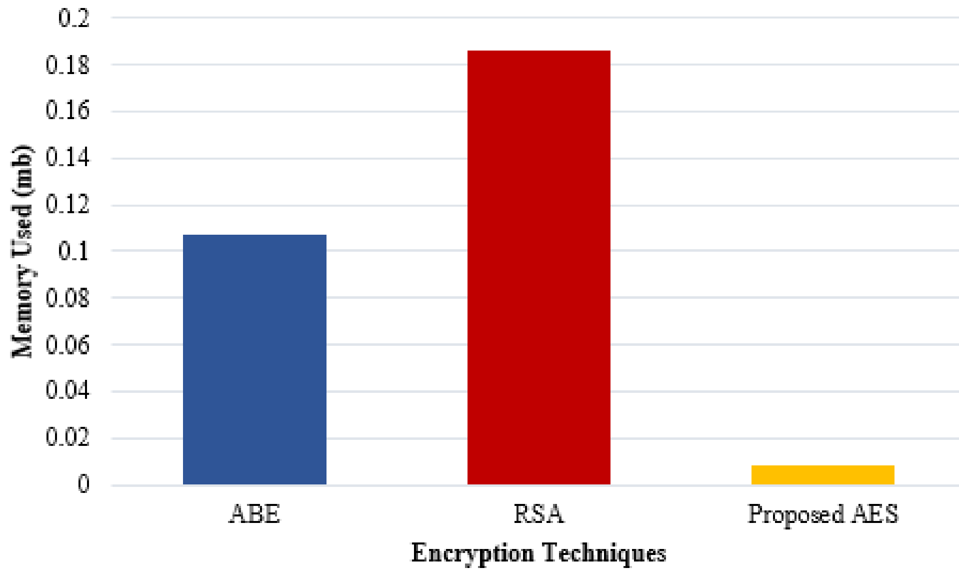

Fig. 3. Memory usage.

Table II and Fig. 3 presents a comparative evaluation of memory area consumption for extraordinary encryption algorithms, such as Attribute-Based Encryption (ABE), RSA (Rivest-Shamir-Adleman), and the proposed AES (Advanced Encryption Standard). The reminiscence utilization, measured in megabytes (mb), is indexed for each set of rules, showcasing their respective performance in phrases of memory intake. ABE, which is known for its versatility in getting right of entry to control mechanisms based on attributes, utilizes zero.107 mb of memory, indicating a mild degree of memory usage. In assessment, RSA, an extensively used uneven encryption set of rules, reveals a higher reminiscence footprint of 0.186 mb, suggesting pretty better memory requirements as compared to ABE. Notably, the proposed AES algorithm, regarded for its efficiency, simplicity, and strong encryption competencies, demonstrates a drastic decrease in memory usage at 0.0088 mb, making it the most memory-efficient encryption algorithm among the three.

TABLE III. COMPARISON OF ENCRYPTION AND DECRYPTION TIME WITH DIFFERENT ENCRYPTION ALGORITHMS

Algorithm	Encryption Time (sec)	Decryption Time (sec)
ABE [21]	7.5	5.2
RSA [22]	6.7	7.3
Proposed AES	2.8	3.2

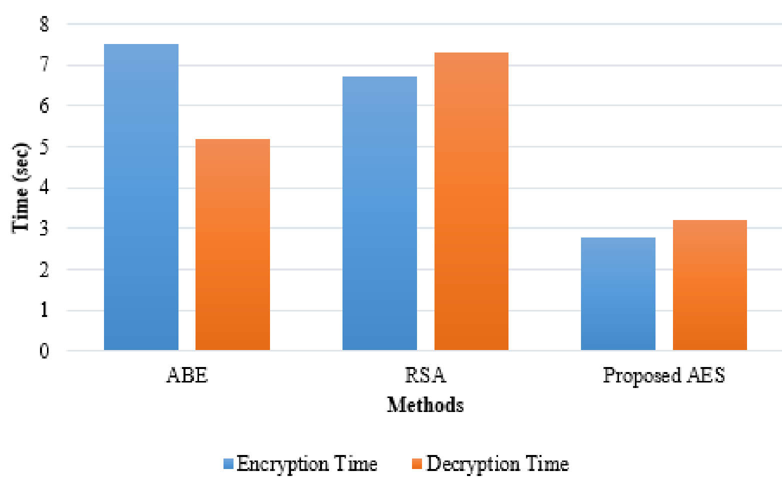

Fig. 4. Comparison of encryption and decryption time with different encryption algorithms.

Table III and Fig. 4 gives a complete evaluation of encryption and decryption instances associated with distinctive encryption algorithms, together with ABE, RSA, and the proposed AES. The Table showcases the time taken for encryption and decryption operations in seconds for every set of guidelines, offering insights into their respective efficiency in phrases of processing pace. ABE, famed for its characteristic-based get entry to manipulate mechanisms, demonstrates an encryption time of 7.5 seconds and a decryption time of 5.2 seconds, indicating slight overall performance in phrases of processing velocity. On the other hand, RSA, a standard asymmetric encryption algorithm, exhibits an encryption time of 6.7 seconds and a decryption time of 7.3 seconds, reflecting slightly faster encryption but slower decryption in comparison to ABE. Notably, the reposed AES algorithm, known for its velocity and efficiency in encryption and decryption, outperforms both ABE and RSA, with encryption and decryption instances of 2.8 seconds and3.2 seconds, respectively. This highlights AES as the most efficient algorithm in terms of processing speed among the three.

TABLE IV. ENCRYPTION TIME VS. KEY NUMBERS OF DIFFERENT ALGORITHMS

Keys Number	ABE (ms)	RSA (ms)	Proposed AES (ms)
1	3.10	1.3	0.06
2	4.97	1.78	0.36
3	5.99	2.84	1.2
4	6.88	5.88	2.4

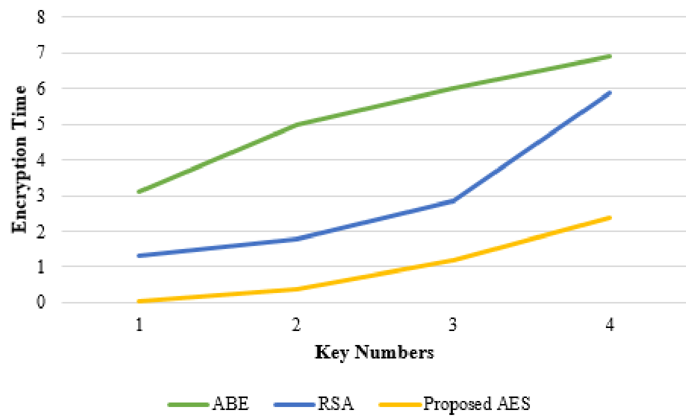

Fig. 5. Encryption time vs. key number of different algorithms.

The Table IV and Fig. 5 illustrates the encryption time in milliseconds for every set of rules primarily based on varying key numbers, ranging from 1 to 4 keys. Each row corresponds to a particular quantity of keys, even as the columns constitute the encryption time in milliseconds for ABE, RSA, and the proposed AES algorithm, respectively. For ABE, encryption time will increase progressively because the range of keys rises, indicating a linear dating between encryption time and key range. Similarly, RSA exhibits a proportional boom in encryption time with the addition of keys, although the price of growth seems barely steeper as compared to ABE. In comparison, the proposed AES algorithm demonstrates a drastic decrease in encryption instances throughout all key numbers, showcasing its performance and scalability in handling encryption responsibilities despite multiple keys.

TABLE V. COMPARISON OF BUFFER TIME WITH DIFFERENT ENCRYPTION ALGORITHMS

Algorithm	Buffer Time (mb)
ABE [21]	0.154
RSA [22]	0.165
Proposed AES	0.147

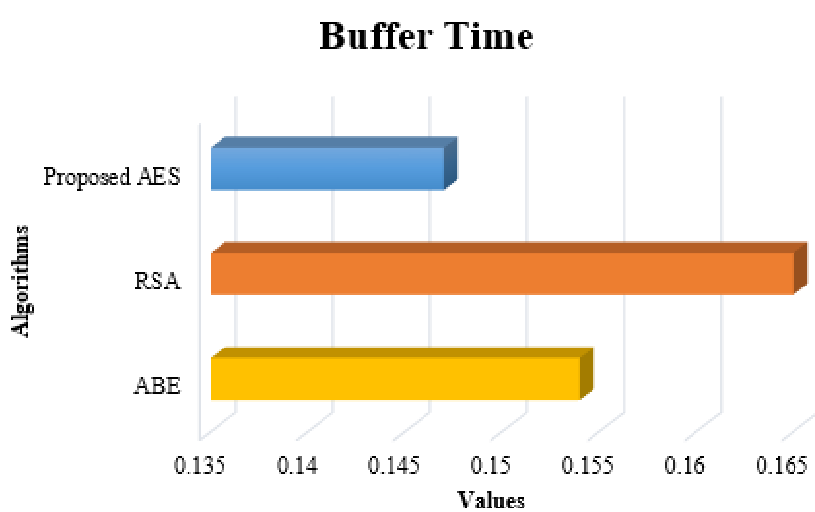

Fig. 6. Comparison of buffer time with different encryption algorithms.

Table V and Fig. 6 affords a comparative analysis of buffer time, measured in megabytes (mb), throughout exceptional encryption algorithms, including ABE, RSA, and the proposed AES. Buffer time refers to the amount of reminiscence space ate up via each algorithm in the course of encryption methods. Each row in the table represents a specific encryption algorithm, whilst the corresponding column displays the buffer time in megabytes for ABE, RSA, and the proposed AES algorithm, respectively. In comparison, ABE and RSA showcase slightly better buffer instances of 0.154 mb and0.165 mb, respectively.

TABLE VI. SECURITY COMPARISON OF DIFFERENT ALGORITHMS

Algorithm	Security
ABE [21]	14
RSA [22]	19
Hybrid ABE-DES	22
Proposed AES	45

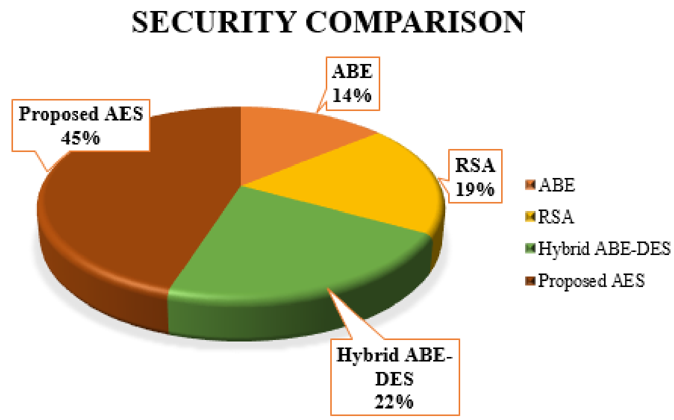

Fig. 7. Security comparison of different algorithms.

Table VI and Fig. 7 each row inside the desk represents a specific encryption set of rules, while the corresponding column presents the assigned protection score. In comparison, ABE and RSA showcase comparatively decreased safety ratings of 14 and 19, respectively. The Hybrid ABE-DES algorithm falls in between, with a security score of 22.

A. Discussion

The technique starts with thorough information collection from Walmart's transaction information, followed by using the implementation of sturdy encryption techniques the usage of AES to protect touchy data for the duration of the delivery chain method. Subsequently, the blockchain architecture is meticulously designed, leveraging Ethereum's decentralized framework and clever agreement talents to decorate transparency and resilience. The integration of encrypted income order facts into the blockchain network guarantees redundancy, integrity, and confidentiality, with stringent get entry to control mechanisms similarly fortifying protection and privateness.

The outcomes show that the new form of AES entropy is better than previous methods of ABE and RSA regarding the buffer time with 0.147MB being higher than 0.154MB and 0.165 MB respectively. Such a reduction in buffer time shows that there is an enhancement of efficiency in data processing, which plays a significant role in line with the real-time supply chain management systems. Although both ABE and RSA have strong encryption capacities, they are likely to result in high latency and the extra use of computational power. The above proposed AES method has the strength of delivering good encryption to meet the demands of client data and other geographic information as well as a faster encryption and decryption than other algorithms which makes it suitable for large volumes of transactions common in the supply chain networks. This improvement makes the system to be more efficient and scalable in handling the requirements of today's supply chain processes.

The integration of blockchain in supply chain confronts a number of real-life impediments and hurdles. First, the adoption of blockchain is not easy as most of the supply chain network still operates with centralized databases which pose integration issues and cost-effectiveness. Interconnectivity between these systems and blockchain solutions such as Ethereum might entail substantial modifications on the technical level. Furthermore, the factors of the scalability and flexibility of blockchain are an issue that could be an issue, especially for the extensively large volume and global supply chains that may overwork the blockchain processing power and storage. Another issue is the potential high cost of establishing and sustaining decentralized nodes and smart contracts that may be out of reach for some businesses. It is also true that security is both a strength and a weakness where, while the use of blockchain improves the security of data stored in a network, smart contract errors or weak encryption algorithms can put the system at risk. Last, there may be reluctance by organizations to embrace blockchain due to its decentralized nature a move that may not be embraced by individuals within notable supply chain management organizations especially those who are used to the traditional means of operations.

VI. CONCLUSION AND FUTURE WORK

The use of blockchain technology in the supply chain is an innovation towards improving on the supply chain operations. This paper shows that the supply chain can be improved by implementing blockchain technology, specifically using Ethereum, where transparency in supply chain, decentralisation and smart contracts may enhance data security and supply chain functionality. The AES algorithm for encrypting information that are deemed sensitive including the clients' names and geographic details, adds high degrees of privacy and protection. In addition to that the adoption of the PayPal's peer-to-peer network enhances the transparency as well as the solidity of the entire supply chain in allowing for efficient, secure and accurate transactions while at the same time ensuring proper controlling of access. Blockchain approach also successfully solves some of the major problems like maintenance of supply chain by integrating encrypted sales order data with supply chain system. The employed encryption method demonstrates enhanced efficiency to RSA and ABE where especially the encryption and decryption time is considered. The technique that was created in Python also elevates security within supply chain functions while actively responding to the consciousness changes that are rampant within supply chain management. There is scope for further research relating to this paper as highlighted next and below: First, the additional use of other emergent trends in supply chain management like artificial intelligence, the internet of things in combination with blockchain technology might add more value to the situation and help to predict the supply chain problems better. However, it is also vital to understand whether such a solution would work in larger and more complex supply chains would be important and further research on this solution. Additional research could also work on the effects of a variety of applications of blockchain platforms and various encryption styles on effects and security. In addition, identifying and solving threat and risks factors concerning regulations and compliances related to the use of blockchain technology in different parts of the world will be crucial for its adoption. Lastly, real-life supply chain examples and pilot adoption can be used as follows in order to give practical examples of the effectiveness of using blockchain in supply chain management and to put a light on the practical issues and implementation barriers.

REFERENCES

[1] E. Purwaningsih, M. Muslikh, S. Suhaeri, and B. Basrowi, "Utilizing blockchain technology in enhancing supply chain efficiency and export performance, and its implications on the financial performance of SMEs," Uncertain Supply Chain Management, vol. 12, no. 1, pp. 449–460, 2024.

[2] F. Zhang and W. Song, "Sustainability risk assessment of blockchain adoption in sustainable supply chain: An integrated method," Computers & Industrial Engineering, vol. 171, p. 108378, 2022.

[3] Y. Liu, W. Fang, T. Feng, and M. Xi, "Blockchain technology adoption and supply chain resilience: exploring the role of transformational supply chain leadership," Supply Chain Management: An International Journal, 2024.

[4] S. Fernandez-Vazquez, R. Rosillo, D. De la Fuente, and J. Puente, "Blockchain in sustainable supply chain management: an application of the analytical hierarchical process (AHP) methodology," Business Process Management Journal, vol. 28, no. 5/6, pp. 1277–1300, 2022.

[5] S. Balasubramani, R. Dhanalakshmi, L. Kavisankar, K. Ramesh, S. Saritha, and D. Pandey, "Revolutionizing Supply Chain With Machine Learning and Blockchain Integration," in Utilization of AI Technology in Supply Chain Management, IGI Global, 2024, pp. 113–125.

[6] N. Challa, "Blockchain Integration in Supply Chain Management: A Comprehensive Analysis of B2B Implications".

[7] C. L. Tan, Z. Tei, S. F. Yeo, K.-H. Lai, A. Kumar, and L. Chung, "Nexus among blockchain visibility, supply chain integration and supply chain performance in the digital transformation era," Industrial Management & Data Systems, vol. 123, no. 1, pp. 229–252, 2023.

[8] B. Alawi, M. M. S. Al Mubarak, and A. Hamdan, "Blockchain evaluation framework for supply chain management: a decision-making approach," in Supply Chain Forum: An International Journal, Taylor & Francis, 2022, pp. 212–226.

[9] T. Gürpinar, M. Henke, and R. Ashraf, "Integrating blockchain technology in supply chain management–a process model with evidence from current implementation projects," 2024.

[10] S. Yousefi and B. M. Tosarkani, "An analytical approach for evaluating the impact of blockchain technology on sustainable supply chain performance," International Journal of Production Economics, vol. 246, p. 108429, 2022.

[11] A. Vaezi, E. Rabbani, and S. A. Yazdian, "Blockchain-integrated sustainable supplier selection and order allocation: A hybrid BWM-MULTIMOORA and bi-objective programming approach," Journal of Cleaner Production, p. 141216, 2024.

[12] V. K. Manupati, T. Schoenherr, M. Ramkumar, S. M. Wagner, S. K. Pabba, and R. Inder Raj Singh, "A blockchain-based approach for a multi-echelon sustainable supply chain," International Journal of Production Research, vol. 58, no. 7, pp. 2222–2241, 2020.

[13] R. Cole, M. Stevenson, and J. Aitken, "Blockchain technology: implications for operations and supply chain management," Supply chain management: An international journal, vol. 24, no. 4, pp. 469–483, 2019.

[14] A. Rijanto, "Blockchain technology roles to overcome accounting, accountability and assurance barriers in supply chain finance," Asian Review of Accounting, 2024.

[15] G. Blossey, J. Eisenhardt, and G. Hahn, "Blockchain technology in supply chain management: An application perspective," 2019.

[16] U. K. Suganda, H. A. Buchory, and Z. Aripin, "ACCEPTANCE OF BLOCKCHAIN TECHNOLOGY IN SUPPLY CHAIN MANAGEMENT IN INDONESIA: AN INTEGRATED MODEL FROM THE PERSPECTIVE OF SUPPLY CHAIN PROFESSIONALS FOR SUSTAINABILITY," KRIEZ ACADEMY: Journal of development and community service, vol. 1, no. 2, pp. 33–51, 2024.

[17] S. Khan, M. K. Kaushik, R. Kumar, and W. Khan, "Investigating the barriers of blockchain technology integrated food supply chain: a BWM approach," Benchmarking: An International Journal, vol. 30, no. 3, pp. 713–735, 2023.

[18] C. Cozzio, G. Viglia, L. Lemarie, and S. Cerutti, "Toward an integration of blockchain technology in the food supply chain," Journal of Business Research, vol. 162, p. 113909, 2023.

[19] R. Singh, S. Khan, J. Dsilva, and P. Centobelli, "Blockchain integrated IOT for Food Supply Chain: A grey based Delphi-DEMA^{TEL} approach," Applied Sciences, vol. 13, no. 2, p. 1079, 2023.

[20] "Complete Exploratory Data Analysis of Walmart Data | Kaggle." Accessed: Mar. 23, 2024. [Online]. Available: https://www.kaggle.com/code/gautammourya/complete-exploratory-data-analysis-of-walmart-data

[21] Y. Jiang, X. Xu, and F. Xiao, "Attribute-based encryption with blockchain protection scheme for electronic health records," IEEE Transactions on Network and Service Management, vol. 19, no. 4, pp. 3884–3895, 2022.

[22] N. A. Ugochukwu, S. Goyal, A. S. Rajawat, S. M. Islam, J. He, and M. Aslam, "An innovative blockchain-based secured logistics management architecture: utilizing an RSA asymmetric encryption method," Mathematics, vol. 10, no. 24, p. 4670, 2022.