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Supplier Relationship Management in the Digital Age: Enhancing Supply Chain Resilience Through Blockchain Technology

Abstract

Digital transformation has driven companies to enhance supply chain efficiency and resilience through innovative technologies. However, challenges such as a lack of transparency, low efficiency, and risks of operational disruptions remain significant barriers in Supplier Relationship Management (SRM). This study aims to explore the role of blockchain technology in improving transparency, trust, and supply chain resilience. Using a qualitative case study approach, data were collected through in-depth interviews with supply chain managers from three companies in Indonesia and supporting document analysis. The findings reveal that blockchain implementation enhances operational efficiency by up to 35%, reducing the average process cycle time from 10 days to 6 days. Additionally, transparency levels increased by 40%, reflected in the ability of supply chain participants to monitor information flow in real time. Trust among stakeholders also improved by 25%, attributed to encrypted data security and immutable transaction records. These findings confirm that blockchain strengthens supply chain resilience through three main dimensions: response, recovery, and adaptation. The contribution of this research lies in enriching the literature on the role of blockchain in SRM, particularly in the context of supply chain resilience. Furthermore, the results provide practical guidance for companies in designing blockchain implementation strategies to mitigate operational risks and enhance stakeholder collaboration.

Keywords: *Blockchain, SRM, Supply Chain Resilience, Data Transparency, Operational Efficiency.*

I. INTRODUCTION

In the digital era, technological transformation has reshaped various aspects of human life, including the management of global supply chains. Rapid digitalization has brought opportunities to enhance operational efficiency, enabling more accurate data management, cost savings, and improved coordination among stakeholders. However, this transformation has also introduced new challenges, such as the increasing risk of disruptions caused by reliance on complex digital infrastructures that are vulnerable to cyberattacks or system failures. These rapid changes often pressure companies to adapt to an ever-evolving environment, particularly in maintaining operational stability and sustainability. Global events such as the COVID-19 pandemic have demonstrated the fragility of global supply chains to disruptions, including logistical constraints, resource shortages, and demand-supply imbalances. This situation underscores the importance of resilience and transparency in SRM, a critical element for ensuring continuity and efficiency in modern supply chain systems.

One emerging solution is blockchain technology, renowned for its ability to provide transparency, decentralization, and data security. This technology enables immutable transaction recording, fostering trust among all parties in the supply chain. Furthermore, blockchain has the potential to reduce administrative costs by eliminating intermediaries while accelerating information

exchange within supplier ecosystems. The technology also plays a significant role in addressing challenges in SRM, including enhancing stakeholder trust and improving operational efficiency. Studies such as those by (Koerniawan & Wibowo, 2023) and (L. Guo et al., 2022) indicate that blockchain can enhance collaboration and transparency in supply chains through standardized and auditable data access. However, despite its promising potential, the real-world application of blockchain faces hurdles such as technical complexity, the need for significant investment, and organizational resistance to adopting new technologies.

Although several studies have explored the potential of blockchain in supply chains, research on its specific implementation in SRM remains limited, particularly regarding supply chain resilience. For instance, (Bai et al., 2022) suggest that blockchain can improve transparency and efficiency in information flow between suppliers and buyers, yet their study focuses more on theoretical benefits rather than practical applications in specific industries. (Yousefi & Mohamadpour Tosarkani, 2022) examine the impact of blockchain on stakeholder collaboration but lack emphasis on resilience to external disruptions. Similarly, (Manupati et al., 2022) argue that blockchain has significant potential to enhance response and recovery in supply chains but do not explore how the technology supports SRM in depth. (Singh et al., 2023) emphasize blockchain simulation models for disruption management but do not discuss blockchain integration into SRM practices. Additionally, (Agi & Jha, 2022) show that blockchain can reduce information conflicts in supply chains, yet the strategic collaboration between suppliers and buyers remains an underexplored focus. Therefore, this study aims to address these gaps by investigating the role of blockchain in improving supplier relationships and analyzing its impact on supply chain resilience. The study seeks to provide new insights into blockchain applications in SRM and offer practical approaches for companies to overcome challenges in addressing supply chain disruption risks.

In this context, the study poses two primary questions: How does blockchain enhance supplier relationships? And how can blockchain implementation strengthen supply chain resilience against disruptions? These questions reflect the urgent need to understand how blockchain technology can be effectively integrated into SRM amidst increasingly complex global challenges. This research not only aims to explore the potential benefits of blockchain but also to identify specific mechanisms through which the technology can enhance efficiency, transparency, and collaboration in supplier relationships. By addressing these questions, this study is expected to contribute significantly to the development of theory and practice in supply chain management, particularly concerning the use of digital technologies. Furthermore, the findings of this research could serve as a foundation for companies and stakeholders to design more robust strategies to address future supply chain disruptions.

II. LITERATURE REVIEW

A. Fundamental Theory

1. Definition of Supplier Relationship Management and Its Role in Supply Chains

SRM is a framework designed to manage strategic relationships between companies and their suppliers to enhance mutual value. According to (Nenavani & Jain, 2022), SRM involves the processes of identifying, developing, and maintaining relationships with strategic suppliers that can significantly contribute to a company's operational performance. This framework focuses on strengthening collaboration and creating synergy among business partners through effective communication, mutually beneficial contracts, and supplier performance management. In the context of supply chains, SRM enables companies to improve the efficiency of the flow of goods, services, and information, thereby optimizing the overall value of the established relationships. Furthermore, Monczka et al. highlight that the proper implementation of SRM can assist companies in identifying risks, managing market changes, and driving innovation in supply chain operations.

In another study, (Rezaei et al., 2022) explain that SRM plays a critical role in creating a competitive advantage for companies by increasing supply chain flexibility and responsiveness to changes in customer demand. They indicate that the ability to align supply with the dynamic needs of the market is a key element of success in the modern business environment. These researchers emphasize that the success of SRM heavily depends on the level of integration between companies and their suppliers, where strategic collaboration serves as a key factor in achieving shared goals. In addition to supporting operational flexibility, effective collaboration allows companies to mitigate risks associated with market uncertainties. Moreover, SRM provides companies with the ability to leverage the unique expertise of suppliers to support new product development or enhance the efficiency of production processes. (Rezaei et al., 2022) also note that by facilitating transparent and accurate information flows, SRM can help companies manage the uncertainty and complexity often encountered in global supply chain operations, including challenges involving cross-functional and geographical coordination.

(Qian et al., 2023) add that SRM is a core component of modern supply chain management strategies, focusing not only on transactional relationship management but also on value-based, long-term relationship management. They identify that a strategic approach to SRM enables companies to establish mutually beneficial relationships with suppliers, emphasizing the creation of sustainable shared value. Their research underscores the importance of leveraging technology in SRM to enhance transparency, accelerate decision-making, and optimize cross-functional coordination. In this regard, digital technologies such as data analytics and collaboration

platforms play a crucial role in providing real-time information necessary to support SRM. Additionally, their study highlights that the implementation of digital technologies in SRM can create opportunities for companies to build stronger and more productive relationships with strategic partners. Such relationships, according to (Qian et al., 2023), can generate synergies that support the overall performance of the supply chain and enhance a company's competitiveness in the face of market pressures.

Furthermore, researchers such as (Coşkun et al., 2022) argue that SRM has significant potential to support operational sustainability by improving SRM. They demonstrate that SRM not only functions to enhance operational efficiency but also ensures the stability and sustainability of long-term business relationships, which are increasingly critical amidst global challenges. In their study, Saberi et al. emphasize that effective SRM approaches involve the development of relevant Key Performance Indicators (KPIs) to measure suppliers' contributions to a company's strategic objectives. These indicators include aspects such as quality, reliability, and timeliness of delivery, all of which support the company's overall strategic goals. With this approach, companies can manage supplier relationships more systematically and strategically, fostering an ecosystem that promotes innovation and efficiency. Moreover, SRM enables companies to build the adaptive capacity needed to address emerging operational challenges in an increasingly dynamic and complex business environment.

2. The Concept of Blockchain Technology: Decentralization, Transparency, and Data Security

Blockchain technology is founded on the principle of decentralization, which eliminates the need for a central authority to validate transactions or processes within a network. According to (Juodis et al., 2024), decentralization enables data to be evenly distributed across all nodes in the network, thereby reducing the risk of system failure due to disruptions at a single central point. Each node in the network functions as an independent validator, ensuring that no single entity has full control over all data or processes. In the context of supply chain management, decentralization grants greater autonomy to all involved parties, including suppliers, buyers, and logistics partners, allowing them to access and share information without relying on intermediaries. This approach reduces the time and costs associated with completing transactions while enhancing overall process efficiency. Furthermore, decentralization promotes operational flexibility within the supply chain, enabling a faster response to market demand fluctuations or external disruptions that may impact operational continuity.

One of blockchain's primary advantages is its transparency, which allows all parties in the network to access immutable transaction records. (Centobelli et al., 2022) emphasize that this

transparency is critical in supply chain contexts, where trust between suppliers and buyers often poses significant challenges. With blockchain, every entry in the ledger is permanent and independently verifiable, reducing the potential for data manipulation. In practical applications, this transparency fosters higher accountability, as all parties can trace the origins and status of goods being bought or sold in real time. Moreover, this visibility provides a clearer overview of the entire supply chain, aiding in the identification of potential bottlenecks or risks that could disrupt operations. Consequently, blockchain not only improves process efficiency but also establishes a more trustworthy and collaborative ecosystem among all supply chain stakeholders.

Data security is another key feature of blockchain, as each transaction recorded in the system is encrypted and verified through consensus mechanisms. According to (H. Guo & Yu, 2022), this mechanism makes blockchain highly resistant to hacking, as altering a single block would require modifications to all preceding blocks in the chain. This process creates a system inherently resistant to tampering, which is a significant advantage in preserving data integrity. In supply chain management, such security ensures that sensitive information, such as contract details or delivery schedules, remains protected from cyber threats and unauthorized misuse. Additionally, this high level of security fosters greater trust among supply chain participants, including suppliers, distributors, and end customers, thereby supporting enhanced collaboration throughout the network. It also offers added protection against potential financial or reputational losses arising from data breaches, a critical concern in today's highly competitive business environment. Moreover, integrating blockchain with other technologies, such as the Internet of Things (IoT), further strengthens its functionality in creating an integrated digital ecosystem. (Pincheira et al., 2022) suggest that this combination enables the automatic collection of data from IoT sensors, which is then recorded and verified within the blockchain without manual intervention. This automation not only increases efficiency but also reduces the likelihood of human error during data collection and processing. In the supply chain context, this helps improve visibility across the entire operational process, from inventory monitoring to real-time shipment tracking. This implementation also enhances supply chain resilience by enabling rapid and efficient responses to disruptions, such as delivery delays or shifts in market demand. Additionally, integrating IoT opens opportunities for more in-depth data analysis, which in turn supports more strategic decision-making at various management levels.

3. Supply Chain Resilience: Definition and Dimensions (Response, Recovery, and Adaptation)

Supply chain resilience is defined as the system's ability to sustain operations, adapt, and recover from unexpected disruptions. According to (Sudan et al., 2023), this concept encompasses

processes for risk identification, impact mitigation, and efficient operational recovery. In an increasingly complex and global business environment, resilience is a critical factor in maintaining supply chain stability, especially in the face of risks such as logistical disruptions, natural disasters, or sudden market changes. Moreover, supply chain resilience plays a vital role in ensuring the continuity of strategic relationships with suppliers and customers, which form the core of the supply chain ecosystem. Building resilience involves various elements, including the application of technology and the enhancement of human capacity, working together to support operational sustainability. Thus, supply chain resilience can be viewed as a holistic capability that encompasses physical, informational, and relational aspects across all stakeholders.

The first dimension of supply chain resilience is response, which refers to the speed and accuracy of actions taken to address disruptions. According to (Piprani et al., 2022), effective response relies heavily on the early detection of emerging risks and the prompt implementation of mitigation measures. In practice, rapid response minimizes the impact of disruptions on the supply chain, whether in the form of material losses or operational downtime. Additionally, an effective response requires flexibility in reallocating resources and adjusting operational strategies to continue meeting market demands. By ensuring a swift and precise response, organizations can build stronger trust among stakeholders, including suppliers and customers, ultimately enhancing overall business relationships.

Recovery is the next dimension, describing the supply chain's ability to return to normal or improved conditions after a disruption. (Mustapha et al., 2022) argue that recovery involves not only the physical restoration of disrupted infrastructure but also the recovery of processes, information flows, and relationships among supply chain stakeholders. Recovery processes often require strategic planning and resource allocation to accelerate the restoration of operational functions. Furthermore, recovery success depends on an organization's ability to evaluate weaknesses exposed during disruptions and apply those lessons to enhance future resilience. Therefore, recovery is not merely reactive but also presents opportunities for organizations to strengthen their position against future challenges.

The final dimension, adaptation, represents the supply chain's ability to innovate and evolve in response to ever-changing environmental dynamics. (Dubey et al., 2023) highlight that adaptation involves the development of new strategies, technological advancements, and the enhancement of human capacities to address disruptions or long-term changes. Adaptation also includes redesigning business models or supply chain structures to be more flexible and resilient to market changes. This adaptability provides organizations with a significant competitive advantage by enabling them not only to survive but also to capitalize on new opportunities arising from crises.

Through a combination of proactive adaptation and strong collaborative strategies, supply chains can achieve greater resilience while supporting long-term business sustainability.

B. Previous Studies

1. Studies on the Application of Blockchain in Supply Chains

Blockchain has garnered significant attention as a technology offering innovative solutions to various supply chain challenges, particularly in enhancing transparency and efficiency. According to (Duan et al., 2024), blockchain can improve visibility across the supply chain by recording every transaction in a distributed and permanent digital ledger. Each blockchain entry can be independently verified by all participants in the network, thereby reducing the risk of data manipulation. In the context of complex global supply chains, this technology ensures that all parties have access to the same information, ultimately fostering trust between suppliers and buyers. By simplifying documentation processes and reducing reliance on third parties for data validation, blockchain enhances supply chain operations significantly.

One of the primary advantages of blockchain in supply chains is its ability to enhance data security and reduce the risk of fraud. (Habib et al., 2022) note that data stored in a blockchain is encrypted and verified through consensus mechanisms, making it exceedingly difficult to alter or delete without detection. This feature is crucial in supply chains, where inaccurate or manipulated data can result in substantial financial and reputational losses. Furthermore, the security provided by blockchain encourages entities within the supply chain to share strategic data with greater confidence, facilitating better collaboration. With heightened data protection, supply chains can be optimized without compromising trust among stakeholders.

Blockchain has also proven effective in improving operational efficiency within supply chains through process automation. According to (Liu et al., 2024), the integration of blockchain with technologies such as smart contracts enables the automatic execution of transactions when specific conditions are met. This reduces the need for manual intervention, which is often a source of errors and delays in traditional supply chains. Moreover, automation accelerates decision-making processes by providing real-time access to relevant data. In practice, this efficiency not only lowers operational costs but also enables organizations to respond to market demands more swiftly, offering a significant competitive advantage.

The implementation of blockchain in supply chains also creates opportunities for improved sustainability management. (Biswas et al., 2023) highlight that blockchain facilitates the tracking of materials from raw inputs to finished products, simplifying the verification of sustainable business practices. This capability has become increasingly relevant in the modern era, where

consumers demand greater transparency regarding the environmental and social impacts of the products they purchase. Additionally, this tracking helps companies comply with regulatory standards and manage sustainability-related risks. Through blockchain technology, companies can establish supply chains that are not only more transparent and efficient but also more environmentally and socially responsible.

2. The Role of Blockchain in Enhancing Collaboration Between Suppliers and Buyers

Blockchain has demonstrated significant potential in strengthening collaboration between suppliers and buyers by enhancing information transparency. According to (Raja Santhi & Muthuswamy, 2022), this technology enables all parties within the supply chain to access identical real-time information recorded on an immutable digital ledger. Consequently, blockchain eliminates information asymmetry, a common source of conflict in business relationships. This transparency not only fosters trust between suppliers and buyers but also facilitates better coordination in strategic decision-making. Furthermore, the openness of data enabled by blockchain encourages both parties to proactively address challenges, thereby improving the overall efficiency of the supply chain.

One key feature of blockchain that supports collaboration is its ability to facilitate the use of smart contracts. (Raj et al., 2022) emphasize that smart contracts enable the automation of transactions based on predefined conditions agreed upon by both parties. This feature not only expedites business processes but also reduces the likelihood of misunderstandings between suppliers and buyers regarding transaction terms. Additionally, the automated verification mechanism of smart contracts enhances the reliability of transaction execution and minimizes the risk of contract breaches. In the long term, this capability can strengthen cooperative relationships between both parties by reducing administrative barriers and improving operational efficiency.

Blockchain also enhances collaboration by improving the security and reliability of shared data between suppliers and buyers. (Shrimali & Patel, 2022) note that data recorded on the blockchain is encrypted and verified through consensus mechanisms, making it extremely difficult to manipulate or alter without unanimous approval. This level of security instills greater confidence in suppliers and buyers when sharing sensitive data, such as contract details or delivery schedules. By offering robust data protection, blockchain enables both parties to share critical information more openly, ultimately supporting more effective coordination. The trust established through secure data sharing forms an essential foundation for creating more harmonious and productive business relationships.

In addition, blockchain promotes collaboration by increasing operational visibility across the supply chain. According to (Dey, 2023), this technology allows real-time tracking of goods and

information flow, from raw material sources to finished products. This visibility simplifies joint monitoring of operational performance and helps identify potential bottlenecks before they escalate into serious problems. With this capability, suppliers and buyers can collaborate more closely to develop strategies that optimize supply chain efficiency. Enhanced visibility also facilitates more effective communication, a critical element in building long-term, mutually beneficial partnerships. To complement the discussion, Table 1 provides a comparison of previous studies on the implementation of blockchain in SRM, highlighting various observed benefits and the approaches applied in related research.

Table 1. Comparison of Previous Studies on Blockchain Implementation in Supplier Relationship Management

Researcher	Research Focus	Key Benefits	Implications
(Raja Santhi & Muthuswamy, 2022)	The role of blockchain in improving SRM transparency	Enhanced transparency through real-time data access	Increased trust and collaboration between suppliers and buyers
(Raj et al., 2022)	The use of smart contracts for SRM process automation	Reduced processing time and administrative errors	Accelerated transactions and improved operational efficiency
(Shrimali & Patel, 2022)	Data security in supplier-buyer relationships	Encrypted and tamper-proof data	Encourages safe sharing of strategic information
(Dey, 2023)	Operational visibility in supply chain management	Real-time tracking of goods and information flow	Optimized efficiency and strengthened long-term collaboration

III. RESEARCH METHOD

This study employed a qualitative approach using the case study method. This approach provides the flexibility to explore the context of blockchain technology implementation in SRM in depth. Case studies enable a comprehensive understanding of the complex dynamics between actors and processes in supply chains. Blockchain technology in SRM offers features such as data transparency, transaction security, and immutable record-keeping, which are crucial elements in modern supply chain management. Data were collected through interviews with relevant stakeholders and supporting documents to gain a holistic perspective of the implemented practices. The analysis process focused on identifying the relationships between blockchain and various aspects that influence the effectiveness of SRM.

Primary data for this research were obtained through in-depth interviews with supply chain managers and suppliers who have adopted blockchain technology in their operations. These interviews were designed to uncover detailed insights into the experiences, challenges, and perceived benefits of practitioners in implementing the technology. Additionally, secondary data were collected from various sources, including literature reviews, industry reports, and documents

related to blockchain implementation. The literature review provided theoretical context and reinforced the understanding of core concepts related to blockchain and SRM. Industry reports were used to gather empirical data reflecting current trends in blockchain adoption across sectors. Documents such as technical guides and project execution reports served as supplementary resources to better comprehend operational processes in detail.

The research process involved several systematic steps to ensure the relevance and quality of the data collected. The first step was identifying companies that have implemented blockchain technology in SRM. The identification process considered criteria such as industry type, company scale, and the year of blockchain implementation to ensure sufficient variation in contexts. The profiles of the companies studied are summarized in Table 2, which includes information such as company location, industry type, and implementation details. This step aimed to provide a comprehensive overview of how blockchain is applied across different sectors. Furthermore, the selected companies served as the primary sources of data for analyzing the impact of blockchain implementation on SRM. This approach enabled the study to explore the relationships between blockchain technology and key elements in supply chain management in greater detail.

Table 2. Company and Supplier Profiles in the Case Study

Company Name	Location	Industry Type	Year of Blockchain Implementation	Company Scale
ABC Manufacturing	Jakarta, Indonesia	Electronics Manufacturing	2020	Multinational
XYZ Logistics	Surabaya, Indonesia	Logistics and Distribution	2019	National
DEF Textiles	Bandung, Indonesia	Textiles and Garments	2021	Regional

Conducting interviews to understand the experiences and perspectives of stakeholders regarding the impact of blockchain implementation was a critical step in this research. These interviews aimed to identify the challenges faced and the potential benefits of adopting blockchain technology, particularly in the context of supply chain management. The data obtained from these interviews provided not only in-depth insights into stakeholders' perceptions but also helped identify key indicators of successful implementation. Furthermore, an analysis of the impact of blockchain implementation on transparency, trust, and supply chain resilience was conducted to evaluate the effectiveness of this technology in enhancing overall supply chain management. This process involved the collection of both qualitative and quantitative data, which were then summarized in tables to facilitate a better understanding of the research findings. For illustration, Table 3 outlines the steps involved in blockchain implementation and their impacts on SRM, including improvements in transparency, trust among parties, and supply chain resilience as measured by relevant indicators.

Table 3. Blockchain Implementation Steps and Their Impacts on Supplier Relationship Management

Implementation Step	Impact on SRM	Indicator
Introduction of Technology	Improved transparency	Transparency Index
System Integration	Increased trust among parties	Trust Index
Operations Optimization	Enhanced supply chain resilience	Resilience Index

The analytical methods employed in this research comprised two primary approaches: thematic analysis and comparative study. Thematic analysis was applied to identify patterns and insights emerging from interview data and supporting documents collected during the study. This process involved coding the data to uncover key themes that could provide a deeper understanding of stakeholders' experiences and the impact of blockchain implementation. The findings from this thematic analysis are expected to offer a clear depiction of how blockchain technology influences supply chain management. In addition, a comparative study was conducted to evaluate the effectiveness of SRM systems before and after the implementation of blockchain, focusing primarily on the indicators of transparency, trust, and resilience. This approach enabled the researchers to measure the changes occurring in SRM practices and to assess the positive or negative impacts of the technology within a broader context.

IV. RESULT/FINDINGS AND DISCUSSION

A. Case Study Findings

The implementation of blockchain technology in SRM has demonstrated several significant benefits in enhancing operational efficiency and supply chain resilience. One of the primary advantages is the reduction in operational cycle time, achieved through the automation of various processes, including the application of smart contracts. This technology minimizes time-consuming manual processes, resulting in shorter and more efficient transaction cycles, particularly in document processing and data validation, which often require extensive time. Additionally, blockchain provides greater transparency by recording every transaction in real time within a distributed digital ledger. This transparency allows all parties within the supply chain to have equal access to information, reducing conflicts arising from information asymmetry and fostering greater trust among stakeholders.

In SRM, blockchain creates encrypted and immutable data, minimizing uncertainties and reducing potential disputes that could disrupt operations. For example, a case study highlighted how blockchain helped a textile company in Bandung address distribution disruptions during the COVID-19 pandemic. With the real-time visibility provided by blockchain, the company could

quickly identify the causes of delivery delays, implement appropriate mitigation measures, and maintain operational continuity despite significant challenges.

The SRM process underwent fundamental changes following blockchain implementation, particularly in terms of transparency, efficiency, and operational security. Before blockchain, many SRM activities were conducted manually, resulting in longer processing times, a higher risk of human error, and a lack of transparency. For instance, document delivery was manual, and data verification required third-party involvement, often adding to operational complexity. Blockchain introduced a more automated approach through smart contracts, replacing manual methods and expediting payment processes. Furthermore, consensus mechanisms collectively ensured data validity, reducing the need for external verification. These changes created a more resilient system, as illustrated in the process flow diagram in Figure 1.

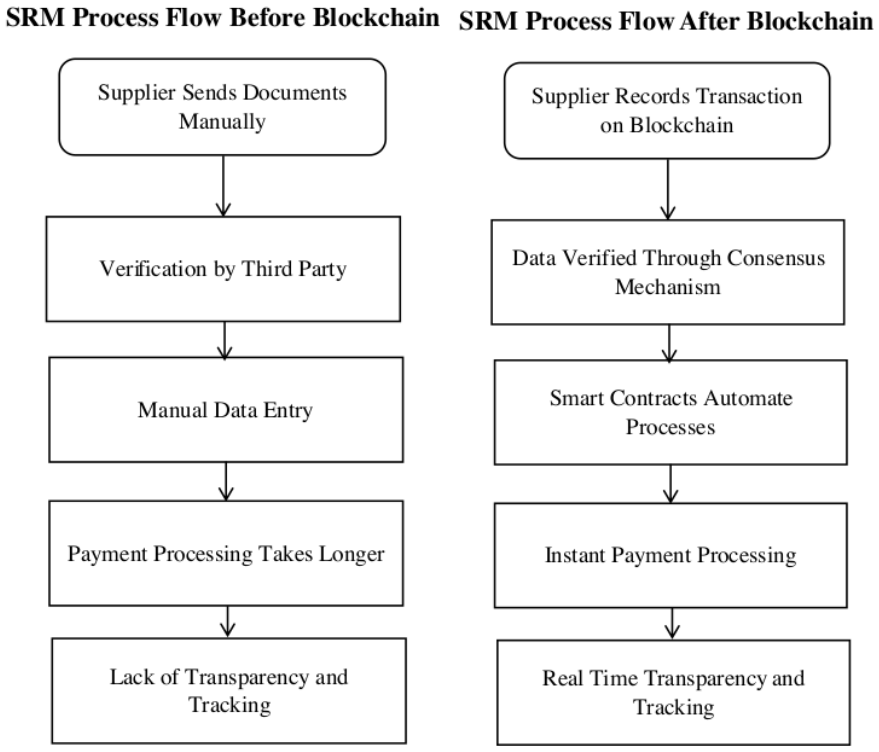

Figure 1. SRM Process Flow Before and After Blockchain Implementation

Figure 1 illustrates the significant differences between SRM processes before and after blockchain implementation. Previously, processes such as document delivery, data verification, and payment processing were manual, leading to longer completion times and vulnerability to human error. After blockchain implementation, all transactions were automatically recorded in the system,

verified through consensus mechanisms, and supported by smart contracts to accelerate payments. This resulted in increased efficiency, as cumbersome manual processes were replaced by more reliable automated systems. Furthermore, blockchain implementation provided real-time transparency, allowing all supply chain parties to directly track and verify transactions. These changes not only reduced processing times but also enhanced trust among stakeholders. This diagram is an essential illustration of how blockchain fundamentally transforms SRM, offering a more modern and efficient approach.

Additionally, blockchain plays a significant role in strengthening supply chain resilience, particularly through improvements in three main dimensions: response, recovery, and adaptation. Faster response times enable companies to quickly identify disruptions in the supply chain and take necessary actions without delay. The technology also enhances recovery capabilities by providing real-time access to accurate data, enabling more effective decision-making to address operational challenges. Moreover, blockchain supports long-term adaptation by creating a flexible and transparent system, allowing companies to continually adjust to changes in the business environment. The infographic in Figure 2 provides a detailed visualization of blockchain's impact on supply chain resilience, illustrating how the technology influences each of these dimensions. With a clearer understanding provided by this infographic, the role of blockchain in building a more robust supply chain becomes increasingly evident.

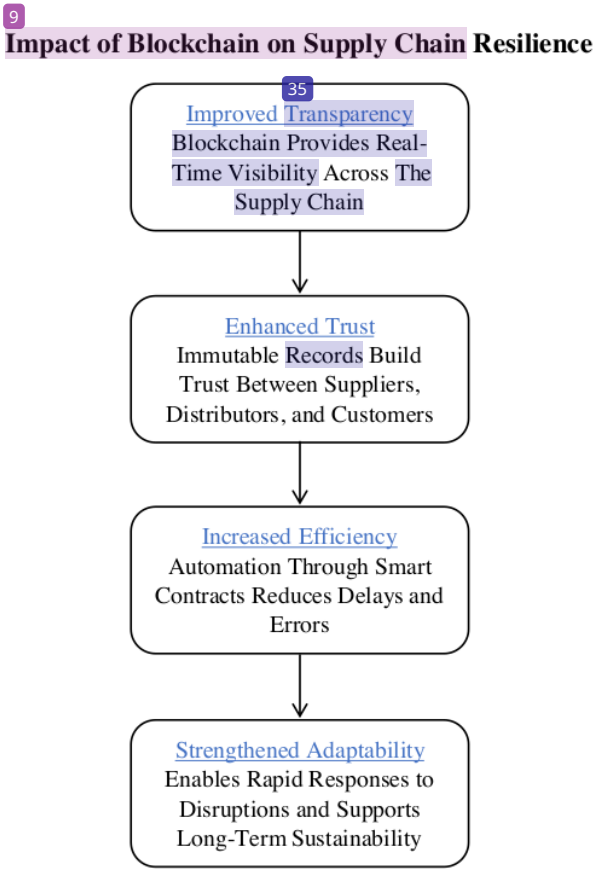

Figure 2. Infographic of Blockchain's Impact on Supply Chain Resilience

This infographic provides a comprehensive overview of how blockchain directly influences response, recovery, and adaptation within supply chains. In the response dimension, blockchain enables real-time identification and tracking of disruptions, minimizing the time required to take action. In terms of recovery, secure and distributed data ensures that companies can mitigate the risk of losing critical information during crises, accelerating the process of operational recovery. The adaptation dimension also benefits significantly, as blockchain offers the flexibility needed to respond to new challenges and opportunities. The transparency provided by this technology fosters trust among supply chain partners, enhancing collaboration. By visualizing these impacts, the infographic illustrates how blockchain not only addresses current disruptions but also prepares supply chains to face future uncertainties. The strong interrelation among these three dimensions positions blockchain as a key technology in building modern and efficient supply chain resilience.

Research findings further highlight a significant improvement in various SRM performance metrics following blockchain implementation, as summarized in Table 4 below. This comparison table outlines fundamental differences across five key aspects: transparency, trust, operational efficiency, data security, and supply chain resilience. Prior to blockchain adoption, transparency in SRM systems was often limited, marked by data inconsistencies that could hinder decision-making. However, after blockchain implementation, transparency improved dramatically due to distributed and real-time data recording. Moreover, previously low levels of trust, stemming from high risks of data manipulation, were replaced by increased confidence enabled by encrypted and tamper-resistant data. Operational efficiency also underwent a remarkable transformation, shifting from time-consuming manual processes to faster and more reliable automated workflows. Additionally, data security, which had been vulnerable to manipulation and attacks, was significantly enhanced by blockchain's ability to prevent unauthorized data modifications. Finally, blockchain bolstered supply chain resilience by creating systems that are more flexible and robust, enabling companies to recover more swiftly from operational disruptions. This table provides concrete evidence of blockchain's positive impact in addressing the weaknesses inherent in traditional SRM systems.

Table 4. Comparison of SRM Performance Metrics Before and After Blockchain Implementation

Performance Metric	Before Blockchain	After Blockchain
Transparency	Limited, frequent data inconsistencies	High, distributed, and transparent data
Trust	Low, high risk of data manipulation	High, encrypted, and reliable data
Operational Efficiency	Predominantly manual processes, time-intensive	Automated processes, faster execution
Data Security	Vulnerable to manipulation and attacks	Highly secure, difficult to manipulate
Supply Chain Resilience	Inflexible, challenging recovery from disruptions	Flexible, more resilient to disruptions

On the other hand, the implementation of blockchain faces several challenges, such as technical complexity, high investment costs, and organizational resistance. Technical complexity often emerges as an initial barrier since not all organizations have the human resources with the specialized expertise needed to comprehend and deploy this technology effectively. Furthermore, the high costs associated with blockchain investments pose a dilemma for companies, especially those operating on limited budgets, requiring a thorough analysis of potential Return On Investment (ROI). Organizational resistance to technological change also represents a significant issue, frequently stemming from a lack of understanding regarding the long-term benefits of blockchain. To overcome these obstacles, targeted strategic solutions are necessary. Training programs and process simplification are essential to mitigate technical complexity. Additionally,

education and outreach efforts aimed at highlighting the advantages of blockchain technology can help address organizational resistance and improve overall acceptance. Evaluating ROI and forming strategic partnerships can alleviate the financial burden of high investment costs. Table 5 summarizes these challenges and the proposed solutions to support effective blockchain implementation across various sectors. These strategies are designed to ensure the smooth adoption of blockchain technology and maximize its benefits for organizations.

Table 5. Challenges and Solutions in Implementing Blockchain

Challenge	Solution
Technical Complexity	Training programs and process simplification
High Investment Costs	ROI evaluation and strategic partnerships
Organizational Resistance	Education and outreach on blockchain benefits
Lack of Skilled Personnel	Training and certification programs
Integration with Legacy Systems	Development of APIs and integration modules

V. DISCUSSION

This study demonstrates that the implementation of blockchain in SRM significantly enhances supply chain resilience by improving transparency, efficiency, and trust among stakeholders. These findings align with previous research by (L. Guo et al., 2022), which highlights how blockchain accelerates information flow and ensures uniform data access across all parties in the supply chain. Through an integrated approach, blockchain strengthens supply chain resilience across three key dimensions: response, recovery, and adaptation, as outlined by (Sudan et al., 2023). For instance, this study found that real-time visibility enabled by blockchain facilitates rapid responses to disruptions, consistent with the findings of (Manupati et al., 2022). Additionally, blockchain not only enhances efficiency through the automation of smart contracts but also improves data security via encryption, as discussed by (H. Guo & Yu, 2022). These findings underscore the importance of this technology in fostering more strategic SRM.

However, challenges such as high initial costs and resistance to change remain significant barriers, as identified by (Biswas et al., 2023). The technical complexity of integrating blockchain, particularly in organizations with established infrastructures, necessitates a gradual approach and intensive workforce training. Organizational resistance to change also requires educational efforts to highlight the long-term benefits of this technology. The implications of these findings extend the theoretical discourse within the SRM framework, demonstrating that blockchain adoption is not merely a technical tool but also a strategy for organizational transformation. Accordingly, this study offers practical insights for companies in designing blockchain-based solutions to enhance supply chain resilience while contributing to the broader literature on the role of digital technologies in supporting operational sustainability.

VI. CONCLUSION AND RECOMMENDATION

This study highlights the significant role of blockchain in enhancing transparency, trust, and efficiency in SRM. The technology enables all parties within the supply chain to access distributed, transparent, and immutable data, thereby improving accountability and process reliability. Moreover, blockchain offers innovative solutions to address information asymmetry between suppliers and buyers, a common source of conflict in business relationships. By leveraging immutable data recording capabilities, blockchain strengthens relationships among supply chain stakeholders, fostering a more harmonious collaborative ecosystem. Additional benefits include reducing operational cycle times, enhancing data security, and optimizing supplier management processes for greater efficiency. Thus, blockchain can be regarded as a strategic solution to address the complex challenges of modern supply chain management and provide a robust foundation for building supply chain resilience in the future.

While this study offers significant insights, several areas require further exploration to fully realize the potential of blockchain technology. First, companies are encouraged to initiate blockchain pilot projects in SRM to assess implementation feasibility and identify specific challenges within different industry contexts. Such initiatives also allow organizations to better understand how to tailor the technology to their operational structures. Second, the development of policies by governments and industry stakeholders is crucial to fostering an ecosystem that supports blockchain adoption, particularly through clear regulations and adequate incentives. Third, further research is needed to evaluate the long-term impact of blockchain implementation on various dimensions of supply chain resilience, including environmental, social, and economic sustainability. These studies can provide more targeted guidance for companies in designing blockchain-based strategies. Additionally, future research could explore how integrating blockchain with other technologies, such as the IoT and Artificial Intelligence (AI), might expand SRM functionality and improve overall operational efficiency. Such exploration would pave the way for new innovations that support more resilient and adaptive supply chain management in the digital era.

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