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A Proposed Secure Framework for Supply-Chain Management using Blockchain Technology

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Abstract: Decentralization increases the performance of the Supply Chain by distributing financial choices more evenly. The technology that is causing the biggest upheaval is the aforementioned challenges that are hampering today's supply chain are addressed by block chain, which is a cost-effective and realistic solution. Many autonomous networks, self-sufficient persons and institutions can emerge and operate in a distributed, dispersed operating environment thanks to block chain. Theblock chain's data is unchangeable, transparent, and recorded in a distributed ledger that adheres to consensus mechanisms throughout.Hence, the data stored in it cannot be edited and forged i.e., it is trusted if the writer is trusted. Block chain also has its own advantages and setbacks: decentralized network operating in centralized computing devices. Web pages are used to captured changes in original data to malicious data, network synchronization, service outages, and other challenges are some of the issues that could arise in block chain.Thereare several entities and modules involved in the model of this Supply Chain which are tested using an efficient top-down manner in this article. The proposed supply chain management model can be adaptive to various supply chains like food, textile, healthcare and also educational institutions. A comprehensive analysis of the major-cause of numerous threats, susceptibility, and hazards is assisted on the system of supply chain management as imitated in different scenarios.

Index Terms—Supply chain management, Block chain, Security issues, Secured framework.

I. INTRODUCTION

Supply chain management in the digital world refers to the application of digital technologies and strategies to enhance and optimize various aspects of the supply chain [1]. Digitalization has transformed traditional supply chain practices, enabling organizations to streamline operations, improve efficiency, and gain competitive advantages.In today's international forum, the expatiation of increased demand variations is very costly and disruptive that should be minimized in the perception of management. In the centralized system of supply chain management, the finances and their security play a major role as the entire operational cost (from collecting material to shipping final products) is to be bearded from the centralized organizational revenue head. Due to the variational behavioral pattern of customers the revenue generated in all the places may not be proportionate to their expenditure. The main strategy of supply chain management relies on the organizational committee for better security, cost, and speedy work. As a result, customers' dynamic behavior suggests the necessity for a protected, scattered and reliable environment in which to operate.Some key elements and advantages of supply chain management in the digital world are as follows:

- Huge volumes of data can be gathered, analyzed, and interpreted across the supply chain thanks to digital technologies. With the help of this data, you may get insightful knowledge, spot trends, predict demand, manage inventory levels, and come to informed judgements.
- IoT devices such as sensors, RFID tags, and connected devices enable real-time tracking and monitoring of goods, assets, and processes. This enhances visibility across the supply chain, improves inventory management, enables predictive maintenance, and enables proactive decision-making.
- Cloud-based platforms provide a scalable and flexible infrastructure for supply chain management. They facilitate collaboration, data sharing, and communication among supply chain partners, regardless of their geographical locations. Cloud-based solutions also support advanced analytics, demand forecasting, and inventory optimization.
- AI and ML algorithms can analyze large datasets to identify patterns, optimize processes, and automate decision-making. They can be applied to demand

forecasting, route optimization, warehouse management, risk assessment, and fraud detection, among other areas.

• For logging and validating transactions throughout the supply chain, blockchain offers a decentralized and secure solution. The danger of fraud and counterfeiting is decreased as a result of improved transparency, traceability, and trust. Blockchain can be particularly useful in industries where provenance and compliance are critical, such as food, pharmaceuticals, and luxury goods.

• Digital platforms enable seamless collaboration and information sharing between suppliers, manufacturers, distributors, and customers. This improves coordination, reduces lead times, and enhances supply chain responsiveness. It also enables the digitization of documents, invoices, and transactions, leading to faster processing and reduced paperwork.

The fundamental concept of supply chain management was given by the Council of Supply Chain Management Professionals (CSCMP) [2]. The planning and management of all logistics, sourcing, and procurements are the major responsibilities of the management. The role of third party is very critical for coordination of better services in the overall process. The definition also includes the integration of supply and demand among the organization and the costumer.

Life-Cycle SCM

The life cycle of supply chain management encompasses various stages from planning and procurement to delivery and post-sales service [2]. Here are the key stages involved:

• Planning: The planning stage involves setting the strategic objectives of the supply chain, such as defining the target market, determining product/service offerings, and establishing the overall supply chain strategy. This stage includes demand forecasting, capacity planning, and inventory management.

• Sourcing: Finding and choosing vendors or suppliers who can deliver the needed products or services is known as sourcing. It entails tasks including contract management, negotiation, and supplier evaluation. Sourcing decisions consider factors like cost, quality, reliability, and sustainability.

• Procurement: The actual purchase of goods or services from pre-selected suppliers takes place during the procurement stage. This includes tasks like putting out purchase orders, managing supplier relationships, keeping an eye on delivery windows, and making sure that contracts and quality standards are being followed.

• Production: The production stage involves the manufacturing or assembly of products based on customer demand. It includes activities such as production planning, scheduling, managing production facilities, and quality control. This stage may also involve coordination with suppliers for timely delivery of raw materials or components.

• Warehousing and Inventory Management: Once the products are manufactured, they need to be stored in warehouses or distribution centers. This stage involves activities like receiving, inspecting, storing, and managing inventory levels. Efficient inventory management ensures optimal stock levels, minimizes holding costs, and prevents stockouts.

• Transportation and Logistics: The transportation and logistics stage focus on moving products from warehouses to customers or retail outlets. It includes activities like selecting transportation modes, optimizing routes, managing freight forwarding, tracking shipments, and ensuring timely and accurate delivery.

• Customer Service: Customer service is an integral part of the supply chain life cycle. It involves activities such as order processing, order fulfillment, customer support, and managing returns or after-sales service. Providing excellent customer service enhances customer satisfaction and loyalty.

• Performance Measurement and Analysis: Throughout the supply chain life cycle, performance measurement and analysis play a crucial role. To evaluate the effectiveness of the supply chain, pinpoint areas for development, and make data-driven decisions, key performance indicators (KPIs) are monitored. This stage involves analyzing data on cost, quality, delivery time, customer satisfaction, and other

relevant metrics.

• Continuous Improvement: The supply chain life cycle is a continuous process of improvement. Organizations regularly review and refine their supply chain processes, strategies, and relationships to adapt to changing market conditions, technological advancements, and customer demands. This stage involves implementing best practices, embracing innovation, and fostering collaboration with supply chain partners.

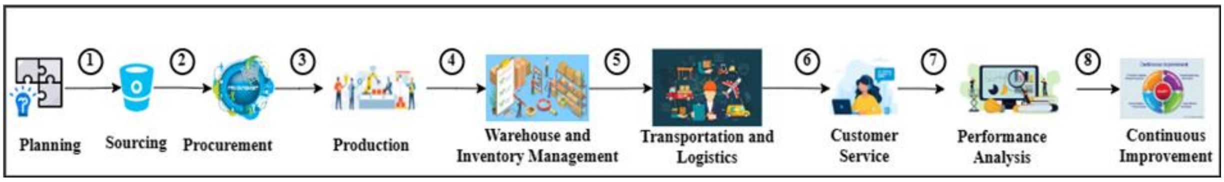

Fig. 1. Product Flow in Supply chain

Because there are so many people involved in the supply chain, the information must be immutable. To keep the information immutable and secured, Blockchain has gained significant attention due to its potential and transparency [3] [4]. There are several reasons to involve blockchain in SCM such as:

• Traceability and Provenance: Blockchain enables the creation of an immutable and transparent record of every transaction and movement of goods within the supply chain. Each transaction is recorded as a "block" and linked together in a chain. This allows stakeholders to trace the origin, manufacturing processes, and movement of products, ensuring authenticity and reducing the risk of counterfeit goods. This is particularly beneficial in industries such as food, pharmaceuticals, and luxury goods, where verifying the authenticity and quality of products is crucial.

• Supply Chain Visibility: Blockchain provides real-time visibility into the supply chain, allowing stakeholders to track and monitor the movement of goods, inventory levels, and delivery status. This visibility helps in identifying bottlenecks, optimizing inventory management, and improving overall supply chain efficiency. With blockchain, participants can access a decentralized ledger that eliminates the need for intermediaries and provides a shared view of the supply chain data.

• Smart Contracts and Automation: Smart contracts built on blockchain technology are self-executing agreements with predetermined terms. When requirements are met, these contracts are automatically carried out. Smart contracts in supply chain management can automate procedures including payments, quality inspections, and compliance verification. For example, payment can be automatically triggered when goods are delivered and verified by IoT sensors or other trusted data sources. This reduces manual intervention, improves accuracy, and accelerates transaction processing.

• Supplier and Vendor Management: Blockchain can facilitate more efficient and secure supplier and vendor management. The decentralized nature of blockchain ensures that supplier information, certifications, and compliance records are securely stored and easily accessible to authorized parties. It simplifies the onboarding process, reduces the risk of fraud or misrepresentation, and streamlines supplier collaboration.

• Risk Mitigation and Transparency: Blockchain enhances supply chain security and reduces the risk of fraud and tampering. The immutability of blockchain records ensures that data cannot be altered or manipulated, providing a high level of trust and transparency. This helps in mitigating risks associated with counterfeit products, unauthorized changes in product specifications, or unauthorized access to sensitive information.

• Efficient Documentation and Compliance: Traditionally, supply chain documentation involves a significant amount of paperwork and manual verification processes. Blockchain can digitize and automate the documentation process, eliminating the need for physical paperwork, reducing errors, and ensuring compliance with regulations. Blockchain-based platforms can securely store and share digital documents, certifications, and compliance records, making audits and regulatory reporting more efficient.

• Collaborative Networks and Trust: Blockchain enables the creation of decentralized and collaborative networks among supply chain participants. By utilizing a shared ledger, stakeholders can trust the integrity of data and transactions without relying on a central authority. This fosters greater trust, cooperation, and information sharing among supply chain partners, leading to improved efficiency and better decision-making.

II. BLOCKCHAIN FEATURES, ARCHITECTURE AND ATTACKS

The idea of blockchain technology has grown in popularity among many researchers and developers [5] due to its constantly expanding database of records. Together with other data, these records are compiled into blocks. Figure 2. illustrates how the blocks are connected together using cryptography. As seen in figure 3, each block comprises a hash of the preceding block, timestamp information, and transactional data expressed as a Merkle tree.The hashing of transactions is implemented by using hash of hash of data. Since a blockchain stores every transaction made in a peer-to-peer network, it is referred to as a decentralized ledger.

Merkle root is a hash value of 32 byte with char data type and uses SHA256 algorithm to engender value[25]. The HASH code at root is computed as,

H(R1-R4) = H(H(H(R1)-H(R2))+H((H(R3)-H(R4))

Where '+ ' is for concatenation , R is for Transaction and H is for Hash Function.

The Merkel tree(MHT) is a popular choice for ensuring the integrity of data as it reduce the amount of data and along with check any of the manipulation[25]. The MHT 256/512, which is implemented in this proposed framework:-

```
Merkel_Node( arr,T_data)
InitalizeI,j,k to 0 , base= 32768
While(T_data){
Append T_data to arr
Compute sha256 for arr[i]
}
while k<16
{
while(i< base){
arr[j]=Compute sha256 for (arr[i]+arr[i+1])
    increment i by 2
    increment j by 1
```

Blockchain becomes secure since intermediaries are no longer necessary [6]. With the elimination of the centralized authority system, blockchain technology, which is decentralized, improves security. Since the data is saved as a cryptographic hash, it cannot be altered. Due to its characteristics, it has a wide range of applications in business, finance, healthcare, and supply chain management systems.

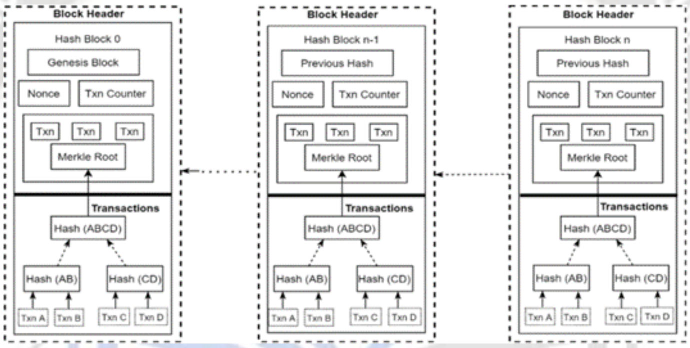

Fig. 2. Representation of Blockchain

A. Features of Blockchain

Decentralized Ledger: A decentralized ledger is a fundamental concept in blockchain technology. It refers to the distributed nature of the ledger, where multiple participants or nodes maintain and update a copy of the ledger. Unlike traditional centralized ledgers, which are managed by a central authority, decentralized ledgers offer transparency, security, and resilience through the consensus of the network[8].In a decentralized ledger, consensus mechanisms are used to validate and agree on the state of the ledger.Transactions are recorded on the ledger in a transparent and immutable manner, allowing participants to independently verify the integrity of the data.Since the ledger is replicated across multiple nodes, it becomes highly resistant to attacks or tampering. Altering or compromising the data on one node would require altering most nodes on the network simultaneously, making it practically infeasible.The immutability of the records ensures the integrity and permanence of the data recorded on the ledger, providing a reliable and auditable record of transactions.

Transparency:Transparency, in the context of blockchain technology, refers to the visibility and openness of information stored on the blockchain. It allows participants in a blockchain network to have access to the same data, enabling them to independently verify and validate the integrity of transactions and records.Transparency in blockchain enhances trust among participants. All participants can independently verify the integrity and accuracy of transactions and records. The transparency enables participants to validate the authenticity of transactions without relying on a central authority or intermediaries, fostering trust in the system.

Security: Blockchain achieves security through cryptographic algorithms. A hash function is used to link each block to the one before it, forming a chain that cannot be altered or tampered with. Furthermore, before a transaction is put to the blockchain, it is validated by the network using consensus mechanisms like proof-of-work or proof-of-stake.

Immutability:A transaction that has been added to the blockchain cannot be changed or removed without the network's approval. This immutability ensures the integrity and permanence of the recorded data, making blockchain suitable for applications that require a tamper-proof and

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auditable record.A chain of blocks is formed when each block in a blockchain uses cryptographic hashes to connect to the one before it. It is computationally impractical to change the data in a block without also changing the hash of that block and all succeeding blocks. This tamper resistance ensures the integrity and security of the recorded information.

Smart Contracts:Self-executing contracts, or smart contracts, are written in blockchain code. When specific criteria are satisfied, these contracts automatically carry out predetermined activities. Automation is made possible by smart contracts, which also do away with the need for middlemen and guarantee accurate and transparent agreement implementation. Lawyers, brokers, or escrow agents are not required in the case of smart contracts. The contract's terms and conditions are immediately inscribed into the blockchain, and when the requirements are satisfied, the contract is instantly carried out. Costs, delays, and reliance on other parties are decreased as a result.

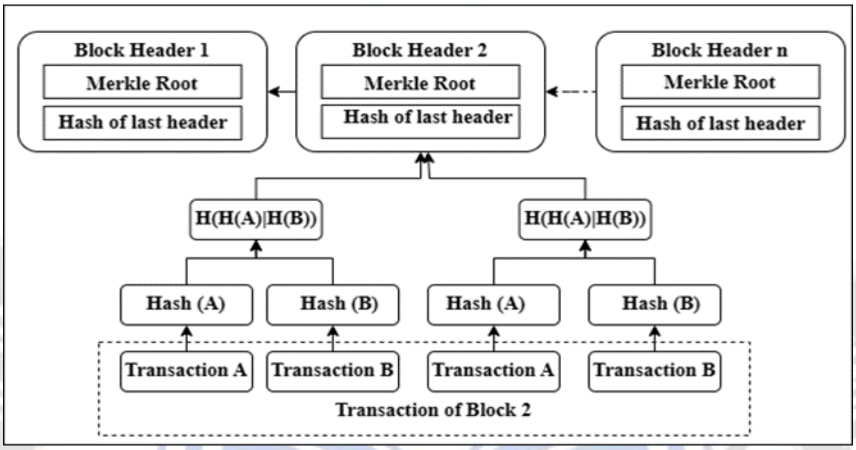

Fig. 3. Merkle Tree of Transactions in a block

B. Blockchain Architecture

Blockchain architecture refers to the underlying structure and components of a blockchain system [9]. It outlines how the various elements of a blockchain network, such as nodes, consensus mechanisms, data storage, and communication protocols, work together to create a secure and decentralized environment. While there are different types of blockchain architectures, the most common one is the architecture used in public blockchains like Bitcoin and Ethereum. Here are the key components of a typical blockchain architecture:

Nodes: Nodes are individual computers or devices that participate in the blockchain network. They maintain a copy of the entire blockchain and communicate with other nodes to validate and propagate transactions and blocks.

Peer-to-Peer Network: Nodes in a blockchain network communicate with each other in a peer-to-peer (P2P) fashion. This decentralized network allows for direct interaction and data sharing among participants, without the need for intermediaries.

Consensus Mechanism: Consensus techniques allow network nodes to concur on the legitimacy of transactions and the sequence in which blocks are added to the blockchain. Proof-of-work (PoW), proof-of-stake (PoS), delegated proof-of-stake (DPoS), and practical byzantine fault tolerance (PBFT) are common consensus procedures. These mechanisms ensure that the network reaches a consensus and prevents fraudulent or double-spending transactions.

Blockchain Data Structure: The blockchain data structure divides information into blocks and links them in a time- and change-stamped chain. Each block has a series of transactions, a reference to the preceding block, a timestamp, and a hash that serves as a unique identification and was created using cryptographic procedures.

Cryptographic Security: Cryptographic algorithms play a crucial role in securing the blockchain. Hash functions are used to generate unique identifiers for each block and transaction, ensuring data integrity and tamper resistance. Digital signatures provide authentication and ensure that only authorized participants can interact with the blockchain.

Smart Contracts: Smart contracts are programmable code that execute predefined actions when specific conditions are met. They are stored and executed on the blockchain, automating the execution of agreements and enabling complex business logic.

Data Storage: Blockchain systems utilize various methods to store data. In public blockchains, all data is stored and replicated across multiple nodes in the network, creating a distributed ledger. In private or consortium blockchains, data storage may be more centralized or restricted to specific participants.

User Interfaces: User interfaces (UIs) allow users to interact with the blockchain system. This can include wallet applications for managing cryptocurrency, decentralized applications (dApps) that leverage the blockchain's capabilities, and other tools for monitoring and interacting with the blockchain network.

The Ethereum blockchain architecture is a specific implementation of blockchain technology that is designed to support the execution of smart contracts and decentralized applications (dApps) [10]. It introduces several key components and concepts that differentiate it from other blockchain architectures. Here are the main elements of the Ethereum blockchain architecture:

Ethereum Virtual Machine (EVM): Smart contracts are carried out in a runtime environment called the Ethereum Virtual Machine. It is a Turing-complete virtual computer, which means that provided there are enough computational resources, it can execute any arbitrary code. Smart contracts written in high-level languages like Solidity are compiled into bytecode that can be executed by the EVM [12].

Ether (ETH): The native cryptocurrency of the Ethereum network is called Ethereum. It is used to motivate miners to carry out smart contracts and validate transactions. Ether can also be used as a medium of exchange within the Ethereum ecosystem.

Gas: Gas is a measurement unit that represents the computational effort required to execute operations in the Ethereum network. Each operation, including executing instructions in smart contracts or storing data, consumes a specific amount of gas. Gas prices are denominated in Ether and serve as a mechanism to prevent spam and prioritize transactions based on their gas fees.

Solidity: Solidity is the primary programming language used for developing smart contracts on the Ethereum platform. It is a statically-typed language with similarities to JavaScript and is designed specifically for writing smart contracts that run on the EVM.

Transactions: Transactions in the Ethereum network consist of sending Ether between accounts or invoking smart contract functions. Transactions contain essential information such as the recipient address, the amount of Ether transferred, and the gas limit and price. They are broadcasted to the network, validated by miners, and included in blocks.

Blocks and Mining: Blocks in the Ethereum blockchain contain a list of validated transactions, along with other metadata such as a reference to the previous block, a timestamp, and a nonce. Mining nodes compete to solve a cryptographic puzzle, called Proof-of-Work (PoW), to create new blocks and append them to the blockchain. Miners are rewarded with Ether for their computational effort[27].

Consensus Mechanism: Currently, Ethereum uses a Proof-of-Work (PoW) consensus mechanism, like Bitcoin. However, Ethereum is transitioning to a Proof-of-Stake (PoS) consensus mechanism called Ethereum 2.0. PoS relies on validators who hold and lock up a certain amount of Ether as collateral to validate transactions and create new blocks, reducing the energy consumption and scalability limitations associated with PoW.

The general mathematical expression for the Proof of Work algorithm is:

SHA256(SHA256(h. n))< =target.

A block header hash is calculated as a double SHA256 hash of all the block constituents, as shown below:

Block header hash = SHA256 (SHA256 (Previous block hash + Merkle root + Timestamp + Difficulty target + Nonce)).

Decentralized Applications (dApps): Ethereum supports the development and deployment of decentralized applications. These are applications that run on the Ethereum blockchain and leverage its smart contract capabilities. dApps can interact with smart contracts and access decentralized storage, enabling various use cases such as decentralized finance (DeFi), gaming, identity management, and more.

The Ethereum blockchain architecture provides a platform for developers to build and deploy decentralized applications, enabling programmable, trustless, and transparent systems on a global scale. It has become a popular choice for blockchain-based development due to its versatility, active developer community, and extensive ecosystem of tools and frameworks.

C. Threats in Blockchain

Although, blockchain technology offers robust security features, it is not immune to certain types of attacks [13]. However, some common attacks that can occur in blockchain systems:

51% Attack: A 51% attacks happens when one entity or a collection of conspiring entities controls more than 50% of the network's mining power in a blockchain network that employs a Proof-of-Work (PoW) consensus mechanism. This allows them to manipulate the blockchain by double-spending coins, excluding certain transactions from confirmation, or reversing confirmed transactions.

Sybil Attack:To take over a decentralized network, an attacker would launch a Sybil attack, creating numerous fictitious identities or nodes. The attacker can interfere with the consensus process, tamper with transaction confirmations, and engage in other illegal acts by controlling many nodes.

Eclipse Attack:By surrounding a targeted node in the network with malicious nodes under the attacker's control, an eclipse attack seeks to isolate it. The attacker can change the targeted node's perception of the blockchain, carry out double-spending assaults, or banish it from the network by manipulating the information it receives.

DoS (Denial of Service) Attack: A DoS attack involves bombarding a blockchain network with a large number of erroneous transactions or excessive resource demands in an effort to reduce its availability and performance. This may result in network sluggishness, delayed transactions, or even an end to blockchain activities altogether.

Smart Contract Vulnerabilities: Smart contracts are susceptible to security vulnerabilities in their code. These vulnerabilities can be exploited by attackers to steal funds, manipulate contract behavior, or execute unauthorized actions. Common vulnerabilities include reentrancy attacks, integer overflow/underflow, and logic errors.

Malicious Code/Exploit Attacks: Attackers may target vulnerabilities in the blockchain software itself or the underlying protocols to exploit weaknesses and gain unauthorized access or control over the network. This can lead to unauthorized transactions, theft of funds, or disruption of network operations.

Insider Attacks: Insider attacks involve malicious actions by individuals who have authorized access to the blockchain system [14]. This can include developers, administrators, or other trusted individuals with privileges who misuse their access to manipulate data, tamper with transactions, or compromise the security and integrity of the blockchain.

III. PROPOSED SECURED FRAMEWORK FOR SCM USING BLOCKCHAIN

Supply Chain Management (SCM) is based on the principle of successfully coordinating the flow of goods, services, and information in order to achieve high performance while minimizing risks [15]. Organizations must interact more closely in today's fast-changing industry to develop successful ways and enhance their logistic process for the improvement of entire process of supply chain [16].

The proposed framework is utilized to solve the information flow problem, capital flow, and logistics. The first section of the proposed framework explored a Secured Transactions in Supply Chain Management (STSCM), which is a supply chain management-based architecture that facilitate thedurability of various operational modes of supply chain.The proposed framework can track the operational mode in the entire process which includes the material management, planning of operations, logistics, retail, order fulfilment, and so on.The second phase of the study focused on deploying and evaluating the framework in various working settings.

A. Proposed Framework

Figure 4 depicts an abstract perspective of the proposed secure framework for SCM using Ethereum Blockchain. The framework is divided into three main modules with the integration of verified users at the top of the framework. These three modules are supply chain management module (SCMM), Transaction management module (TxMM), and Ethereum Blockchain module (EBM). The framework also utilized the smart contract with pre-defined rules and condition encoded directly onto a blockchain. Smart contracts automate the execution of contractual obligations once the predefined conditions are met. By eliminating the need for manual intervention, they reduce human error, increase efficiency, and save time and resources.

B. Supply Chain Management Module (SCMM):A comprehensive Supply Chain Management (SCM) module with raw material, supplier, manufacturer, distributor, retailer, and customer components would cover the entire supply chain process from procurement to the end customer [17].Here are the key functionalities and features that such a module would include:

Raw Material Management:

- Raw material inventory management, including tracking stock levels, reorder points, and safety stock.
- Supplier selection and onboarding.
- Demand forecasting and planning for raw materials.
- Purchase order management and automation.
- Quality control and inspection of incoming raw materials.

Supplier Relationship Management:

- Supplier performance evaluation and monitoring.
- Contract management and negotiation.
- Collaboration tools for real-time communication with suppliers.
- Supplier portal for order placement, delivery tracking, and invoice management.

- Supplier compliance and documentation management.

Manufacturing Management:

- Production planning and scheduling.
- Bill of Materials (BOM) management.
- Work order creation and tracking.
- Shop floor control and production monitoring.
- Quality assurance and control throughout the manufacturing process.

Distribution and Logistics Management:

- Warehouse management, including receiving, storage, and picking.
- Inventory tracking and management across distribution centers.
- Order fulfillment and allocation.
- Transportation management, including carrier selection, route optimization, and freight tracking.
- Reverse logistics for returns and product recalls.

Retail and Point of Sale (POS) Management:

- Store-level inventory management and replenishment.
- Point of sale system integration for sales tracking and customer purchase history.
- Promotions and pricing management.
- Real-time visibility into stock levels and product availability.
- Store performance analytics and reporting.

Customer Order Management:

- Order capture and processing across various channels (online, phone, etc.).
- Order status tracking and updates for customers.
- Customer communication and notifications regarding order fulfillment and delivery.
- Returns and refunds processing.
- Customer self-service portal for order tracking and returns initiation.

Supply Chain Analytics and Reporting:

- Dashboards and reports for monitoring key performance indicators (KPIs) across the supply chain.
- Supplier performance metrics and scorecards.
- Inventory turnover and carrying cost analysis.
- Demand forecasting accuracy and sales performance analysis.
- Real-time data visualization for improved decision-making.

Integration and Collaboration:

- Integration with external systems, such as ERP, CRM, and e-commerce platforms.
- Collaboration tools and communication channels for seamless interaction among supply chain stakeholders.
- Data exchange and synchronization for real-time visibility and information sharing.

Compliance and Risk Management:

- Compliance tracking and reporting, including regulatory and sustainability requirements.
- Risk identification, assessment, and mitigation strategies.
- Supplier compliance monitoring and audits.
- Supply chain traceability and product recalls management.

Track and Trace:

- Serialization and unique identification of products for traceability.
- Track and trace capabilities using technologies like barcode scanning, RFID, or blockchain.
- Real-time visibility into product movement and location throughout the supply chain.
- Recall management and identification of affected products.

By incorporating these functionalities into an SCM module, organizations can effectively manage and optimize their supply chain operations, enhance collaboration with stakeholders, improve customer satisfaction, and drive overall efficiency in the supply chain processes.

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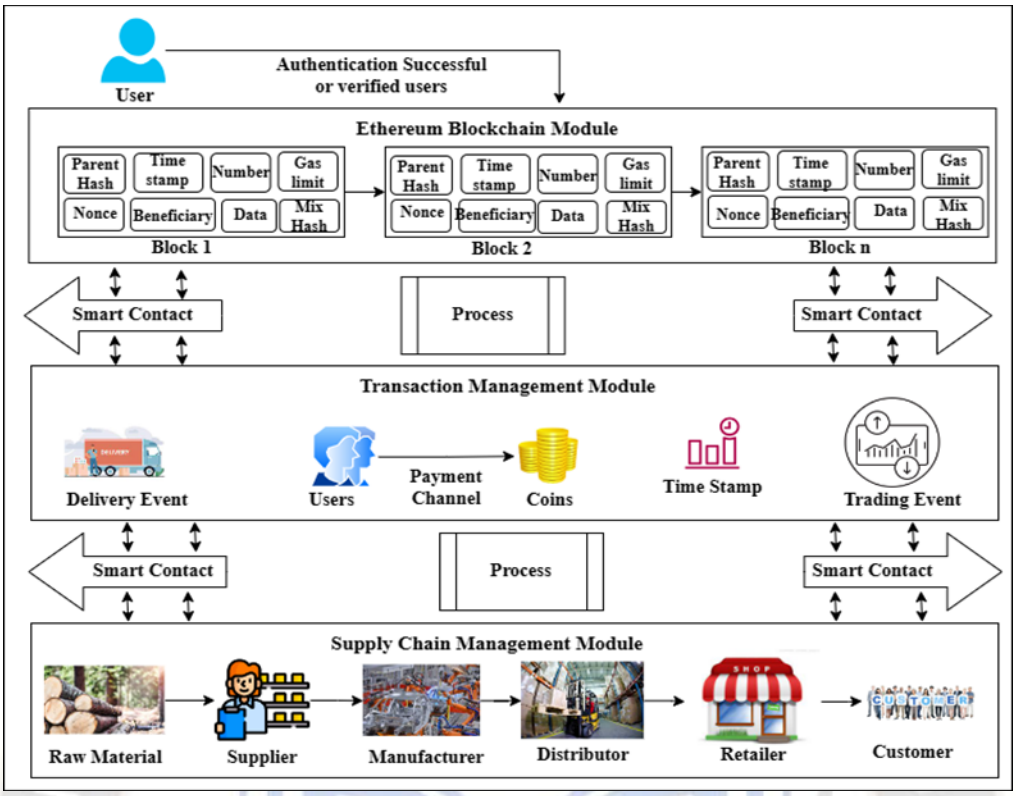

Fig. 4. Proposed Secured Framework for SCM using Ethereum Blockchain

Transaction Management Module (TxMM):A Transaction Management module for SCM using the Ethereum blockchain can leverage the unique features of Ethereum to enhance transparency, security, and traceability in supply chain transactions [18]. Here is an outline of how such a module could function:

Smart Contracts for Transactions: Utilize smart contracts on the Ethereum blockchain to facilitate and automate various supply chain transactions, including purchase orders, sales orders, invoices, and payments. Smart contracts can define the terms, conditions, and rules of the transactions, ensuring trust and accuracy without the need for intermediaries.

Immutable Transaction Records: All supply chain transactions are recorded on the Ethereum blockchain as immutable entries. This provides an auditable and tamper-proof record of each transaction, ensuring transparency and traceability throughout the supply chain.

Decentralized Identity and Access Management: Implement decentralized identity solutions on Ethereum, such as ERC-725 or ERC-735, to manage the identity and access of supply chain participants. This enables secure and permissioned access to transaction-related information based on cryptographic signatures and role-based access controls.

Smart Contract Escrow and Payment Handling: Utilize smart contracts to handle escrow and payment processing in supply chain transactions. This allows for secure and automated payment settlements based on predefined conditions and triggers, reducing the risk of fraud or disputes.

Event and Condition Tracking: Utilize Ethereum's event-driven architecture to track and monitor key events and conditions in supply chain transactions. For example, trigger events can be set for order fulfillment, shipment updates, quality control checks, or payment milestones. These events can automatically update the transaction status and trigger subsequent actions.

Supply Chain Traceability: Leverage the transparency and immutability of the Ethereum blockchain to enhance supply chain traceability. Each transaction can include relevant information, such as product details, origin, quality certifications, and shipment tracking. This enables stakeholders to verify the provenance and authenticity of products throughout the supply chain.

Integration with External Systems: Integrate the Ethereum-based Transaction Management module with other systems and data sources within the supply chain ecosystem. This may include integration with ERP systems, inventory management systems, IoT devices, or external data providers. APIs or oracle services can facilitate seamless data exchange and interoperability.

Secure Data Exchange and Encryption: Implement encryption techniques and secure communication protocols

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for data exchange within the Ethereum-based SCM module. This ensures the confidentiality and integrity of sensitive transaction data, such as pricing, quantities, or customer information.

Auditability and Compliance: Leverage the transparency and immutability of the Ethereum blockchain to enhance auditing and compliance in supply chain transactions. Auditors can independently verify the integrity of transaction records and assess compliance with regulatory requirements or industry standards.

Continuous Monitoring and Upgrades: Regularly monitor the Ethereum blockchain network for potential security threats, vulnerabilities, or performance issues. Stay updated with the latest Ethereum upgrades, patches, and best practices to ensure the security and reliability of the Transaction Management module.

By utilizing the Ethereum blockchain for Transaction Management in SCM, organizations can achieve increased transparency, automation, and efficiency in their supply chain operations. The decentralized and immutable nature of the blockchain provides a trusted and auditable foundation for managing transactions and enhancing collaboration among supply chain participants [19]. Some key points that are used by TxMM are as follows:

- The TxMM updates the blockchain about all the transactions updated by logistics.
- Manufacturer send their goods for quality check to the unit.
- The quality unit sends them the quality report.
- It also updates this certificate to the TxMM.
- The TxMM updates the blockchain about all the transactions updated by quality unit.
- Ancillary places a request to logistic department to transfer goods to Manufacturer.
- The logistic department gathers the goods from ancillaries and prepares for transfer to Manufacturing unit.
- Ancillaries delivers goods to Manufacturing unit.
- The logistic department updates the TxMM about cost incurred for the inherent transactions.
- The TxMM updates the blockchain about all the transactions updated by the logistic department.
- The manufacturers send goods to quality unit for quality check.
- The quality unit sends back the quality report to Manufacturer.
- The quality unit updates this certificatetotheTxMM.
- Manufacturer places request to the logistic to transfer goods to Distributor.
- The logistic department delivers goods to Distributors.
- The logistic department updates the TxMM about cost incurred for the inherent transactions.
- The TxMM updates the blockchain about all the transactions updated by the logistic department.
- Customer places a request to the distributor for the required goods.
- Distributor verifies the customer's request and sends the goods to them.
- Distributor places the request to the logistic department for transferring goods to Customers.
- Customer makes payment to the logistic department after receiving the required goods.
- The logistic department updates the TxMM about cost incurred for the inherent transactions.
- The TxMM updates the blockchain about all the transactions updated by the logistic department.

Ethereum Blockchain Module (EBM):The Ethereum blockchain is a decentralized platform that utilizes a specific data structure known as a block to store and validate transactions [20]. Each block in the Ethereum blockchain contains several important components, including the parent hash, timestamp, number, mix hash, and nonce. An overview of each component are as follows:

Parent Hash: The parent hash refers to the hash of the previous block in the blockchain. It forms a chain-like structure, connecting each block to its preceding block. This linking ensures the integrity and immutability of the entire blockchain. By including the parent hash, Ethereum maintains a chronological order of blocks, enabling secure and consistent transaction processing.

Timestamp: The timestamp represents the date and time when the block was created or mined. It provides a reference point for identifying the sequence of blocks in the blockchain. The timestamp serves as an essential component for establishing the order of transactions and maintaining synchronization across the network.

Number: The number denotes the unique identifier assigned to each block in the Ethereum blockchain. It signifies the position of the block within the blockchain's linear sequence. By assigning a unique number to each block, Ethereum enables efficient indexing and retrieval of specific

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blocks for verification and reference.

Mix Hash: The mix hash is a component specific to Ethereum's Proof-of-Work (PoW) consensus algorithm. It is an intermediate hash value generated during the process of mining a block. Miners compute the mix hash by combining the nonce (explained next) with the block's header information. The mix hash plays a role in determining the validity of the block's PoW solution.

Nonce: The nonce (short for "number only used once") is a randomly generated value that miners modify to find a valid PoW solution. Miners repeatedly adjust the nonce value until they discover a value that, when combined with the other block header information, results in a hash below a specific target threshold. The nonce serves as a parameter that miners manipulate to perform the computational work required for block mining.

Beneficiary: The beneficiary, also known as the recipient or the destination address, represents the Ethereum account or smart contract address that receives the transaction. It specifies where the transaction's value or data is being sent within the Ethereum network.

Data: The data component refers to the payload or information associated with the transaction. For regular value transfers, the data field is usually empty. However, for smart contract interactions, the data field contains the input parameters and function calls required to execute the desired actions on the smart contract.

Gas Limit: Gas is the execution fee required to perform operations on the Ethereum network. The gas limit specifies the maximum amount of gas that can be utilized by a transaction. Each operation within a transaction consumes a specific amount of gas, and the gas limit prevents a transaction from consuming an excessive number of computational resources. If the gas limit is insufficient to complete a transaction, the transaction will fail.

To impart inventory control , to calculate the time when we generated purchase order has to be emitted .The quntitity of item k to be ordered t time t at the network node i, qik(t), it depends on the target level Ɵik(t)and the inventory position,πik(t):

$$q_{ik}(t) = \Theta_{ik}(t) - \pi_{ik}(t) \qquad (1)$$

The equation is kept in mind for the calculation of inventory control.

In a supply chain, demand forecasting often entails predicting future demand for goods or services using a variety of mathematical models. The exponential smoothing approach is a popular model for demand forecasting. This approach uses time series data and weighted averages of previous observations to forecast demand in the future

The basic exponential smoothing equation is as follows:

$$Ft+1=\alpha \times Yt+(1-\alpha)\times Ft \qquad (2)$$

- Ft+1 is the forecasted demand for the next period (t+1).
- Yt is the actual demand for the current period (t).Ft is the forecasted demand for the current period (t).
- α is the smoothing parameter (0 <= α <= 1), The weight assigned to the most recent observation is determined by Yt. Greater values of place more weight on the most recent observation, whereas smaller values of place more weight on earlier observations.

The framework's one of the major objective is to calculate the demand forecasting in inventory and also in the transaction . The Ether components are instigated for the performance measures.

IV. EXPERIMENTAL TESTBED AND RESULTS

To implement a supply chain management (SCM) system using the Ethereum blockchain, we need a well-designed system configuration that includes various components and their interactions. First of all, we need to set up a private or test network using Ethereum nodes, such as Geth or Parity with network parameters like block time, gas limit, consensus algorithm, and network ID which ensure that nodes are synchronized and connected to form a reliable blockchain network [21]. Only registered users are allowed to interact with the system. Each registered user receives their own set of personal credentials. The system grants authorization to do certain operations based on their job after authenticating their details. Sellers are granted the ability to add and ship items. Buyers can buy an item, get information about it, and receive it [22]. The SCM smart contract validates the operations that are carried out. The suggested system's prototype is being tested to see how well it works and to see if the security levels are being met.

Solidity, an object-oriented, high-level language for building smart contracts, is used in the prototype of this system. Smart contracts, called software programmers that manage the behavior of accounts within Ethereum, are expanded using the REMIX IDE.The version of solidity used is v12.7.0. We deployed our SCM model is deployed in eight machines (containing ubuntu and Windows operating systems), each possessing 2.30GHz core Intel processor with 8 GB primary memory [23].This experiment uses node (of version 12.7.0) which is an asynchronous event-driven JavaScript runtime, which is designed to build scalable network applications, npm (version 6.11.2) is the package manager for the Node JavaScript platform which is used to

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publish, discover, install, and develop various node programs. go-Ethereum is a licensed open-source implementation of Ethereum also used as the platform for implementing blockchain.

Value (in wei)	Exponent	Common Name	SI Name
1	1	wei	wei
1,000	10^3	babbage	kilowei or femtoether
1,000,000	10^6	lovelace	megawei or picoether
1,000,000,000	10^9	shannon	gigawei or nanoether
1,000,000,000,000	10^{12}	szabo	microether or micro
1,000,000,000,000,000	10^{15}	finney	milliether or milli
1,000,000,000,000,000,000	10^{18}	*ether*	*ether*
1,000,000,000,000,000,000,000	10^{21}	grand	kiloether
1,000,000,000,000,000,000,000,000	10^{24}		megaether

Fig. 5. Ether Exponent and Unit name

Truffle (version 5.0.30) is a programming environment, testing framework, and asset pipeline for Ethereum Virtual Machine-based blockchains (EVM). Web3js (version 1.2.0) maintains request handling between Ethereum nodes. It contains a collection of modules that allow you to interface with a local or distant Ethereum node using HTTP, IPC, or WebSocket [24]. Figure 5 shows the exponent, its value, and name of SI unit used for the blockchain. The complexity of this experiment is measured in terms of gas because it is used to deploy or execute a smart contract. The total cost of the project is equal to the number of units of gas utilized multiplied by the cost of each unit of gas.

. The dataset considered here contains 7 tables, one table containing all the information about the orders and the other tables specifying the limitations. From the first table we consider the following parameters as shown in table I. There are hundreds of records available in these two tables, from which we have generated our synthetic data.

We have several performance parameters for the evaluation of results and testing measurements. The gas cost is the first parameter that is evaluated for the deployment of smart contracts.The total gas that is consumed by nodes during binding technique. Execution cost, transaction cost, and total cost are other parameters used to evaluate for each event occurred during SCM. The total consumed gas is also evaluated utilized for the goods tracing.

TABLE 1: ATTRIBUTES OF ORDER TABLE

Attribute	Category
Product ID	Number
Order ID	Number
Customer ID	Number
Weight	Number
Order date	Number
Unit quantity	Number
Destination address	Number

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TABLE II
JVM RESULTS GENERATED

S. No.	Operation Applied	Transaction Cost		Execution Cost		TotalCost (in Ether)	TotalCost (in INR)
		Gas units	**Cost (in Ether)**	**Gas units**	**Cost (in Ether)**		
1.	Deployment of SCM	2109599	0.0010548	1564487	0.0007822	0.001837	79.50
2.	Quality of item	22910	0.0000115	1638	8e-7	0.0000123	0.53
3.	Item Replacement	35378	0.0000177	12890	0.0000064	0.0000241	1.04
4.	Item Shipment	29988	0.000015	8588	0.0000043	0.0000193	0.84
5.	Adding item to Supply chain	189960	0.000095	167664	0.0000838	0.0001788	7.74
6.	Buy Item	123922	0.000062	117522	0.0000588	0.0001208	5.23
7.	Sending amount to buyer	19073	0.0000095	12801	0.0000064	0.0000159	0.69
8.	Item Receipt	35235	0.0000176	13835	0.0000069	0.0000245	1.06
9	Deposit amount into supply Chain contract	44331	0.0000222	21459	0.0000107	0.0000329	1.42
10.	Item Cancellation	44769	0.0000224	51897	0.0000259	0.0000483	2.09

Our model was executed in four different environments which are in (i) JVM Environment (ii) Injected Web3 Environment (Rinkeby test network) and (iii) Injected web3 and ganache Environment and (iv) Injected Web3 Environment (Ropsten test network) as a test for efficiency.

- When our model in a JVM environment, we got the following results (shown in Table II).
- The following output as shown in table III were originated on deploying our framework in Injected Web3 surroundings (Rinke by test network).
- The output we get, on deploying our model in Web3 provider and ganache Surroundings are shown in (table
- IV).
- When we deployed our model in the Injected Web3 Environment, we got the following results (see table V) (Roopsten test network).

TABLE III
OUTPUT GENERATED IN WEB3 (RINKEBY TEST NETWORK)

S. No.	Accomplishedoperation	Cost of Transaction		Block number	Number of transactions mined	Size of the block Bytes	Transaction Fee	
		Gas units	**Transaction cost**				**In INR**	**In ETHER**
1.	Deployment of SCM	1740935	1740935	7665957	14	13,080	30.410	0.001740935
2.	Quality of item	23197	23197	7666196	19	5,119	0.4049	0.000023197
3.	Item Replacement	39680	38198	7666106	56	16,138	0.6675	0.000038198
4.	Item Shipment	34178	32780	7666064	43	13,556	2.7089	0.000155127
5.	Adding item to Supply chain	201936	201936	7666008	58	17,649	3.51	0.000201936
6.	Buy Item	170127	155127	7666044	54	13,987	2.7089	0.000155127
7.	Sending amount to buyer	33865	18865	7666166	16	5,346	0.328	0.000018865
8.	Item Receipt	40025	38627	7666080	27	9,684	0.6688	0.000038627
9	Deposit amount into supply Chain contract	35273	34654	7666098	10	3,056	4.01971	0.00023565
10.	Item Cancellation	83669	53669	7666143	24	6,155	0.926	0.000053669

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TABLE IV
RESULTS GENERATED IN WEB3 AND GANACHE CLIMATE

S. No.	Operation performed	Gas Consumed	Cost of Transaction	Transaction fee (INR)	Transaction fee (ETHER)
1.	Deployment of SCM	1740935	1740935	3039	0.06963
2.	Quality of item	23197	23197	40.496	0.00092
3.	Item Replacement	39680	38198	67.978	0.00155
4.	Item Shipment	34217	32780	58.48	0.00133
5.	Adding item to Supply chain	201936	201936	352.53	0.00807
6.	Buy Item	170127	155127	283.90	0.00650
7.	Sending amount to buyer	33865	18865	46.0269	0.0010546
8.	Item Receipt	40025	38627	68.65	0.00157
9	Deposit amount into supply Chain contract	30567	23459	47.15	0.00108
10.	Item Cancellation	83669	53669	119.879	0.002746

TABLE V
RESULTS GENERATED IN INJECTED WEB3 (ROPSTEN TEST NETWORK)

S. No.	Operation performed	Gas	Block number	Number of transactions	Size of the block	Block Reward		Transaction fee	
						In ETHER	In INR	ETHER	INR
1.	Deployment of SCM	16,63,051	845045	**mined** 16	**(Bytes)** 38,802	2.9927	86,463.2	0.0831525	2402
2.	Quality of item	23109	8451100	51	18,176	2.25625	65,184.43	0.0016176	47
3.	Item Replacement	39614	8450817	18	4,480	2.0131	58161.35	0.0023641	68
4.	Item Shipment	34112	8450672	6	7,047	2.0664	59,699.75	0.0019301	54
5.	Adding item to Supply chain	1,91,092	8450552	34	78,857	2.2004	63,571.87	0,0002586	180
6.	Buy Item	1,28,765	8450627	21	5,051	2.03802	58,879.66	0.0070051	202
7.	Sending amount to buyer	32943	8450976	4	25,816	2.08171	60,141.87	0.0019238	55
8.	Item Receipt	39937	8450703	29	8,841	2.0395	58,924.32	0.0021196	62
9	Deposit amount into supply Chain contract	46231	8450761	22	5,887	2.0367	58,842.25	0.0027795	81
10.	Item Cancellation	68581	8450876	49	14,308	2.05252	59,298.63	0.0027006	78

V. ANALYSIS AND DISCUSSION

The experimentation results presented above show that the current model is highly portable and efficient as it produces almost equivalent results with respect to the operations performed and the cost incurred in all the environments it is implemented. The implementation of SCM model using blockchain technology and validating it as authentication and authorization are automatically and mandatorily performed.

Fig. 6 shows the cost incurred for deploying our SCM model which has 10 operational codes inclusive in it. To deploy this model 2.8374 USD were used which is equivalent to 0.024 Ether. Fig. 7 demonstrated the deployment of STSCM model in Rinkeby Environment. Fig. 8 shows the deployment of STSCM model in Roopsten Environment. Figure 9 and Figure 10 shows the gas consumption for goods and smart contracts.

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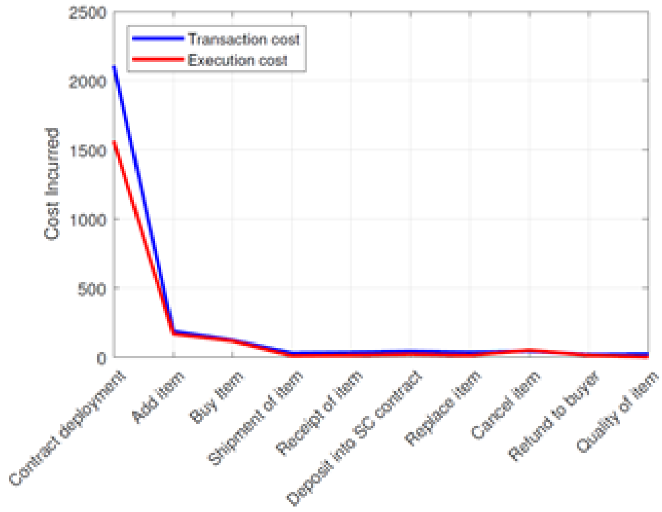

Fig. 6. Transaction cost Vs Execution Cost in JVM

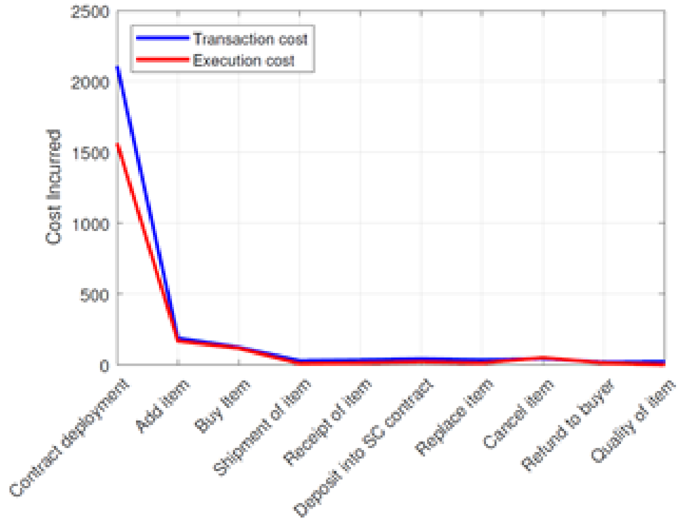

Fig. 7. Transaction cost Vs Bytes of Information in Rinkeby

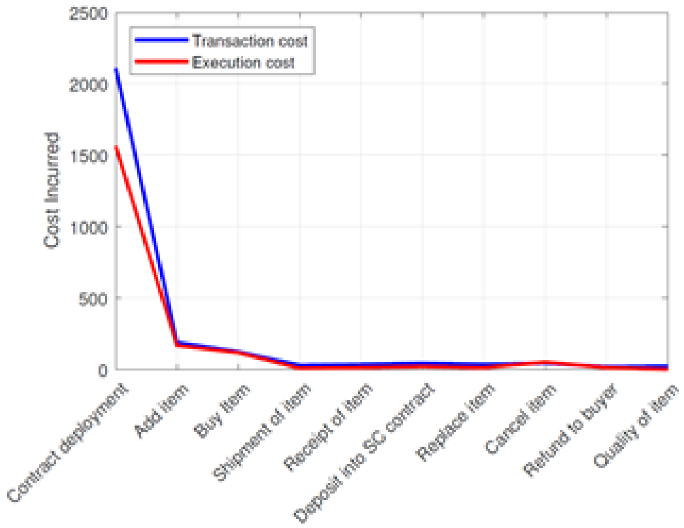

Fig. 8. Transaction cost Vs Bytes of Information in Roopsten

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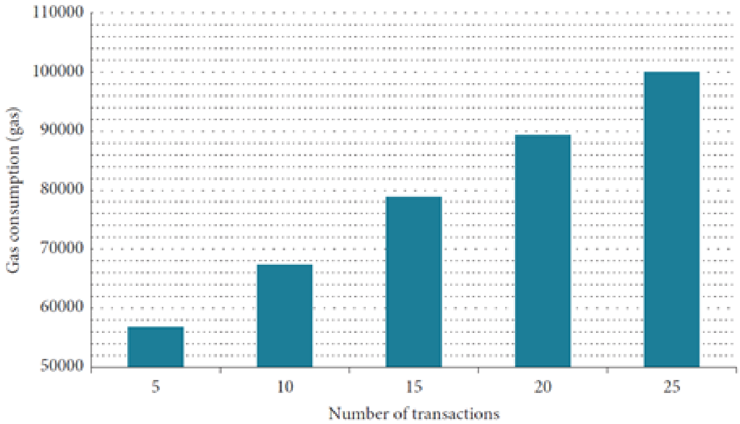

Fig. 9. Gas Consumption for Goods

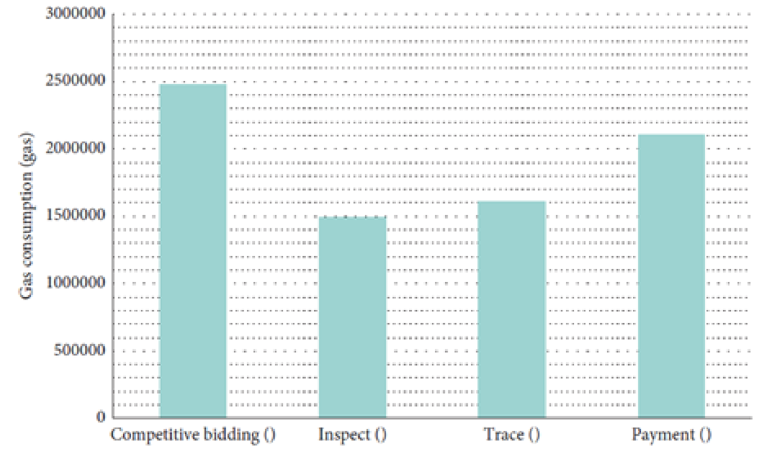

Fig.10. Gas Consumption for Smart Contracts

VI. CONCLUSION

Form the recent work, we have found few observations with regard to present environment and for customer satisfaction by providing good services using emerging technologies. Customer have a very much interested in the transparency, trust, security, quickness, right from the ordering the product to the delivery at a door step with an easy and customer-friendly manner. To provide solution to the transparency, trust, security, quickness issues blockchain technology is a very good platform in a current day's scenario. Blockchain technology used to develop a very secure supply chain management, since it has inherent features of security for the records, transparency in the transactions and database, decentralized ledger.

This article focused on the designing of a proposed supply chain management framework (STSCM), This has advanced features that allow customers an easy way to buy and have products delivered to their homes without great effort,for the cost of the real goods, and delivered quickly to the customer's door.Even if the security protections are provided by blockchain technology, smartcontract byte code is exposed to all players due to transparency. As a result, the suggested SCM smart contract is capable of protecting against these attacks.

Beyond our recommended SCM and security approaches, there are still a number of obstacles in SCM, such as consumer expectations for more clarity in merchandise pricing, because consumers are not giving the genuine price for merchandise, and Suppliers, stakeholders, and the environment must all have faith in each other.Another issue is that blockchain has vulnerabilities, such as network vulnerabilities, and that coordination between suppliers, manufacturers, logistics, and the environment is difficult. And, because there are so many people working in SCM, risk management is also a challenge. One of the major issues is that most people are unaware to this new technology, So, professionals in the field are scarce, and the cost of ethers is also very high. For middle-class folks, it is quite difficult to afford.

COMPETING INTEREST

We hereby declare that the above-mentioned title work is under our supervision and we have NO Conflict of Interest. Himani Saraswat*,Mahesh Manchanda, Sanjay Jasola

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AUTHOR CONTRIBUTIONS

"The conceptualization of the whole paper and idea was done by Himani Saraswat. The methodology was created by all the three writers i.e. Himani Saraswat, Mahesh Manchanda and Sanjay Jasola. The validation and the supervision is done by Mahesh Manchanda and Sanjay Jasola. The editing, data curation, writing review along with the project visualization and the original draft writing is done by Himani Saraswat. The investigation of resources are done by Sanjay Jasola. The formal analysis was done by Himani Saraswat and Mahesh Manchanda The whole project was administered by Mahesh Manchanda. There is no external funding available for this project"

DATA AVAILABILITY STATEMENT.

The dataset considered here is synthetically generated from Tatiana Kalganova 's dataset. It available online.

RESEARCH INVOLVING HUMAN AND/ OR ANIMALS

Research does not Involve Human or Animal

INFORMED CONSENT.

This is an observational study.

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