Utilizing Blockchain Technology for the US Supply Chain Management

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ABSTRACT

Blockchain technology is being introduced gradually into supply chain management, addressing long-standing problems and waste-related parts of the industry. This study aims to illustrate the various ways that blockchain might improve supply chains' efficiency, traceability, security, and simplicity. Blockchain technology offers a permanent, decentralized record-keeping system that fosters honesty and trust between participants; all important data is stored in an unalterable manner. Additionally, supply chain processes like payment processing and inventory management are automated by intelligent contracts, which significantly lowers both human error and regulatory expenses. Blockchain's capacity to encrypt this data ensures a high level of security by guaranteeing information availability in the event of sophisticated cyber assaults. This increase in security makes the supply chain less vulnerable to sabotage and extortion. Through the provision of an easily accessible and verifiable record of every trade, this innovation significantly streamlines administrative compliance. Furthermore, it provides a means of confirming that the technical support standards and material sources adhere to current standards, which in turn helps to enhance customer trust in a brand and promote brand identity for the product bearing the brand mark. The study shows how blockchain technology has enhanced the capabilities of US logistics companies. It also looks at supply chain management's effectiveness and transparency in terms of blockchain technology implemented in the US.

1. Introduction

Blockchain technology is an advanced database mechanism that enables transparent information sharing within a business network. It stores data in blocks linked together in a chain, creating an unalterable or immutable ledger for tracking orders, payments, accounts, and other transactions. Blockchain technology mitigates challenges in traditional database technologies by creating a decentralized, tamper-proof system to record transactions (Pilkington, 2016). In the property transaction scenario, blockchain creates one ledger each for the buyer and seller, with all transactions being approved by both parties and automatically updated in both their ledgers in real-time (Ammous, 2016; Pilkington, 2016). Blockchain architecture consists of a distributed ledger, smart contracts, and public key cryptography. A distributed ledger stores transactions, while smart contracts self-manage business contracts without the need for an assisting third party. Public key cryptography uniquely identifies participants in the blockchain network, generating two sets of keys for network members: a public key common to everyone in the network and a private key unique to every member. Blockchain works by recording the transaction, which shows the movement of physical or digital assets from one party to another in the blockchain network. Participants must agree that the recorded transaction is valid and that the blocks and chains link securely, preventing data tampering (Sun et al., 2016). Each additional block strengthens the verification of the previous block and the entire blockchain. Blockchain technology has been used in various sectors, including the creation of digital currency like Bitcoin (Singhal et al., 2018).

Supply chain management (SCM) is a crucial aspect of a company's operations, focusing on the monitoring and optimization of the production and distribution of its

products and services. It aims to improve the efficiency of all processes involved in turning raw materials and components into final products and delivering them to the ultimate customer. Effective SCM can help streamline a company's activities, eliminate waste, maximize customer value, and gain a competitive advantage in the marketplace (Sharma et al., 2021). The five most critical phases of SCM are planning, sourcing, production, distribution, and returns. A supply chain manager is responsible for controlling and reducing costs and avoiding supply shortages. By centrally controlling or linking the production, shipment, and distribution of a product, companies can cut excess costs and deliver products to the consumer faster. This is achieved by keeping tighter control of internal inventories, internal production, distribution, sales, and the inventories of company vendors. SCM is based on the idea that nearly every product that comes to market does so as a result of efforts by multiple organizations that make up a supply chain. A supply chain manager's job is not only about traditional logistics and purchasing but also about finding ways to increase efficiency and keep costs down while also avoiding shortages and preparing for unexpected contingencies (Richey et al., 2022; Sodhi & Tang, 2021). The SCM process consists of five phases: planning, sourcing, manufacturing, delivery, and returns. Planning involves matching supply with customer and manufacturing demands, taking into account raw materials or components needed during each stage of manufacturing, equipment capacity and limitations, and staffing needs. Enterprise resource planning (ERP) software is often used to coordinate the process. Sourcing is essential for effective SCM processes, as it relies heavily on strong relationships with suppliers. SCM sourcing ensures that raw materials or components meet manufacturing specifications, prices are in line with market expectations, vendors have the flexibility to deliver emergency materials due to unforeseen events, and they have a proven record of delivering goods on time and of good quality. Making is the heart of the SCM process, using machinery and labor to transform raw materials or components into something new. Companies must be mindful of waste or other factors that may cause deviations from their original plans. A company with effective SCM will have robust logistic capabilities and delivery channels to ensure timely, safe, and inexpensive delivery of its products. Returns are a crucial aspect of the SCM process, as they provide valuable feedback and help identify defective or poorly designed products. Without addressing the underlying cause of a customer return, the SCM process will likely fail, and returns will likely persist into the future (Kumar & Mallipeddi, 2022; Sodhi & Tang, 2021).

Blockchain technology revolutionizes the supply chain by enhancing security, transparency, and efficiency. It can enhance tracking, reduce counterfeiting, address food safety issues, encourage sustainable sourcing, improve payments, and enable better communication and collaboration (Kumar & Mallipeddi, 2022; Modak, 2023). By implementing blockchain with Internet of Things devices like smart sensors and RFID tags, companies can record the movement of goods through the supply chain and their condition at each stage. Blockchain offers more transparent and accurate visibility into the tracking process, helping organizations detect and address potential issues such as compliance violations, counterfeit goods, delays, and waste. It builds trust among supply chain partners by providing open access to key information. Traceability is another use of blockchain in the supply chain. It allows partners to efficiently trace activities along the supply chain, allowing stakeholders to access information about products, including dates, prices, origin, quality, certification, destination, and more. This helps in reducing counterfeiting, addressing food safety issues, and encouraging more sustainable and ethical sourcing. Blockchain-based smart contracts can make payments more efficient, enabling all parties in the supply chain to view transactions, and reducing human error and fraud (Wamba & Queiroz, 2020). Supply chain partners using blockchain-based cryptocurrencies can pay each other without having to use banks, saving money on fees and accelerating the payment process. Blockchain technology can also improve communication and collaboration between stakeholders by sharing databases between different parties and motivating all stakeholders to meet obligations in a timely manner. However, implementing blockchain in the supply chain requires significant expertise and adherence to governmental regulations (Modak, 2023; Wamba & Queiroz, 2020).

Blockchain technology revolutionizes supply chain management in the USA by providing transparency, traceability, and security. It has eliminated the need for a central authority, reducing the risk of a single point of failure. Blockchain provides an open ledger of all transactions, allowing all participants in the network to view them (Awwad et al., 2018). This helps detect bottlenecks, track compliance, and maintain standards throughout the supply chain. Advanced encryption methods ensure data security and protection from unauthorized changes. Blockchain also automates processes through digital ledgers and smart contracts, improving efficiency by reducing manual documentation, administrative tasks, and the risk of human error. These agreements speed up transactions and inventory management, improving the speed and accuracy of operations. In industries like food and pharmaceuticals, blockchain is essential for reliable traceability of products from raw materials to the final consumer. It has effective security measures against fraud and cyber threats, ensuring data is not tampered with. Cost savings are realized by reducing intermediaries, paperwork, automation of processes, and administrative costs. Blockchain also reduces losses due to fraudulent activities and errors, as it provides provable evidence of each transaction and movement to

regulators for more accessible reporting. By providing transparency, efficiency, security, and cost-effectiveness, blockchain technology sets new standards in reliability and performance for all players involved in the supply chain management process.

The research provides evidence of how blockchain technology has improved the faculties of logistics firms in the USA. It also examines the efficiency and transparency in supply chain management in terms of blockchain technology settled in the United States.

2. Literature review

Blockchain is an emerging technology that allows transactional data to be decentralized and shared across a wide peer-to-peer network, allowing non-trusting participants to connect verifiably and without the need for an intermediary. In this essay, we go over the fundamentals of blockchain technology as well as its varieties, applications, and operations. The technology's consensus processes, security, and privacy concerns are also significant factors that underpin this creative method (Sarmah, 2018). Blockchain technology enables users to share a common view of a system's state across a distributed network, enabling peer-to-peer value transfer and securely executable agreements through smart contracts. Blockchain solutions, including Bitcoin and Ethereum, build trust, transparency, reliability, speed, and effectiveness in transactions. However, challenges such as the representation of off-chain assets, external data sources, performance, standardization, and governance of Blockchains must be addressed. Blockchain challenges traditional models of regulatory compliance, organization, governance, and business operations, and its potential to disrupt is urgently needed before exploring its applicability in climate finance (Ahmad et al., 2019). Blockchain databases are a revolutionary structure that offers a new way to store and trade data among network members. Blockchain technology is crucial for biomedical and human services applications, particularly in social insurance. Blockchain databases are decentralized, permanent, and equipped with advanced digital payment frameworks and hash chain event structures. They are used for allocation, trading, dissecting, and verifying social insurance-related information among partners. Blockchain technology is expected to be widely adopted across medical organizations worldwide, offering a more efficient and secure way to manage and share data. This review article provides an in-depth understanding of the current and future developments in blockchain innovation from a specialized perspective in the healthcare system (Meunier, 2018).

The Global Supply Chain Forum has identified eight supply chain processes, providing strategic and operational descriptions of these processes. However, many are vague about the sub-processes and activities within each process, and how they interact with each other and traditional functional silos. The aim is to provide managers with a framework for implementing supply chain management, instructors with useful material for supply chain management courses, and researchers with opportunities for further development in the field (Croxton et al., 2001). Vertical integration and obligational contracts are increasingly being explored in the literature and practice of supply chain management. These concepts offer advantages and disadvantages, but supply chain management combines them while overcoming some disadvantages. Utilizing industrial organization literature and case studies, prerequisites for supply chain management are developed, and three competitive situations are described. Supply chain management holds promise as a competitive form, provided certain hazards are avoided and a competitive advantage results (Ellram, 1991).

A paper explores the potential of blockchain technology in operations and supply chain management (OSCM) and its implications. It highlights the high hype surrounding digital ledger technologies and highlights the potential for enhancing product safety, and quality management, reducing counterfeiting, improving sustainable supply chain management, advancing inventory management, reducing intermediaries, impacting new product design, and reducing supply chain transaction costs. The paper suggests that organizations can gain an advantage by using blockchain technology ahead of competition, but managers must assess their products, services, and supply chains to determine if they would benefit sufficiently from blockchain adoption. Additionally, organizations should build human capital expertise to develop, implement, and exploit blockchain applications effectively. This is the first paper in a leading international OSCM journal to analyze blockchain technology, complementing a recent article on digital supply chains that omitted blockchain (Cole et al., 2019). Blockchain technology, the driving force behind the Bitcoin revolution, has been a subject of debate due to its potential to mitigate risks and vulnerabilities. Its peer-to-peer network, free from intermediaries like banks and governments, allows for secure digital asset transactions, reducing the risk of hacking, compromised privacy, political instability, and costly compliance with regulations. This technology can also enhance supply chain resilience during times of increased uncertainty (Min, 2019).

Blockchain technology is gaining traction as a potential solution for global supply chain management. It offers transparency, traceability, and security, making it a promising solution for global sustainability goals. However, the adoption of blockchain technology faces several barriers, including inter-organizational, intra-organizational, technical, and external barriers. Despite these challenges, blockchain's potential to aid supply chain sustainability is still in its early stages, and further research is needed to overcome these barriers and

improve the adoption of blockchain technology in global supply chain management (Saberi et al., 2019). Blockchain technology is gaining attention as a distributed secure technology in the 21st century, enabling virtually all economic transactions. This technology has the potential to revolutionize industries, improve commerce, and drive the economy. However, few studies have focused on supply chain integration and collaboration. This study explores the application of blockchain in New Zealand's supply chain, focusing on smart contracts and consensus algorithms. The study aims to advance understanding of blockchain and supply chain literature, and inspire researchers and practitioners to consider its use in future context-aware studies (Wang et al., 2020). In China, food safety is an outstanding problem, necessitating the development of a traceability system for the agri-food supply chain. RFID and blockchain technology can help achieve this by gathering, transferring, and sharing authentic data from production, processing, warehousing, distribution, and selling links. This system can guarantee food safety by ensuring trusted information throughout the supply chain, addressing the market demands and improving supply chain efficiency (Tian, 2016).

A study explores the impact of blockchain technology on supply chain management efficiency and transparency in Pakistan. Using a desk methodology, it found significant improvements in efficiency and transparency. Blockchain integration reduced delays, increased automation, and streamlined operations. Transparency was enhanced through real-time tracking and secure data sharing among stakeholders. The findings suggest that adopting blockchain technology can enhance supply chain management in Pakistan, promoting efficiency and transparency. Future research should address data privacy, interoperability, and standardization concerns (Huzaifa, 2024). The digitalization phenomenon is revolutionizing the supply chain network, with blockchain technology transforming relationships between logistics and supply chain systems. However, there is a lack of research on individual blockchain adoption behavior in the logistics and supply chain field in India and the USA. A model based on the unified theory of acceptance and use of technology (UTAUT) was developed, revealing distinct adoption behaviors between India-based and USA-based professionals. The findings contribute to the literature on IT adoption, supply chain management, and blockchain, suggesting that blockchain technology has the potential to disrupt established business models in logistics and supply chains. Performance expectancy is a significant factor influencing adoption, and facilitating conditions vary across countries (Queiroz & Wamba, 2019).

The literature review explores what blockchain technology and supply chain management are. Also, it covers the field for the role of blockchain technology in supply chain management in various countries. The research shows how logistics companies in the USA use

blockchain technology to improve supply chain transparency and efficiency, which improves supply chain management as a whole.

3. Methodology

Blockchain technology is revolutionizing supply chain management through its Architectural Framework shown in Fig. 2. This framework outlines the benefits of blockchain in supply chain management, including improved transparency, trust, and stakeholder access. Fig. 1 shows a flow chart of Blockchain Technology for Supply Chain Management.
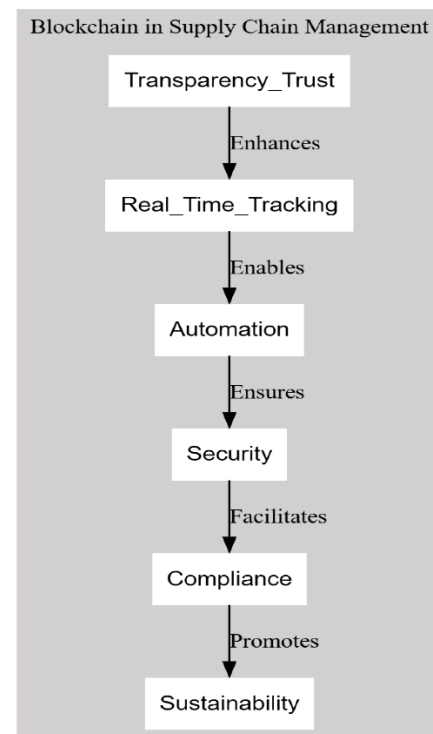

Fig. 1. Flow chart of Blockchain Technology for Supply Chain Management (Prakash, 2024).

Key elements include Immutable Ledger, Decentralization, and Stakeholder Access, which enhance trust and transparency. Real-time tracking is crucial for traceability of products across the supply chain, with Origin to Consumer, Product Authenticity, and Rapid Response being key components. Automation is also a key aspect, focusing on the process automation of smart contracts, including Smart Contracts, Task Automation, and Administrative Overhead. By leveraging blockchain in supply chain management, the industry is reshaping itself for safer, more efficient, and smarter supply chains.

The supply chain is a critical aspect of any business, and blockchain technology has significantly enhanced security measures. Smart Contracts automate tasks, reducing administrative overhead. Blockchain technology also ensures data integrity through encryption validation, a process known as cryptographic verification by security cluster. Compliance cluster is

another key aspect of blockchain, allowing for auditability along the supply chain. Immutable records, regulated compliance, and automated audits simplify compliance processes. The Sustainability Cluster focuses on promoting sustainability practices and ethical purchasing in the supply chain, incorporating elements like transparent records and ethical sourcing. Transparent Records support ethical sourcing, meeting consumer demand for environmentally friendly and ethically sourced products as shown in Fig. 2.
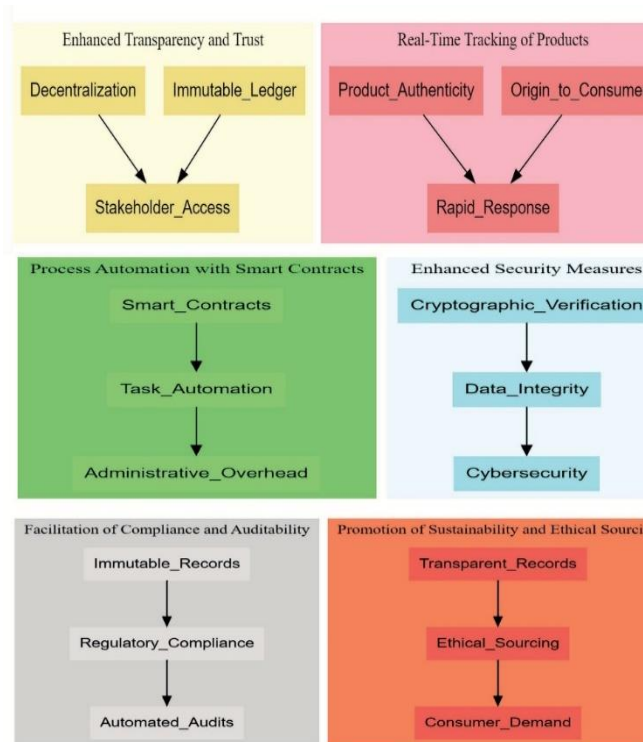

Fig. 2. Architectural Framework (Prakash, 2024).

4. Results and discussion

4.1. Supply chain efficiency gain with blockchain:

Blockchain technology has the potential to significantly reduce supply chain administrative costs by 90%, according to IBM. The company has completed over 300 blockchain projects in the supply chain industry, resulting in significant savings for various industries. Walmart, Maersk Line, the healthcare industry, Coca-Cola, the food industry, the pharmaceutical industry, the automotive industry, the agriculture sector, the aerospace industry, and the fashion industry have all seen significant reductions in the time taken to trace products using blockchain technology.

The automotive industry is projected to achieve a 15% increase in efficiency by integrating blockchain technology into supply chain processes. Supply chain visibility can be increased by 25% by integrating blockchain technology. The agriculture sector is projected to save up to $2 billion annually by leveraging

blockchain for supply chain management. The aerospace industry could save $3.5 billion per year by implementing blockchain technology in supply chain management. Blockchain technology can also streamline cross-border transactions and trade processes, reducing fraud-related losses in supply chains by 90%. It can also lead to a 50% reduction in errors in product information and fraud-related losses in supply chains. Integrating blockchain into the logistics industry could reduce costs by $2.6 billion annually by 2023. The cosmetics industry could save $4.3 billion annually by using blockchain technology for product provenance tracking. By adopting blockchain, the fashion industry could reduce counterfeit goods by 45%. The aerospace industry is projected to save $4 billion per year by 2025 through the use of blockchain in supply chain management. 62% of companies reported that blockchain helped improve collaboration among supply chain partners, reducing operating costs by 15%. Blockchain technology can also reduce compliance costs in supply chains by up to 30%, decrease product recalls by 50%, and lead to faster dispute resolution among partners. The integration of blockchain in supply chains could reduce paperwork by 80%, inventory costs by 10%, and retail industry costs by $50 billion annually. In the next 6 years, the percentage is predicted to grow more as shown in Fig. 3.
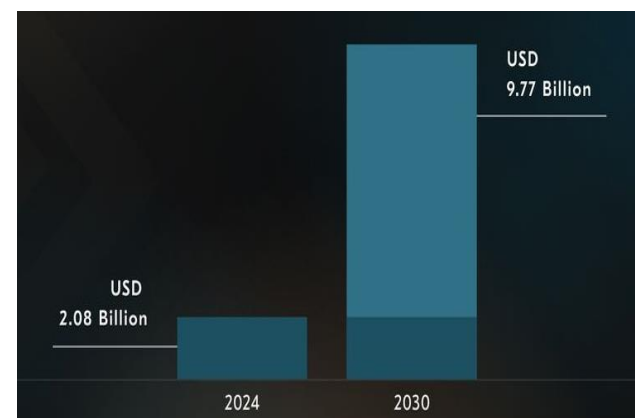

Fig. 3. Supply chain efficiency gain percentage with blockchain in the USA.

4.2. Supply Chain Efficiency Gains with Blockchain:

A Deloitte 2019 Global Blockchain Survey revealed that 90% of executives believe blockchain technology will be crucial for their industry. A Statista survey showed that 77% of respondents expressed confidence in blockchain improving supply chain transparency. 58% of companies anticipate blockchain disrupting supply chain management within 3-5 years. Supply chain professionals believe blockchain will enhance transparency and traceability in supply chains, with 84% using or planning to use it for supply chain applications. 64% of supply chain professionals believe that blockchain technology will reduce fraud and errors. Fig. 4 shows supply Chain Efficiency Gains with blockchain all over the world.
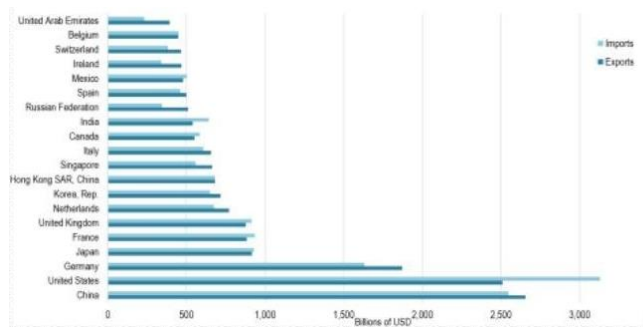
Fig. 4. Supply Chain Efficiency Gains with blockchain all over the world.

In the next decade, 83% of organizations expect blockchain to significantly impact supply chain operations. 79% of supply chain leaders believe that blockchain can increase operational efficiency. Over 50% of professionals expect blockchain to improve supply chain visibility and transparency. Blockchain technology is considered a strategic technology for future success by 63% of executives. It is expected to enhance security measures in supply chains, create more sustainable supply chains, and improve overall supply chain security. It is also expected to revolutionize warehouse management processes, enable more effective supplier relationship management, and improve overall supply chain visibility. In conclusion, blockchain technology is expected to revolutionize supply chain operations, improve transparency, and provide a competitive advantage in the global supply chain industry.

4.3. Blockchain with supply chain management:

Blockchain technology has revolutionized supply chain management (SCM) by enhancing transparency, security, and compliance. By making transactions and data items immutable, blockchain provides a single source of trust for all stakeholders, reducing issues of data uncertainty and mistrust. This trust fosters greater transparency between subjects in the supply chain, creating a shared space where trust becomes the currency of the realm. Blockchain implementation also improves traceability, as it can track products from the source to the final customer, providing zero chains of custody. This direct monitoring ensures reliability and quality in products at the exact time, particularly in the medical and food industries. Automation of optimization processes and cost savings are another benefit of blockchain technology. Blockchain encryption features prevent unauthorized access or manipulation of data, protecting sensitive information and securing the integrity of the supply chain.

Blockchain technology also reduces fraud risk by modifying data hard to execute without being noticed. This not only safeguards financial interests but also maintains the good reputation and integrity of the supply chain. Compliance and compliance advantages are further enhanced by blockchain technology, which

provides a transparent, locations, and auditable record of all transactions. Automating compliance checks paired with real-time reporting ensures supply chain operation aligns with industry standards and regulations, especially in high-regulation industries like medicine and food processing.

Blockchain records are immutable, simplifying auditing processes and instilling trust from regulators and stakeholders in sustainability and ethical tracking aspects. Blockchain technology also offers underlying details about sourcing and production practices for sustainable development agendas, allowing companies to track commitments to sustainability practices like ethical sourcing and environmental stewardship. Ethical verification is another key benefit of blockchain technology in supply chains. A product can be traced back to its origin or destination, allowing companies to verify if their food has been ethically sourced. Blockchain strengthens customer trust and brand loyalty by writing about certifications and adhering to ethical standards. In conclusion, blockchain technology has the potential to transform supply chain management, providing more transparent, efficient, and secure supply chains that support sustainability. With increased adoption, the potential for blockchain to transform supply chain management will increase, making it more innovative and efficient.

4.4. Role of blockchain in revolutionizing supply chain transparency and security:

Blockchain technology enhances supply chain transparency by providing a distributed ledger for transactions, ensuring a tamper-evident and transparent record of goods and information movement across the entire supply chain, thereby enhancing overall efficiency and security(Al-Farsi et al., 2021; Oriekhoe et al., 2024; Xu et al., 2021).

- **Traceability:** Blockchain makes it possible to track things from beginning to finish by logging all transactions, ownership transfers, and product movements on a blockchain ledger. Transparency and accountability are ensured by allowing each supply chain participant to see and validate the data.

- **Smart Contracts:** Self-executing contracts that are stored on a blockchain are known as smart contracts. Numerous supply chain procedures, including delivery verification, quality assurance, and payment settlements, can be automated using these contracts. Smart contracts guarantee adherence to predetermined rules and conditions, do away with the need for middlemen, and lower transaction costs.

- **Real-time Visibility:** Blockchain makes it possible to see supply chain activities in real-time by giving everyone with permission access to a shared, synchronized, and decentralized database. Transparency reduces information asymmetry and

promotes improved decision-making and collaboration throughout the supply chain.

- **Provenance Verification:** Blockchain makes it possible to confirm the provenance and legitimacy of goods. Through the blockchain, consumers and businesses may record details like batch numbers, certificates, and production details to track a product's full history, guaranteeing its ethical origin and legitimacy.

5. Conclusion

Blockchain technology has revolutionized supply chain management by enhancing transparency, trust, and compliance. By providing record maintenance and reducing conflict and dispute incidences, blockchain technology has built trust and improved transparency across the supply chain. It enables real-time product trace from origin to end customers, ensuring product reliability and safety in industries like medicine and food. Automation brings efficiency to operations, reducing administrative work and human error, leading to cost savings and increased supply chain performance. Blockchain technology also provides strong security requirements through double encryption and decryption features, shielding sensitive information from cyber-attacks. It simplifies auditing for regulatory compliance, maintaining industry standards. Blockchain underpins sustainability and ethical discovery by massive paging and auditing in discovery and publication processes, answering consumer demand for responsible business conduct and enhancing brand reputation. In short, blockchain technology has revolutionized supply chain management by eradicating problems associated with it and presenting new ways to improve transparency, traceability, efficiency, security, and compliance.

Blockchain technology is revolutionizing supply chain management by integrating with IoT and Artificial Intelligence to enhance operations. IoT devices provide real-time data on product condition and location, while AI analyzes this data for optimized processes. This integration leads to faster, more efficient supply chains. Global standardization is expected to increase adoption and interoperability across industries, allowing blockchain solutions to be seamlessly integrated across existing systems and geographies. Advanced smart contracts will make supply chain processes more complex and adaptive, enabling sophisticated and responsive management. Blockchain can also create improved supply chain networks, reducing costs, improving transactions, and increasing resistance, stability, and circulation economy. This technology is crucial for achieving sustainability and circulation economy for exhibitions, re-service, and product life cycle encouragement. Overall, blockchain technology is transforming supply chain management and fostering innovation.

Blockchain technology revolutionizes supply chain management by providing transparency and demonstrating adherence to sustainable practices. This transparency enhances customer trust by providing information on product origin, production methods, and ethical practices. Blockchain's real-time data can improve risk management and supply chain efficiency, ensuring continuity and reliability. As regulatory frameworks evolve, blockchain provides automated real-time compliance checks, ensuring supply chain compliance with current regulations and standards. The future outlook for blockchain technology in supply chain management is crucial for innovation and improvement. By integrating blockchain's unique capabilities with other advanced technologies, supply chains can achieve unprecedented levels of efficiency, clarity, security, and sustainability. These developments not only address current challenges but also offer new opportunities for growth and competitive advantage in global markets.

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