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Blockchain in Supply Chain

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Abstract: Blockchain is a decentralized digital ledger for storing and recording transactions securely. It is a technology that securely records transactions—blocks—using multiple computers, which comprise the chain. Blockchain technology provides a secure and transparent way to record transactions without the need for intermediaries or centralized control. In a supply chain, blockchain technology acts as a decentralized, transparent ledger that records every transaction and movement of goods, enabling real-time tracking, improved traceability, and enhanced visibility for all participants throughout the supply chain. Blockchain enhances collaboration among supply chain stakeholders, fostering a more sustainable and ethical supply chain. In this paper, we will explore the adoption of blockchain in supply chain and how blockchain technology can help improve its operations.

Keywords: *Blockchain, Distributed Digital Ledger, Supply Chain, Supply Chain Management, SCM*

I. INTRODUCTION

A supply chain is typically composed of independent organizations which are directly involved in the upstream and downstream flows of products, services, finances, and information from a source to a customer. Supply chains underpin the macroeconomy and global markets. Figure 1 shows what supply chain is really about [1]. As goods move from one location to another, it can be challenging to track all the transactions accurately within outdated supply chain systems. This is where blockchain and supply chain management meet to ensure transparency, the key success metric. Blockchain is a technology with unique combination of features such as decentralized structure, distributed notes and storage mechanism, consensus algorithm, smart contracting, and asymmetric encryption to ensure network security, transparency, and visibility. Blockchain has immense potential to transform supply chain (SC) functions.

Figure 1: What supply chain is really about [1].

Blockchain technology has recently gained importance as a promising technology in the area of supply chain management. The core technology of the blockchain is the decentralized ledger, which records and protects transaction data shared among multiple parties. Blockchain may be used by supply chain members to share demand, inventory, and capacity-related data. A higher degree of coordination and operational efficiency may be obtained through the implementation of blockchain enabled smart contracts to automate transactions among supply chain members. The technology may also be used by supply chain members to share sustainability-related data from the different processing and transportation stages the product went through. Blockchain technology is typically used in supply chain management to create and share unique data records among trade partners to increase transparency and visibility of information through the whole supply chain [2].

II. WHAT IS BLOCKCHAIN?

Blockchain, a type of distributed digital ledger technology (DLT), is a relatively new and exciting way of recording transactions in the digital age. It is a decentralized and distributed digital ledger technology that securely records and verifies transactions across multiple computers or nodes in a network. Basically, it is a chain of blocks in which each block contains a list of transactions. The symbol of a blockchain is depicted in Figure 2 [3].The blockchain technology was created as the foundational basis for Bitcoin – a digital currency in which secure peer-to-peer transactions occur over the Internet. It is expected that the spending on blockchain solutions worldwide would grow from 4.5 billion USD (2020) to an estimated value of 19 billion USD by 2024 [4].

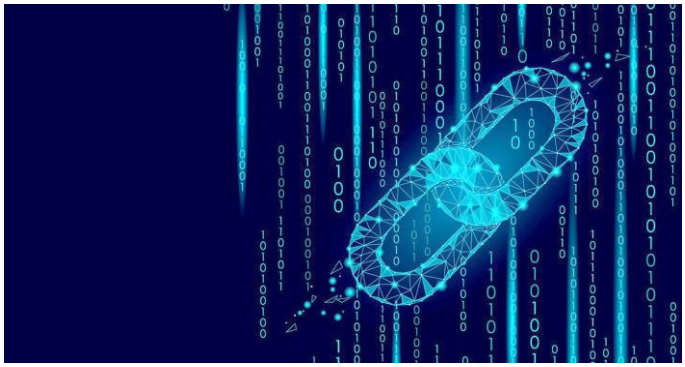

Figure 2: The symbol of blockchain [3].

Originally developed as the accounting method for the virtual currency Bitcoin, Blockchains are appearing in a variety of commercial applications today. Blockchain technology is a type of distributed digital ledger that uses encryption to make entries permanent and tamper-proof and can be programmed to record financial transactions. It is used for secure transfer of money, assets, and information via a computer network such as the Internet without requiring a third-party intermediary. It is now being adopted across financial and non-financial sectors. As a catalyst for change, the Blockchain technology is going to change the business world and financial matters in major ways.

The first Blockchain was conceived in 2008 by an anonymous person or group known as Satoshi Nakamoto, who published a white paper introducing the concept of a peer-to-peer electronic cash system he called Bitcoin [5,6]. Bitcoin and Ethereum are the first two mainstream blockchains. Other modern blockchains include Namecoin, Peercoin, Ether, and Litecoin. Figure 3 shows different components of blockchain [7].

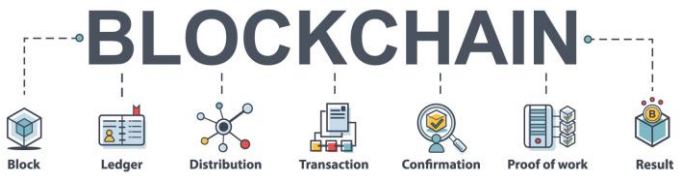

Figure 3: Different components of blockchain [7].

Blockchain combines existing technologies such as distributed digital ledgers, encryption, immutable records management, asset tokenization and decentralized governance to capture and record information that participants in a network need to interact and transact. As illustrated in Figure 4, a complete blockchain incorporates all the following five elements [8]:

- *Distribution:* Digital assets are distributed, not copied or transferred. A protocol establishes a set of rules in the form of distributed mathematical computations that ensures the integrity of the data exchanged among a large number of computing devises without going though a trusted third party. A centralized architecture presents several issues including a single point of failure and problems of scalability.
- *Encryption:* BC uses technologies such as public and private keys to record data securely and semi-anonymously. Completed transactions are cryptographically signed, time-stamped, and sequentially added to the ledger.
- *Immutability:* The blockchain was designed so these transactions are immutable, i.e. they cannot be deleted. No entity can modify the transaction records. Thus, Blockchains are secure and meddle-free by design. Data can be distributed, but not copied.
- *Tokenization:* Value is exchanged in the form of tokens, which can represent a wide variety of asset types, including monetary assets, units of data or user identities.
- *Decentralization*: No single entity controls a majority of the nodes or dictates the rules. A consensus mechanism verifies and approves transactions, eliminating the need for a central intermediary to govern the network.

Bitcoin and its underlying blockchain technology increasingly impact all facets of society. Bitcoin's status as digital gold is merely the tip of this technology. Figure 5 shows Bitcoin [9], while Figure 6 shows how blockchain works [10]. Although blockchain technology will for all time be associated with Bitcoin due to their common genesis, it has broader applications. Cryptocurrency will increasingly become a factor in family law issues as well.

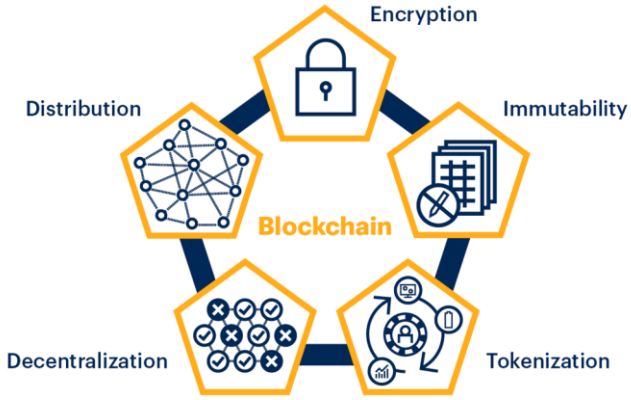

Figure 4: Five key elements of Blockchain [8].

Figure 5: Bitcoin [9].

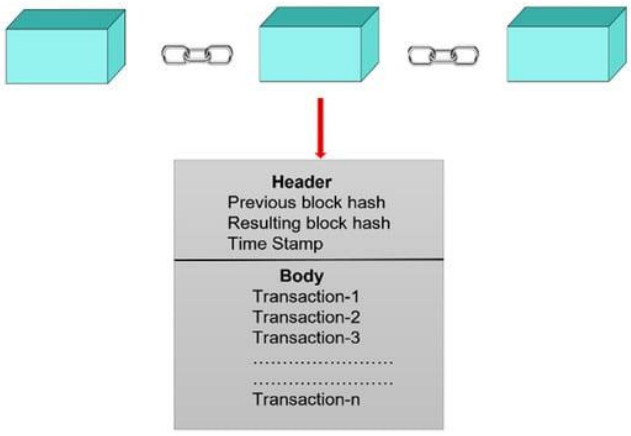

Figure 6: How blockchain works [10].

A blockchain is a tamper-proof, distributed database that stores blocks of information for cryptographically bound transactions via peer-to-peer networks. At the heart of blockchain's functionality is cryptographic hashing. Each block in a blockchain contains a cryptographic hash of the previous block, creating an immutable chain of blocks. If anyone attempts to tamper with the data in a block, it would alter the block's hash. This would disrupt the entire chain, making it virtually impossible to manipulate. The security feature ensures data integrity and prevents unauthorized changes [11].

In a nutshell, blockchain technology involves three basic concepts [12]: (1) It is a system for recording a series of data items (such as transactions between parties); (2) It uses cryptography to make it difficult to tamper with past entries; (3) It has an agreed process for storing copies of the ledger and adding new entries (also called a consensus protocol).

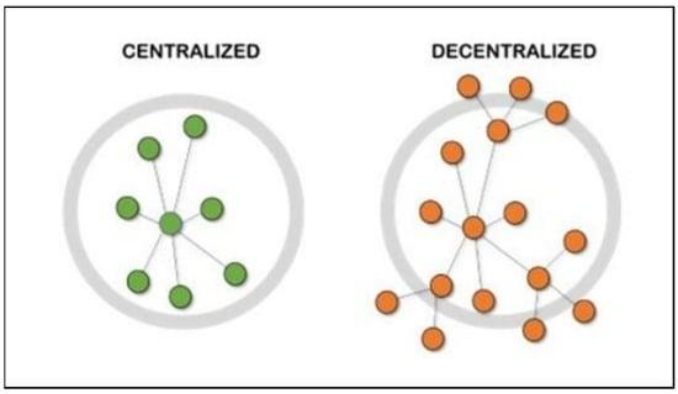

Figure 7: The decentralized property of blockchain [10].

Blockchain is a novel decentralized infrastructure and distributed computing paradigm that uses a chained data

structure for verification, storage, and distributed consensus algorithms to generate and update data. Decentralization is a key feature of blockchain technology, which refers to the distribution of power and decision-making across a network of nodes or participants rather than being controlled by a central authority or system. It provides robustness while eliminating many-to-one traffic flows to avoid delays and single points of failure. Figure 7 shows the decentralized property of blockchain [10]. The advantages of decentralized property of blockchain network include the following [10]:

- The decentralized property of blockchain makes it less prone to failure and more expensive for hackers to attack the network.
- There is no third-party involvement; therefore, there is no added risk.
- Every change made in the network is traceable and concrete.
- Users maintain full autonomy of their properties and are not dependent on third parties to maintain and manage their assets.
- It provides enhanced security.

III. BLOCKCHAIN IN SUPPLY CHAIN

Today, companies must be agile, flexible, competitive, and responsive to survive. As the pace of change accelerates, improving the efficiency and transparency of an organization's supply chain becomes critical. Fortunately, blockchain technology can help simplify the process. Blockchain technology has transformed the business world, and supply chain management is no exception. With its ability to create secure and transparent networks, blockchain will reshape the way we manage supply chains. Nevertheless, blockchain technology is no silver bullet. Supply chains are often hostage to a host of factors including geopolitical tensions, cyberattacks, inflation, droughts that disrupt shipping by lowering water levels, and critical product stockouts, as well as the many unforeseen effects of global warming. Since supply chains involve many parties, often across the globe, an accurate, rapidly updated, secure, and visible record benefits everyone involved.

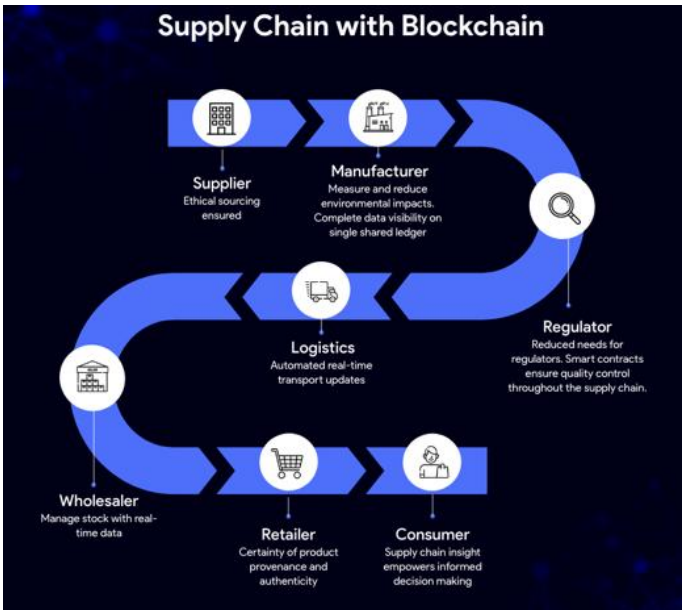

Figure 8: Blockchain in supply chain [13].

A blockchain is a secure and decentralized digital ledger that is publicly readable for auditing and other purposes. Its use of cryptography makes entries in the ledger unchangeable. Blockchain has the potential to unlock significant value for organizations by reducing supply chain risk, increasing visibility, and enhancing trust across a complex ecosystem. Blockchain can be applied to supply chains to create an audit trail of transactions and automate processes through smart contracts. Blockchain makes supply chains transparent and traceable. Traceability and transparency throughout the supply chain now means that consumers can be sure they are getting what they paid for. Customers benefit from blockchain technology in supply chain management because businesses can deliver products quicker and more efficiently. Figure 8 illustrates blockchain in supply chain [13].

IV. INDUSTRIAL EXAMPLES OF BLOCKCHAIN SUPPLY CHAIN

Many large-scale corporations already experiment with blockchain and put the blockchain's capabilities to good use in their own supply chains. The prominent companies that use blockchain for supply chain management include IBM, Walmart, FedEx, British Airways, DHL, Dole, and Nestle. For example, Maersk used an IBM blockchain solution to efficiently track its containers around the world. Similarly, Walmart and IBM have successfully implemented a blockchain-based solution for tracking pork products in China with a farm-to-table approach, providing transparency and full information about the supply chain stages every individual product went through. Industrial examples of blockchain applications in supply chain include the following [14,15]:

- *Walmart:* Since 2018, Walmart has been using blockchain to manage their suppliers of leafy greens. Their goal is to ensure the safety of the products they sell and to reduce the time it takes to provide evidence in the event of a claim. The solution gathers data about every step the greens go through, from when the seeds are planted. Once the greens are on the shelves, the company can continue to add data to the platform. For example, sourcing the origin of sliced mangoes in their US stores takes two seconds with blockchain, while using traditional tracing methods would take a week. Walmart has taken a serious interest in the blockchain, piloting multiple programs. From tracing the origins of mangoes in the US to tracking pork sold in its Chinese markets, the retail giant has embraced leveraging the blockchain to improve supply chain visibility and traceability. Walmart and IBM collaborated to create a blockchain-based platform for tracking food products in the supply chain. The platform aims to improve the traceability of food products, reduce food waste, and increase consumer trust in the food supply chain.
- *Nestlé:* This company was not involved in the incident with baby milk, but their business was affected by it. They decided to use blockchain to strengthen their position in the Chinese market. The solution records the journey baby formula takes on its way to the supermarket shelf. With a mobile phone, a consumer can scan a chip located on the formula package to see the ingredients, their source, and the organizations that produced them. Nestlé also provided the milk packages with antennas that will break if someone tries to open them. This helps reassure customers that products have not been tampered with on their way to the supermarket.
- *Unilever:* This company aims to achieve a deforestation-free supply chain by the end of 2023, so they need to know how sustainable their supply chains

really are. Existing systems for sustainability certification are not enough to provide this information; so the company decided to use blockchain. They started a pilot project in Indonesia to trace the palm oil they bought. As a result, Unilever could get information about the product, including the conditions in which it was grown and harvested.

- *FedEx:* FedEx has integrated the blockchain into its chain of custody to improve traceability and provide a trustworthy record, helping to address customer disputes. The company has also joined the Blockchain in Transport Alliance (BiTA) and is a vocal advocate for the adoption of a blockchain-based industry standard.
- *Tracifier*: This German startup provides supply chain traceability solutions. Tracifier's offerings include verification and tracking across the supply chain. The company sought to make it easier to track, trace, and verify food products—where they originated, when they were produced, and the relevant safety standards and inspections. Tracifier saw a path to this through blockchain technology and integrated Oracle Blockchain into its supply chain management database. Tracifier saw its own operational improvements with greater efficiency, fewer delays, and reduced costs.

V. APPLICATIONS OF BLOCKCHAIN IN SUPPLY CHAIN

Blockchain offers several key features that significantly enhance transparency and traceability in supply chains. The common use cases of blockchain for supply chain management include the following [16,17]:

- *Traceability:* This is one of blockchain's most compelling use cases in supply chain management. In supply chain management, traceability refers to tracking inventory locations and custody from raw materials to end customers. Blockchain traceability helps verify the authenticity of products, which is especially crucial in industries like pharmaceuticals and luxury goods. Blockchain technology brings inherent security and traceability, all while providing a data source that is readable by all parties. Blockchain's public ledger provides a product's provenance, tracking it from start to finish. Organizations need processes to dependably label individual goods or components so they can be traced back to lots, for example. By recording each step of a product's journey on the blockchain, it enables detailed tracking of goods from origin to final destination, facilitating recalls and quality control. Blockchain empowers businesses to create an immutable ledger of every product's journey, from its origin to its final destination. With blockchain's transparent and tamper-proof record-keeping, companies can trace the movement of goods with unparalleled accuracy.
- *Transparency:* One of the biggest challenges facing supply chain managers today is maintaining visibility across the entire network. As goods move from one location to another, it can be difficult to track them accurately. This lack of transparency can lead to delays, errors, and even fraud. Transparency is a significant use case of blockchain for supply chain management. Traditional supply chains often suffer from a lack of visibility and trust among participants. Blockchain technology addresses this challenge by providing a decentralized and immutable ledger that all stakeholders can access and verify. It allows every participant in the supply chain to access the same data, creating transparency and eliminating the need for intermediaries to verify information. A decentralized, immutable record of transactions allows stakeholders to track goods from source to delivery, enhancing transparency. By integrating blockchain through smart sensors and RFID tags, companies can accurately track goods through the supply chain. Such IoT and blockchain-powered tools record conditions such as temperature and humidity at each stage. Every transaction recorded on the blockchain is transparent and cannot be altered, ensuring a single source of truth for all involved parties. This transparency enables real-time tracking of goods, from raw materials to the end product, allowing businesses to identify bottlenecks, inefficiencies, and potential areas for improvement.
- *Tradeability:* This is a unique blockchain offering that redefines the conventional marketplace concept. Using blockchain, one may "tokenize" an asset by splitting an object into shares that digitally represent ownership. Similar to how a stock exchange allows trading of a company's shares, this fractional ownership allows tokens to represent the value of a shareholder's stake of a given object. These tokens are tradeable, and users can transfer ownership without the physical asset changing hands. Blockchain provides consensus, which means there is no dispute in the chain regarding transactions by design. All entities on the chain have the same version of the ledger, giving it the unique potential to track ownership records for real estate, automobiles, and digital assets.
- *Smart Contracts*: These represent a transformative use case of blockchain technology in supply chain management. Smart contracts are self-executing agreements with predefined rules and conditions encoded on the blockchain. By leveraging blockchain's decentralized and transparent nature, smart contracts eliminate the need for intermediaries, reduce administrative costs, and minimize the risk of errors or disputes. Figure 9 shows different components of a smart contract [1].
- *Inventory Management:* Inventory management represents a crucial use case for blockchain technology in supply chain management. Traditional inventory management systems often suffer from inefficiencies, inaccuracies, and a lack of real-time visibility. Blockchain addresses these challenges by providing a secure and transparent ledger that tracks the movement and status of inventory items across the supply chain. Blockchain provides real-time inventory tracking, reducing discrepancies. Maersk and IBM's TradeLens platform use blockchain to track shipping containers and warehousing automation, improving visibility and reducing delays.
- *Compliance:* Regulatory compliance is a growing concern among most companies, as failure to adhere can result in penalties and reputational damage. Thankfully, blockchain's ability to create tamper-proof records helps you meet relevant standards and requirements by documenting every transaction

accurately. With its immutable and transparent nature, blockchain provides a reliable and auditable record of all transactions and activities throughout the supply chain. This data enables businesses to demonstrate compliance with various regulations, standards, and certifications.

- *Food Supply Chain:* Information sharing lies at the core of most governance interventions within agro-food commodity supply-chains. Blockchain is under consideration by the food industry for the food supply chain health. For example, Walmart with the collaboration of IBM innovatively uses blockchain technology to track the provenance and condition of its pork supply coming from China. Blockchain technology can potentially alleviate the numerous sustainability problems related to agro-food commodity supply-chains by fostering traceability and transparency. Ensuring that sustainability information at all stages, from farm to consumers, passes unmodified through the supply chain is onerous, costly and entails risks of fraud. Throughout agro-food supply chains, blockchain supposedly provides ample opportunities for addressing sustainability issues.

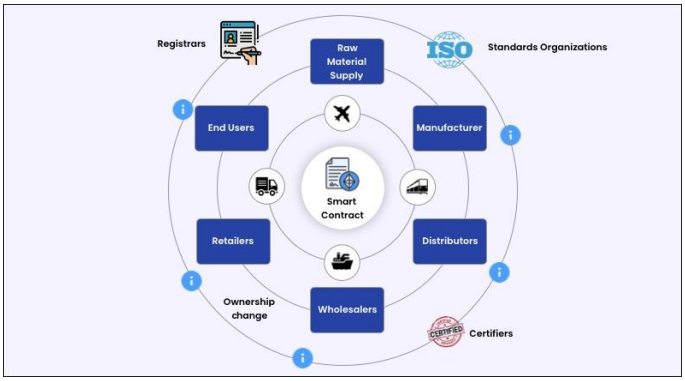

Figure 9: Components of a smart contract [1].

VI. BENEFITS

Enabling traceability, enhancing transparency and establishing product provenance are not the only benefits of using blockchain technology. Blockchain is widely used in numerous industries to enhance supply chain operations through increased transparency, visibility, compliance, and collaboration. With its decentralized and immutable nature, blockchain offers unprecedented transparency, efficiency, and trust in supply chain processes. Blockchain technology can be used to ensure that products meet certain quality standards throughout the supply chain. Other benefits include [16,18]:

- *Automation:* Blockchain can be used to automate certain processes within a supply chain through smart contracts. Smart contracts on blockchain automate and streamline various supply chain processes, such as procurement, payments, and compliance. They automate payments upon delivery, reducing administrative overhead. Blockchain also facilitates the automation of compliance processes through smart contracts, ensuring that all parties adhere to predefined rules and regulations.
- *Decentralization:* One of the key features of blockchain technology is its decentralization. Unlike traditional databases, which are typically controlled by a single entity, blockchain allows for multiple parties to participate in the network and verify transactions. This means that there is no central point of control and no single point of failure.
- *Reduced Costs:* The gains to efficiency and reductions in stock loss and waste are significant sources of cost savings with blockchain technology. Implementing blockchain technology can help reduce costs across the entire supply chain by eliminating intermediaries and reducing administrative overheads. For example, the automotive industry can save costs through reducing the cost of inventory tracking. Currently, tracking inventory levels involves manual tasks such as checking for stock availability and manually updating records. By leveraging blockchain, companies can automate these processes and reduce the administrative overheads associated with them.
- *Increased Efficiency:* Traditional supply chains often involve multiple intermediaries, manual record-keeping, and time-consuming reconciliations. They suffer from information disparity, where participants have limited visibility into the activities and transactions of others, leading to inefficiencies and potential fraud. Blockchain technology streamlines these operations by creating a decentralized, transparent ledger that all parties can access in real time. This process eliminates the need for intermediaries, reduces the risk of errors, and expedites transaction processes. Blockchain technology in supply chain management also contributes to timely resolved compliance problems and automated workflows, resulting in higher efficiency. The enhanced visibility helps detect and address issues like compliance violations, counterfeits, delays, and waste more rapidly.
- *Enhanced Security:* Another important feature of blockchain technology is its security. A blockchain addresses security by using one-way hashing and recording transactions on multiple systems; this ensures that data is, for all practical purposes, unchangeable. Blockchain technology is highly secure due to its distributed nature and use of cryptography. The use of cryptography ensures that once data has been recorded on the blockchain, it cannot be altered without consensus from the network participants. This makes it virtually impossible for hackers or malicious actors to tamper with data on the blockchain. The cryptographic features protect sensitive information, making it harder to access or alter data for unauthorized entities. Supply chain and blockchain transparency allows all stakeholders to verify transactions independently, lowering the risk of compromise and errors.
- *Reduced Risk:* The risks associated with the supply chain mainly originate from four channels: sourcing, transportation, processing, and distribution. With blockchain, businesses can track and verify every step of the supply chain process, from sourcing to distribution, in a secure and decentralized manner. This transparency helps identify potential risks and vulnerabilities, such as counterfeit products, unauthorized modifications, or delays in transportation.
- *Enhanced Trust:* A supply chain typically consists of multiple stakeholders, processes, and transactions. Trust is critical for establishing efficient operations and a sustainable delivery stream. With blockchain, each transaction is time-stamped and linked to

previous transactions, creating an immutable audit trail that can be verified by all parties involved. By having a shared and tamper-proof record of transactions, blockchain technology enables increased trust among supply chain participants.

- *Improved Collaboration:* Implementing blockchain technology requires collaboration with partners across the supply chain. A traditional supply chain involves multiple parties, such as manufacturers, suppliers, distributors, retailers, and customers, each with its own systems and databases. This fragmentation often leads to inefficiencies, delays, and a lack of collaboration among the participants. With blockchain, all participants access a shared ledger that records and verifies every transaction or event in real time. Globalisation and advances in technology have made it possible for companies to operate across borders and collaborate with suppliers and partners from all over the world.
- *Enhanced Compliance:* Blockchain can help ensure adherence to regulations and standards by providing a complete audit trail. By recording data on the blockchain at each stage of production, companies can track and verify compliance with specific requirements.
- *Sustainability*: As ESG (environmental, social and governance) and sustainability aspects become crucial, blockchain development services are greatly used to promote environmental sustainability. This emerging technology tracks carbon emissions and many other environmental impacts throughout the supply chain. As sustainability becomes more important in our world, blockchain technology will be used to promote environmental sustainability by tracking carbon emissions and other environmental impacts throughout the supply chain. This information can then be used to identify areas for improvement and reduce overall environmental impact. Europe will soon have mandatory reporting on ESG issues.

Some of these benefits are displayed in Figure 10 [16].

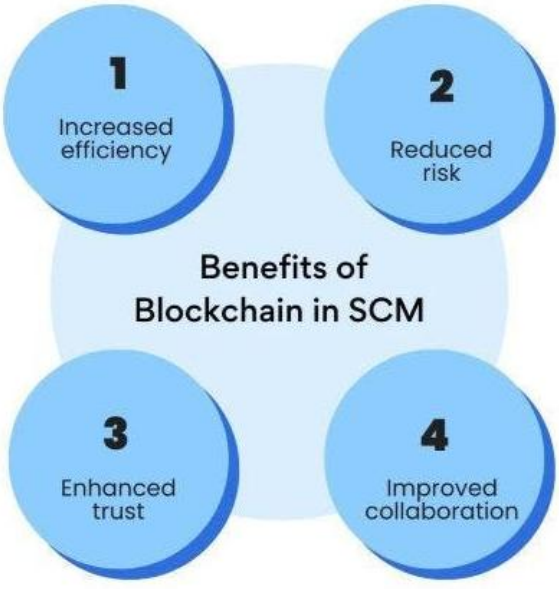

Figure 10: Some benefits of blockchain in supply chain [16].

VII. CHALLENGES

Although blockchain offers multiple benefits in different industries, there are several challenges in its implementation for supply chain operations. Supply chain enterprises should consider these challenges during the decision-making process. Companies must consider the costs associated with developing and maintaining a blockchain network over time. Since blockchain technology is still relatively new, there is some uncertainty around how it will be regulated in different jurisdictions. The technology's intrinsic transparency can raise privacy issues, especially when public blockchains are used. Other challenges include [13,18,19]:

- *Complexity:* Complexity indicates to which degree the innovation is perceived as being difficult to understand and use. Supply chains are complex networks of actors who perform different functions and are usually located in different parts of the world. In recent years, supply chain management has become increasingly complex. The more complex the supply chain, the more black holes there can be. Blockchain is a disruptive and relatively complex technology. Embracing blockchain in supply chain management can be complex due to the fragmented nature of global supply chains, which involve multiple stakeholders, systems, and processes. Integrating blockchain technology across diverse systems and ensuring compatibility can be challenging.
- *High Cost:* The initial investment required for technology adoption can also be daunting. To alleviate this, startups might seek partnerships with established supply chain entities, sharing resources and expertise. This collaboration not only eases the financial burden but also accelerates integration and adoption.
- *Resistance to Change*: A primary challenge is resistance to change. Traditional supply chain systems are deeply entrenched, and introducing new technology like blockchain often meets skepticism. To counter this, startups focus on educating stakeholders about the long-term benefits, such as enhanced transparency, security, and efficiency.
- *Inefficiencies*: Traditional supply chains often face inefficiencies and delays due to manual processes, redundant paperwork, and lack of real-time information. Moreover, employing blockchain for supply chain management requires re-engineering these processes, which can disrupt operations and face resistance.
- *Scalability*: The more companies use blockchain technology, the more the question of scalability arises. The current infrastructure may not be able to process large volumes of transactions without significant delays or other performance issues. Several scalability considerations in implementing blockchain for supply chain operations include high-speed connectivity, processing power, storage capacity, and energy consumption. Traditional blockchains use proof-of-work (PoW), which requires significant computational power and time to validate transactions. Another scalability challenge is the storage and processing requirements of blockchain data. Each transaction is recorded on every node in the network, leading to a large amount of data storage. As the supply chain grows and more transactions occur, the storage and processing demands increase exponentially. The increase in demand can strain the network's resources and hinder scalability. Additionally, the scalability and performance of blockchain networks can vary, further complicating interoperability efforts.

- *Regulatory Compliance:* The decentralized nature of blockchain technology raises concerns regarding legal compliance. Different countries and regions have varying regulations and standards for data protection, intellectual property rights, and cross-border transactions. Implementing blockchain in a supply chain requires careful consideration of these regulations to ensure compliance.
- *Interoperability:* As blockchain adoption becomes more mainstream, there must be a universal agreement on interoperability standards for ensuring global alignment. Each blockchain network may have its unique structure, consensus mechanism, and smart contract language, making it difficult to establish a standard protocol for data exchange. There must be universal consensus and interoperable standards to ensure compatibility across multiple blockchain platforms, applications, and ecosystems.
- *Risks:* Businesses must be aware of any security risks associated with the use of blockchain technology. There is a risk that sensitive information could be exposed if proper precautions are not taken due to its transparency of the blockchain. Companies must be vigilant in protecting their systems against security threats, data breaches, and malicious actors. Cybersecurity measures such as encryption, firewalls, and identity verification should be part of any security protocol, regardless of whether the blockchain is involved or not.
- *Cooperation:* Cooperation at the supply chain level seems to be very important for blockchain adoption. This is highlighted by the ranking of the cooperation between supply chain members for process standardization and agreement on the type and level of details of the data to be shared on the blockchain. Blockchain also allows supply chain participants to create a network, with each participant as a node. This can provide that granular information-sharing missing from today's legacy systems.
- *Lack of Communication:* Even though goods pass from touchpoint to touchpoint along a supply chain, there is often a lack of communication between them. A lack of tracking results in a lack of quality assurance, as well as the inability for thorough compliance reporting. A lack of communication can result in a lack of access to financing for upstream suppliers who remain cut off from downstream financiers.
- *Lack of Privacy:* Across today's supply chain, there is a lack of symmetry when it comes to information-sharing. Upstream suppliers will be more likely to withhold information about their operations, pricing and sourcing to keep a competitive advantage. However, downstream retailers want to know this information about their products and goods. Unfortunately, legacy data management tools often lack the ability for such granular control over information-sharing.
- *Lack of Security:* Another supply chain challenge is keeping the system secure, especially when centralized servers are vulnerable to attacks that can easily impact the entire supply chain.

CONCLUSION

Blockchain technology has emerged as a game-changer in supply chain management, revolutionizing how businesses track, verify, and secure their transactions. It has immense potential to transform the way supply chain management is conducted. It has already begun to transform supply chain management, but its impact is only just beginning. From enhancing traceability and reducing fraud to optimizing inventory management and streamlining logistics, blockchain has the potential to reshape the supply chain landscape.

In spite of the promises and the enormous potential of blockchain technology, its adoption in supply chains is still underexplored. Integrating blockchain technology in supply chain management can transform how businesses operate. As blockchain technology matures, it will gradually replace traditional supply chain processes. As more businesses recognize the benefits of blockchain technology, we can expect to see greater adoption across the entire supply chain. The future of blockchain in supply chain management is promising, with the potential for wider adoption and integration [20]. The future of supply chain management is clear: blockchain technology will make supply chains more transparent, secure, and efficient. More information on the integration of blockchain technology into the supply chain industry is available from the books in [21-30] and a related journal: *IEEE Blockchain.*

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