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BLOCKCHAIN UNCHAINED: REVOLUTIONIZING SUPPLY CHAIN MANAGEMENT FOR PRECISION, PRODUCTIVITY AND PRIVACY

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Abstract

Blockchain is an open-source, decentralized ledger that underpins its transformative role in supply chain management. It facilitates direct transactions between parties, ensuring greater transparency than traditional financial institutions. This transparency extends to supply chain operations, where participants gain trust through identical ledgers, enhancing overall business transactions. Blockchain's utilization helps eliminate inaccuracies in payments, shipment delays, and financial ledger entries, thereby improving accuracy and efficiency. This paper aims to provide a concise overview of Blockchain's potential long-term effects, outlining fundamental differences between supply chains with and without Blockchain. The methodology adopted in this paper is to carry out a systematic literature review that covers contemporary supply chain management knowledge, Blockchain applications, and the technology's foundations, contributing to a holistic understanding of its transformative potential in the supply chain landscape. Moreover, in this study, we apply the theoretical base framework analysis approach to fill the gap regarding the knowledge of blockchain technology integration in supply chain management in the organization. This study will contribute to covering theoretically based blockchain supply chain management by thoroughly analyzing the state of the industry today, highlighting important issues, and putting up creative solutions. Policymakers, business professionals, and researchers attempting to negotiate the challenges of integrating and maximizing Blockchain technology inside the supply chain ecosystem will also find great value in the insights obtained from this study. In addition to adding to the body of knowledge in academia, the results offered here will provide useful advice for creating and implementing reliable, transparent, and effective supply chain systems that make use of Blockchain technology. As we explore deeper into this developing landscape, the conclusions of this research will surely play a crucial part in influencing the path of future studies and breakthroughs in Blockchain-based Supply Chain Management Systems.

Keywords: Blockchain, Distributed Ledger Technology, Smart Contracts, Supply Chain, Sustainable, Resilience, Immutability.

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Introduction

The strategic discipline of supply chain management (SCM) is used to professionally organize the smooth movement of goods, services and information with the overall goal of improving operational efficiency and mitigating potential risks. To manage the flow of products and services effectively, a wide range of information is used in order to achieve high performance and minimize risk; supply chain management (SCM) is used (Tan, 2001). However, to increase the performance and the output of the businesses, organizations must collaborate and integrate their Supply chains with the board level more intensely in today's fast-paced sector (Soosay & Hyland, 2015).

Globalization, a variety of legal requirements, cultural differences, and human behavior all make it challenging to evaluate information and manage risk in supply chain networks (Sarpong 2014 and Ivanov & Sokolov 2019). Lack of trust results from ineffective transactions, fraud, theft, and inefficient supply chains, which calls for extra infrastructure changes.

Traceability is increasingly becoming a basic necessity and a critical differentiator in a number of supply chain industries, including agri-food (Costa et al., 2013), pharmaceutical and medical items (Rotunno et al., 2014), and high-value commodities (Rotunno et al., 2014; Maurer, 2017). Paper certificates and receipts that attest to the provenance of expensive and valuable objects are easily misplaced or altered. Customers and supply chain organizations are unable to confirm and authenticate the item's genuine value because the supply value of every item is opaque. Because of the expense of dealing with intermediaries as well as their dependability and transparency, maintaining supply chain traceability is made more challenging. These dangers, in addition to a lack of openness, lead to competitive problems in terms of strategy and reputation.

The internal information management systems used in current supply chains, systems like enterprise resource planning, which have a unique set of problems, are centralized, frequently divergent, and stand-alone (Casey & Wong, 2017). Supply chain organizations must have a high level of confidence in a single business or broker before they provide them with sensitive and crucial information (Abeyratne & Monfared, 2016). A single point of failure, which exposes the entire system to mistakes, hacking, corruption, or attack, is another problem with centralized information systems (Dong et al., 2017). In addition, there are new requirements for supply chain strategy and practice that analyze and confirm the sustainability of the supply chain. The triple-bottom-line concept, which integrates a balance of Economic, social, and environmental factors while managing the supply chain, has been referred to as sustainability (Elkington, 2020).

Blockchain has become a practical solution to address the issues above (Abeyratne & Monfared, 2016). Supply chain transparency is something that customers seek. Hence, the development of this technology is timely. Customers typically seek confirmation that the fish they buy and eat does not come from illegal netting techniques or off-limits waters (Earley, 2013). Additionally, jewelry customers want confirmation that the diamonds they purchase are real and were not obtained from regions of the world that are in conflict (Swan, 2015).

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Rationale of the Study

Modern supply chain management is considered to be an incredibly challenging undertaking. Networks frequently include a sizable number of far-scattered participants from around the world who must maintain intricate relationships with one another. Due to its intricacy, it can be difficult to get a clear picture of what is going on in some chain links, which encourages dishonest activity such as fraud and breaking of conduct rules. These complex, widely distributed supply networks are vulnerable to disruptions, creating a dangerous atmosphere (Deloitte, 2018). Not only has globalization made it more difficult to maintain openness, but it has also greatly increased competitiveness, which has put margins under much pressure.

Additionally, there is additional pressure coming from the stakeholders downstream. Consumers now have higher expectations: More and more people want to know where a product came from and whether or not the supply chain it traveled through was sustainable. Supply chain transparency is something that customers want. Hence, the development of this technology is timely. For instance, customers frequently seek guarantees that the fish they buy and eat do not come from illegal netting techniques or off-limits waters (Earley, 2013).

Research Problem

According to the study by Casey and Wong, 2017, Blockchain will enhance supply chain trust. However, there is no evidence that the technology may be employed in supply chains because the majority of Blockchain research is focused on the financial industry and the use of the cryptocurrency Bitcoin.

Research Questions

The following are the research questions that drive this study.

1. What is the scope of research into supply chain solutions based on Blockchain?
2. How does Blockchain affect enterprise traceability of items, data immutability, computational needs, security, and privacy in the supply chain?
3. How has Blockchain technology impacted the trade supply chain?
4. What programs, laws, and regulations are required for the effective use of Blockchain in the supply chain?

Research Objectives

By concentrating on the following research objectives (RO), the current study will explore the impact of Blockchain integration in the supply chain:

- To explain the Scope of Research into Blockchain-based Supply Chain Solutions
- To assess the Impact of Blockchain on Enterprise Traceability, Data Immutability, Computational Needs, Security, and Privacy in the Supply Chain

- To investigate the Impact of Blockchain Technology on Trade Supply Chain
- To examine the programs, laws, and regulations required for effective Blockchain utilization in the Supply Chain

Significance of the Study

In order to direct the research, a definition of "supply chain management" was chosen before the study began. A description that adequately describes the field of supply chain management was chosen since it covers a wide range of concepts. This concept includes the crucial idea of long-term inter-organizational supply chain process improvement. This is relevant to the modern supply chain difficulties, many of which are attributed to the complexity brought on by a large number of actors and worldwide dispersion. The use of Blockchain in supply chain management is a relatively new field of study that addresses a wide range of technological properties, applications, opportunities, and deployment difficulties related to supply chain management. While supply chain management with Blockchain technology is the primary emphasis of this paper, it is also crucial to look at difficulties that are closely related to this topic. The pertinent topics covered as part of this paper's theoretical framework are discussed in the remaining portion of this section.

Limitation of the Study

After defining what is covered by this paper, it is critical to recognize the off-limits subjects. This study discusses the elements that fall outside the defined scope. This paper discusses Blockchain-based supply chain management systems, emphasizing supply chain consequences above underlying technological concepts. The literature review in this paper provides basic information on Blockchain technology. The goal of giving a brief description of the technology is to increase knowledge of Blockchain's function in supply chain management. Advanced hardware- and software-related insights are not part of this study. However, researchers with background knowledge of software and hardware knowledge will contribute more effectively to technical development and practical applications of Blockchain-based supply chain management.

This research employs a theoretical methodology rather than an empirical one, as is more fully discussed in "Research Methodology." For this purpose, only peer-reviewed research papers have been gathered and analyzed. In the first stage of this paper, it was also suggested that a poll be conducted and that supply chain experts and Blockchain developers be interviewed due to the difficulty in identifying the experts who are willing to share the private firm information required to address this research. Therefore, it should be noted that the analysis does not reflect an interpretation of data acquired through field research but rather a critical review and formulation of theory based on existing literature.

Literature Review

In recent years, supply chain management systems have paid much attention to the incorporation of Blockchain technology. Blockchain is a distributed ledger system that operates on a decentralized network. The mentioned studies highlight the

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growing importance of using blockchain in managing supply chains. Supply chains can turn out to be more green, traceable, and obvious through using blockchain (Merkle, 1987).

Examining the capability applications of the blockchain era in supply chains is a critical topic inaccessible inside the literature (RO1). In an attempt to apprehend the implications of blockchain on supply chain operations, researchers have taken into consideration a huge variety of blockchain applications (Lacity et al., 2018; Tapscott & Tapscott, 2016), ranging from transaction processing to inventory control.

The study specializes in how blockchain impacts records' immutability, delivery chain safety, privateness, traceability of organization operations, and computational power needs (RO2). Researchers have studied how blockchain preserves information integrity, the way it facilitates product traceability, and how much processing electricity is required for a trusted, decentralized community.

A crucial area of study is how blockchain technology impacts the delivery chain in the context of commerce (RO3). Research has tested the potential of blockchain technology to lessen fraudulent interest, expedite global exchange tactics, and grow the efficiency of cross-border transactions.

Furthermore, the significance of rules (RO4) is diagnosed. Researchers have observed the need for initiatives, regulations and tips to make sure that blockchain technology is used successfully in supply chains (Swan, 2015; Catalini & Gans, 2016).

Research on the use of blockchain technology in supply chain management shows that people's curiosity about this technology is increasing. Based on the research goals, scholars evaluated the amount of research, how it affects corporate operations, how it affects commercial supply networks, and regulatory aspects. It lays the foundation for additional study and real-world application in the evolving field of supply chain management.

Research Gap

Despite the disruptive potential attributed to blockchain technology and its related academic research, current academic studies suggest a lack of theoretical frameworks to explore blockchain technology and its uses. Academic study on Blockchain technology is still in its early stages because it is still relatively new. The majority of the study is exploratory and relies heavily on conceptual models.

There have been few proposed Blockchain-based supply chain management systems, according to the brief literature assessment. Therefore, a thorough study is required to familiarize new researchers in the field of blockchain supply chain management systems. (Alazab et al. 2020, Juma et al. 2019, Zhang et al. 2020) Present the supply chain surveys. A comprehensive analysis of the common factors influencing the adoption of Blockchain in the supply chain is investigated by Alazab et al. 2020 this study is limited to just one region. Moreover, Juma et al. 2019 suggest presenting a survey of Blockchain-based systems in the trade supply chain. Similar to this, a study that focuses on IoT-based supply chains is investigated by Zhang et al.

2020. However, these studies have created a lack of critical evaluation of the current systems and prospective research directions. In this paper, a thorough study of current Blockchain-based supply chain management systems is proposed along with some exciting new research avenues and a critique of the current systems in response to the highlighted deficiency.

Research Methodology

We have developed a theory-driven framework for Blockchain-SCM study using the framework analysis approach in order to accomplish the research goal. Framework analysis is a well-researched, rigorous technique for analyzing data in qualitative research. It is most effective when used in studies with clear goals and deadlines (Furber, 2010; Srivastava & Thomson, 2009). It offers a systematic, thorough, and iterative approach to data analysis. It is an open approach where anyone who can assess the data analysis process can view the data, thematic framework, and indexing procedures (Srivastava & Thomson, 2009). In order to determine the reasons and barriers pertaining to Blockchain adoption, implementation, and use, as well as the theories employed or suggested for Blockchain-SCM research studies up until December 2022, we examined and analyzed the body of literature already in existence on the subject of supply chains and Blockchain. This phase assisted in providing broad insights into the various areas of Blockchain-SCM research that still require attention. It also assisted in identifying pertinent theoretical stances that will be useful in the future to gain a deeper understanding of this rapidly expanding topic. The second step is to choose a theme structure. Even though the facts may build upon previous themes or difficulties, they should still influence the themes and how they are portrayed in the framework. The two main themes we found in the literature for this study were the factors influencing blockchain adoption, deployment, and application in supply chain management (SCM) as well as the challenges and barriers. As a result, an extensive framework will be created that offers direction and presents a variety of theoretical viewpoints that might be applied to explore many aspects of supply chain blockchain applications.

Analysis and Discussion

Blockchain: An Overview of Factors Affecting blockchain technology

Distributed Ledger Technology (DLT)

Blockchain systems are built on distributed ledger technology (DLT), which is based on two main ideas: immutability and distribution. Decentralized power is what decentralized and distributed ledger technology (DLT) does by denying complete control to a single person or organization. Each node in the network has a copy of the ledger, and participants work together to reach a consensus.

Distributed nodes are beneficial to the network because they reduce the chance that a single failure will bring down the entire system. They use methods like Proof of Stake (PoS) and Proof of Work (PoW) to achieve consensus on the current state of the ledger. The system is reliable and transparent as common people verify the data.

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Another concept of DLT is immutability, which means data cannot be changed. They protect transaction history using complex mathematical methods. For a system to be reliable, its information must be up-to-date.

Nodes are essential to maintain network stability and reliability. A majority of nodes must agree to any changes to the registry, which is copied by every node. As a result, there are no intermediaries involved in transactions, which increases the security of the system. Because everyone commits to being truthful and acts as a backup, the blockchain system is trustworthy.

Blockchain

Blockchain is the core data structure of distributed ledger systems, which is a decentralized support technology that is critical to the revolution in data storage and verification. A blockchain is essentially an immutable distributed ledger that provides a transparent and safe means of recording transactions (Narayanan et al., 2016).

The core of blockchain is its ability to operate as a backordered hash list that is shared among users, or nodes, in a peer-to-peer network. A sequential and impenetrable structure is created by each block in the chain having a cryptographic hash of the preceding block (Swan, 2015). Because changing one block would require modifying all following blocks, which is impossible in a decentralized and widely dispersed network, this block chaining protects the integrity of the whole transaction history.

Known as Blockchain 1.0 in its early stages, the technology rose to popularity in the era of cryptocurrencies. With blockchain serving as the foundational technology for a decentralized digital currency, Bitcoin is the most well-known use of this age (Narayanan et al., 2016). With the introduction of sophisticated smart contracts in Blockchain 2.0, the evolution proceeded. One of the main platforms during this time was Ethereum, which made it possible to carry out programmable contracts and automate more complicated transactions than just exchanging money (Tapscott & Tapscott, 2016).

With the arrival of the Blockchain of Things (BoT) generation, the 1/3 step of the process has begun. This step includes combining Blockchain technology with the Internet of Things (IoT) in order to provide comfy and transparent tool interactions. The Blockchain of Things gives a decentralized and dependable foundation for the massive series of associated gadgets, extending the usage of blockchain technology past monetary transactions (Swan, 2015).

Smart Contracts

A powerful software program of blockchain technology is Wise Contracts, which automates transaction protocols to meet predefined requirements without the want for intermediaries. Better automation, flexibility, and communication among unique strategies are made feasible by the manner of those virtual contracts, which might be stored in the blockchain (Buterin, 2013). Smart contracts are basically without a doubt a hard and fast of policies that outline the parameters of a given trade or transaction. When predetermined conditions are met, those contracts are

robotically terminated (Swan, 2015). The integrity of the way is maintained due to the immutable and decentralized nature of blockchain technology.

One of its key blessings is the functionality of smart contracts to automate and streamline complicated transactions. Sometimes a traditional settlement entails a couple of intermediaries, which can result in delays and capacity disputes. In comparison, clever contracts feature independently, removing the need for intermediaries and speeding up the fulfillment of contractual duties. This automated processing improves productivity by using way of lowering the threat of mistakes and conflicts. Another vital thing to recall is the capability of smart contracts. Parties to a smart agreement can also choose to embody a massive number of phrases, privileges, and responsibilities regarding a selected transaction. Due to its versatility, automation may be used to resolve a wide style of issues, from clean economic transactions to complex multi-party contracts.

The communication constituent of smart contracts is another crucial aspect. By encoding the contents of an agreement directly within the code, smart contracts provide an accessible and auditable record of the whole transaction history. Participants may easily verify the terms and outcomes, which fosters trust and reduces the likelihood of misunderstandings or conflicts.

Blockchain Architecture

Blockchain architecture comprises the following six levels: data, network, consensus, contract, service, and application layers. You can select between permissioned and permissionless versions. Consortium chains offer a hybrid concept. A well-configured ledger guarantees trustless agreements, robustness, and transformational potential.

Potentially Transformed Sectors

Blockchain is gaining traction in a variety of sectors by providing novel means of generating and transferring value. Its potential impact is often likened to the revolutionary influence of the internet (Swan, 2015). As Blockchain continues to evolve, industries are exploring creative solutions for enhancing processes and fostering trust.

Integration with emerging technologies such as cloud computing, big data, and artificial intelligence (AI) holds the potential to revolutionize IT systems and applications. Blockchain's decentralized and secure nature aligns seamlessly with the principles of these technologies, promising to reshape the landscape of information technology in the coming years (Mougayar, 2016).

Supply Chain Management Today

Supply Chain Status Quo in Large Industries

Contemporary supply networks encounter intricacies stemming from several elements like political, cultural, and geoeconomic concerns. Different industries have different stages of supply chain growth, including food, clothing, electronics, aviation, and autos. Retailers actively manage the channel as dominating partners,

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overcoming obstacles pertaining to sourcing, multichannel strategy adaptation, and the complexity of the supply chain.

Blockchain in Supply Chain Management

Figure 1

Implementing blockchain in Supply chain



Note: The image is taken from article available on Linked "Implementing Blockchain in the supply chain" by Mac Mani (2023)

Disruptive Potential

Blockchain's ability to solve current problems in international contexts holds great promise for revolutionizing supply chain management. The implementation of technology has the potential to revolutionize supply chain operations by improving regulatory compliance, transparency, and traceability.

Blockchain Integration in Supply Chains

Blockchain technology can be integrated with other technologies, especially the Internet of Things (IoT), to provide improved sustainability indicators, data verifiability, and real-time tracking. Supply chain management may now be done more affordably with the help of Blockchain and IoT.

The Blockchain-driven Supply Chain

Permissioned access may be available in Blockchain-based supply chain networks, and smart contracts may be used to facilitate communication. The notion of a Blockchain-enabled self-aware supply chain implies improved efficiency and modified supply chain flows.

Blockchain Supply Chain Applications

Supply chain Blockchain applications include decentralized administration, improved auditability, real-time data access, and process automation via smart contracts. Distinct online identities for both products and system players are possible thanks to Blockchain technology, which also makes disintermediation easier. This could change how supply chain interactions are conducted overall.

Forging a More Sustainable Supply Chain

Blockchain can help supply chains become more sustainable by enhancing the procedures for choosing, assessing, and enhancing suppliers. It stores sustainability values, gives decision-makers access to high-quality data, and enables smart contracts to enable autonomous monitoring of sustainability standards.

Enhancing Supply Chain Resilience

Cloud computing and Blockchain improve the robustness, flexibility, and visibility of the supply chain. With the help of Blockchain technology, the Low Certainty-Need (LCN) supply chain concept manages supply chain disruption risks by using real-time data tracking.

Supply Chain Management Blockchain Challenges

Unanswered questions regarding Blockchain's potential, security hazards in smart contract design, cybersecurity threats, scalability issues, and the possibility of centralization are among the challenges associated with its implementation. Since the technology is still developing, further research is needed to address concerns about data sharing and transaction speed between Blockchains and other systems.

Conclusion

Systems that use distributed consensus to verify immutable transactions are known as distributed ledger technologies. A Blockchain is the main data structure of a distributed ledger system, to which a new block is added once each transaction is validated. The advancement also facilitates the incorporation of smart contracts, which possess conditional business logic and can be configured to execute automatically upon fulfillment of specific conditions. Blockchain-based systems can be made public so that a wide range of people can utilize them, or they can be made private to restrict access and authority to particular institutions.

Blockchain is one of the technologies that is believed to have a big potential to change government, business, and financial operations. In the current world, supply chains are complex systems with several individuals interacting with one another in unexpected ways. The modern supply chain is becoming more and more global, bringing with it both opportunities and challenges as new markets and production bases are opened up. Over the past few decades, a growing number of disruptive events have overtaken supply lines, indicating the need for a more resilient supply chain. This has spurred numerous firms to adopt a more hybrid design approach. In addition, today's end user is far more powerful and has high standards for multichannel shopping. Furthermore, there is increasing demand for corporations

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to manage their supply networks responsibly. The difficulties of today's world call for robust inter-organizational cooperation. Furthermore, supply networks are expected to undergo a major transformation due to breakthroughs.

It is believed that new technology could bring about a particularly major revolution in the field of supply chain management. When combined with Internet of Things (IoT) technology, Blockchain has the potential to bring significant benefits in terms of increased efficiency, security, transparency, and disintermediation. This is projected to have a substantial positive impact on product provenance identification, supply chain resilience, supply chain sustainability, supply chain financing, and business process management in general. However, experts also anticipate problems that would keep Blockchain from being a widely used technology. These worries center on the constraints of smart contracts, laws, the resources needed, security, the requirement to involve the entire supply chain network, consumer information access, employment losses, and a decline in democratization. The field of Blockchain technology is still quite young, with many ongoing initiatives only reaching the pilot stage. It might take decades for supply networks to adopt this widely. Initial Blockchain deployments operate best with supply chains that have a small number of players. Players will need to persuade other members of the network of the benefits of the technology in order to have a completely covered supply chain.

Recommendations

Exploring Interdisciplinary Solutions

Given the intricate nature of modern supply chains, future research should focus on interdisciplinary collaboration. Promote research that fills the knowledge gap between supply chain management specialists and Blockchain technology experts in order to provide all-encompassing solutions that tackle both operational and technical issues.

Performance Optimization and Scalability

Recognize the issue of Blockchain systems' scalability and suggest focused research efforts to improve performance. Look into novel consensus methods, smart contract optimizations, and other technological developments to make sure supply chain systems built on the Blockchain can effectively manage massive transactions.

Security and Privacy Frameworks

Acknowledge the significance of security and privacy in supply chain management; suggest conducting a comprehensive study on permissioned blockchains, cryptography, and privacy-preserving solutions. Create frameworks that ensure the stability of blockchain solutions by striking a balance between the requirement to protect sensitive information and transparency.

Regulatory Compliance and Standards Adherence

Emphasize how critical it is to abide by the industrial standards and regulatory requirements. Promote further research into the evolving regulatory

landscape and the development of compliance frameworks tailored to blockchain-based supply chain systems.

User Training and Adoption Strategies

Encourage the development of educational resources and intuitive user interfaces to facilitate the adoption of blockchain technology in supply chain management. Investigate methods for overcoming the opposition and fostering comprehension among participants via initiatives for training and efficient communication.

Real-world Case Studies and Best Practices

Urge academics to look into actual case studies of supply chain management using Blockchain technology. Examine the achievements, difficulties, and best practices of businesses that have used Blockchain technology to offer insightful information to aspiring adopters.

Environmental Sustainability Considerations

Acknowledge the effects of Blockchain technology on the environment and suggest researching sustainable Blockchain solutions. Examine eco-friendly methods and energy-efficient consensus processes to make sure Blockchain applications are in line with international sustainability objectives.

Continuous Monitoring and Adaptation

Emphasize the significance of ongoing observation and assessment following implementation. Urge academics to create frameworks for continuous evaluation that take user input, performance indicators, and flexibility to new developments in technology and shifting demands from the industry into account.

Blockchain and IoT Integration Studies

Emphasize how Blockchain and Internet of Things (IoT) technologies may work together. Encourage comprehensive research on the ways in which integrating these technologies can improve supply chain data integrity, traceability, and real-time monitoring.

Collaborative Persuasion Strategies

Acknowledge the necessity of teamwork in supply chain networks. Provide tactics for convincing interested parties of the advantages of Blockchain technology, particularly in situations where there might be doubts. Provide exemplary cases of businesses that have successfully conveyed the benefits of using Blockchain technology.

Timeline for Industry-wide Adoption

Recognize that Blockchain technology is still in its early stages of development and offer an estimate of when it will be widely adopted. Consider

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elements including supply chain stakeholders' preparedness, technological maturity, and regulatory advancements.

By addressing these recommendations, future research in the field of Blockchain-based supply chain management systems can contribute to the development of robust, secure, and widely adopted solutions that effectively address the challenges faced by modern supply chains.

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