

(REVIEW ARTICLE)



Enhancing supply chain security and transparency with ai and blockchain integration for future-proof solutions

Adeoluwa Omoyemi Yekeen ^{1,*}, Chikezie Paul-Mikki Ewim ² and Ngodoo Joy Sam-Bulya ³

¹ *Independent Researcher, Clarksville, Tennessee, USA.*

² *Independent Researcher, Lagos, Nigeria.*

³ *Independent Researcher, Abuja, Nigeria.*

International Journal of Frontline Research in Science and Technology, 2024, 04(01), 043–062

Publication history: Received on 01 September 2024; revised on 11 October 2024; accepted on 14 October 2024

Article DOI: <https://doi.org/10.56355/ijfrst.2024.4.1.0052>

Abstract

The objective of this review paper is to examine the integration of Artificial Intelligence (AI) and blockchain technology to enhance supply chain security and transparency, providing future-proof solutions for global industries. As the digital landscape evolves, traditional supply chain management methods face increasing vulnerabilities and inefficiencies. This paper reviews existing literature to assess the current challenges and potential benefits of integrating AI and blockchain in supply chains.

The review highlights how AI enhances predictive analytics, demand forecasting, and operational efficiency, while blockchain ensures immutable, decentralized ledgers for real-time tracking and verification of goods. The synergy between these technologies offers unprecedented levels of transparency, enabling stakeholders to detect and respond to anomalies swiftly. Case studies across various industries demonstrate significant improvements in reducing fraud, counterfeiting, and human errors, alongside enhanced compliance with regulatory standards.

Conclusions drawn from this review underscore the transformative potential of AI and blockchain in creating resilient, transparent, and secure supply chains. The integration of these technologies not only addresses current vulnerabilities but also lays the foundation for adaptive, intelligent supply chain networks capable of withstanding future disruptions. This paper provides actionable insights and practical frameworks for businesses and policymakers aiming to implement AI and blockchain solutions, emphasizing the importance of strategic planning, cross-industry collaboration, and continuous innovation in achieving long-term supply chain sustainability and security.

Keywords: Artificial Intelligence (AI); Blockchain Technology; Supply Chain Management; Security; Transparency; Internet of Things (IoT); Smart Contracts; Predictive Analytics; Data Integrity; Scalability; Regulatory Compliance; Quantum Computing; Federated Learning; 5G Technology; Emerging Technologies; Decentralized AI Models; Real-time Tracking; Supply Chain Optimization; Supply Chain Sustainability; Corporate Social Responsibility (CSR)

1 Introduction

1.1 Importance of Supply Chain Security and Transparency

Supply chain security and transparency are critical components in the contemporary global economy. These aspects ensure the integrity and efficiency of supply chains, which are essential for the seamless movement of goods and services across borders. In an increasingly interconnected world, supply chains are susceptible to a multitude of risks, including fraud, counterfeiting, and disruptions from geopolitical tensions or natural disasters. These vulnerabilities

* Corresponding author: Adeoluwa Omoyemi Yekeen

necessitate robust mechanisms to safeguard supply chain operations and enhance their transparency, thereby maintaining trust among stakeholders and ensuring compliance with regulatory requirements.

The significance of supply chain security cannot be overstated. Supply chains are the backbone of global trade, encompassing the processes involved in the production, transportation, and distribution of goods. Any disruption within this intricate network can have far-reaching consequences, not only for businesses but also for economies at large. For instance, the COVID-19 pandemic exposed the fragility of global supply chains, causing widespread shortages and delays (Ivanov and Dolgui, 2020). Such disruptions underscore the need for resilient supply chain systems that can withstand unforeseen challenges.

Transparency in supply chains is equally crucial. It refers to the visibility and traceability of products and processes throughout the supply chain. Transparency ensures that all stakeholders, from manufacturers to consumers, have access to accurate and timely information about the origin, movement, and handling of products. This level of visibility is vital for building trust, especially in an era where consumers and regulators are increasingly concerned about ethical sourcing, environmental sustainability, and product safety (Kouhizadeh et al., 2021). For example, consumers demand transparency regarding the origins of their products to ensure they are not linked to unethical practices such as forced labor or environmental degradation (Grimm et al., 2014).

Integrating advanced technologies like Artificial Intelligence (AI) and blockchain into supply chain management offers promising solutions to enhance security and transparency. AI can optimize various supply chain processes, from demand forecasting and inventory management to predictive maintenance and risk assessment. Its ability to analyze vast amounts of data and generate actionable insights can significantly improve decision-making and operational efficiency (Min, 2010). For instance, AI-driven predictive analytics can identify potential disruptions and suggest proactive measures, thereby minimizing risks and enhancing supply chain resilience.

Blockchain technology, on the other hand, provides a decentralized and immutable ledger for recording transactions. Its inherent features of transparency, traceability, and security make it an ideal tool for supply chain management. By recording every transaction on a blockchain, stakeholders can have a verifiable and tamper-proof record of the product's journey from origin to destination (Casino et al., 2019). This level of transparency can help detect and prevent fraud, reduce counterfeiting, and ensure compliance with regulatory standards. For example, the pharmaceutical industry has leveraged blockchain to track the authenticity of drugs, thereby combating the issue of counterfeit medicines (Mackey et al., 2019).

The integration of AI and blockchain technologies can create a synergistic effect, further enhancing supply chain security and transparency. AI can process and analyze the vast amounts of data generated by blockchain, providing insights that can optimize supply chain operations. Meanwhile, blockchain can provide a secure and transparent platform for sharing these insights among stakeholders. This combination can lead to more informed decision-making, reduced risks, and improved efficiency across the supply chain (Kshetri, 2018).

Moreover, the application of these technologies can address some of the most pressing challenges in supply chain management. For instance, counterfeit products pose a significant threat to various industries, including pharmaceuticals, electronics, and luxury goods. Blockchain's ability to provide an immutable record of transactions can help verify the authenticity of products and prevent counterfeiting. Similarly, AI's predictive capabilities can identify suspicious patterns and anomalies, enabling proactive measures to prevent fraud (Montecchi et al., 2019).

In addition to enhancing security and transparency, the integration of AI and blockchain can also promote sustainability in supply chains. Transparency regarding the environmental impact of products and processes can drive more sustainable practices. Consumers and regulators are increasingly demanding information about the carbon footprint, waste management, and resource usage associated with products. Blockchain can provide this information in a transparent and verifiable manner, while AI can optimize processes to reduce environmental impact (Saber et al., 2019).

The importance of supply chain security and transparency cannot be understated in the modern global economy. The integration of AI and blockchain technologies offers powerful tools to address the inherent vulnerabilities and inefficiencies in traditional supply chain management. By enhancing visibility, traceability, and operational efficiency, these technologies can create more resilient, ethical, and sustainable supply chains. As industries continue to evolve in response to global challenges, the adoption of AI and blockchain will be crucial for ensuring the security and transparency of supply chains, ultimately benefiting businesses, consumers, and the broader economy.

1.2 Introduction to the significance of security and transparency in supply chain management, highlighting the need for robust solutions to address current challenges

In the contemporary global economy, the significance of security and transparency in supply chain management cannot be overstated. Supply chains are intricate networks that span across multiple geographies and industries, involving numerous stakeholders from suppliers and manufacturers to logistics providers and retailers. The seamless functioning of these networks is vital for the timely delivery of goods and services, making supply chain management a cornerstone of modern commerce. However, the increasing complexity and globalization of supply chains have exposed them to various risks and challenges that necessitate robust solutions for enhanced security and transparency.

Supply chain security is paramount as it ensures the integrity, authenticity, and safety of products as they move from origin to final destination. The globalization of trade has led to longer and more complex supply chains, which are more susceptible to disruptions, fraud, and cyber-attacks. These risks can lead to significant financial losses, damage to brand reputation, and potential harm to consumers. For example, the prevalence of counterfeit products in industries such as pharmaceuticals and electronics poses a serious threat to consumer safety and company credibility. Therefore, securing the supply chain against such threats is critical for maintaining trust and ensuring the smooth operation of global trade.

Transparency, on the other hand, refers to the visibility and traceability of products and processes throughout the supply chain. It involves providing stakeholders with accurate and real-time information about the origins, movements, and handling of products. Transparency is essential for building trust among stakeholders, ensuring compliance with regulatory requirements, and fostering sustainable practices. Consumers, regulators, and businesses are increasingly demanding greater transparency to verify the authenticity of products and ensure ethical sourcing and environmental sustainability. For instance, consumers are more likely to support brands that provide clear information about the ethical and sustainable practices involved in their supply chain operations.

The integration of advanced technologies such as Artificial Intelligence (AI) and blockchain presents promising solutions to enhance supply chain security and transparency. AI has the potential to revolutionize supply chain management by optimizing various processes, including demand forecasting, inventory management, and risk assessment. AI's ability to analyze vast amounts of data and generate actionable insights can significantly improve decision-making and operational efficiency. For instance, AI-driven predictive analytics can identify potential disruptions and suggest proactive measures, thereby enhancing the resilience of supply chains.

Blockchain technology, with its decentralized and immutable ledger system, offers unparalleled transparency and security for supply chain transactions. Blockchain can provide a tamper-proof record of each transaction, ensuring that all stakeholders have access to a single, verifiable source of truth. This level of transparency can help detect and prevent fraud, reduce counterfeiting, and ensure compliance with regulatory standards. For example, the pharmaceutical industry has adopted blockchain to track the authenticity of drugs, thereby addressing the issue of counterfeit medicines.

The combination of AI and blockchain can create a synergistic effect, further enhancing supply chain security and transparency. AI can process and analyze the vast amounts of data generated by blockchain, providing insights that can optimize supply chain operations. Meanwhile, blockchain can provide a secure and transparent platform for sharing these insights among stakeholders. This integration can lead to more informed decision-making, reduced risks, and improved efficiency across the supply chain.

Moreover, the adoption of these technologies can address some of the most pressing challenges in supply chain management. For instance, counterfeit products pose a significant threat to various industries, including pharmaceuticals, electronics, and luxury goods. Blockchain's ability to provide an immutable record of transactions can help verify the authenticity of products and prevent counterfeiting. Similarly, AI's predictive capabilities can identify suspicious patterns and anomalies, enabling proactive measures to prevent fraud.

In addition to enhancing security and transparency, the integration of AI and blockchain can also promote sustainability in supply chains. Transparency regarding the environmental impact of products and processes can drive more sustainable practices. Consumers and regulators are increasingly demanding information about the carbon footprint, waste management, and resource usage associated with products. Blockchain can provide this information in a transparent and verifiable manner, while AI can optimize processes to reduce environmental impact.

The importance of security and transparency in supply chain management is paramount in the modern global economy. The integration of AI and blockchain technologies offers powerful tools to address the inherent vulnerabilities and

inefficiencies in traditional supply chain management. By enhancing visibility, traceability, and operational efficiency, these technologies can create more resilient, ethical, and sustainable supply chains. As industries continue to evolve in response to global challenges, the adoption of AI and blockchain will be crucial for ensuring the security and transparency of supply chains, ultimately benefiting businesses, consumers, and the broader economy.

1.3 Objectives of the Review

The primary objective of this review is to critically examine the integration of Artificial Intelligence (AI) and blockchain technology in enhancing supply chain security and transparency. In an era characterized by globalization and digital transformation, supply chains have become increasingly complex and vulnerable to various risks, including fraud, counterfeiting, and cyber-attacks. This review aims to provide a comprehensive analysis of how AI and blockchain can address these challenges, offering robust solutions that ensure the integrity, efficiency, and sustainability of supply chain operations.

The first objective is to explore the current landscape of supply chain management, identifying the key vulnerabilities and inefficiencies that compromise security and transparency. Supply chains today are intricate networks that span multiple geographies and involve numerous stakeholders, making them susceptible to disruptions. The increasing complexity of supply chains has led to higher risks of disruptions, which can have significant financial and operational impacts. By understanding these vulnerabilities, this review sets the stage for analyzing how advanced technologies can mitigate these risks.

The second objective is to investigate the potential of AI in optimizing supply chain processes. AI technologies, such as machine learning and predictive analytics, have the capability to analyze vast amounts of data and generate actionable insights. AI can significantly enhance decision-making in supply chain management by providing accurate demand forecasts, optimizing inventory levels, and identifying potential disruptions before they occur. This review will assess various applications of AI in supply chain management, demonstrating its potential to improve operational efficiency and resilience.

The third objective is to examine the role of blockchain technology in ensuring supply chain transparency and security. Blockchain, with its decentralized and immutable ledger system, offers a secure platform for recording and verifying transactions. Blockchain can provide unparalleled transparency and traceability in supply chains, helping to detect and prevent fraud, reduce counterfeiting, and ensure compliance with regulatory standards. This review will explore how blockchain can be integrated into supply chain management to create a verifiable and tamper-proof record of product movements and transactions.

The fourth objective is to analyze the synergistic effects of integrating AI and blockchain technologies in supply chain management. While AI can optimize supply chain processes through data analysis and predictive insights, blockchain can provide a secure and transparent platform for sharing these insights among stakeholders. The combination of AI and blockchain can lead to more informed decision-making, reduced risks, and improved efficiency across the supply chain. This review will evaluate case studies and empirical evidence to illustrate the benefits of this integration.

The fifth objective is to address the challenges and barriers to the adoption of AI and blockchain in supply chain management. Despite their potential, these technologies face several implementation challenges, including high costs, technological complexity, and resistance to change. The integration of AI requires significant investments in infrastructure and expertise. This review will discuss these challenges and propose strategies for overcoming them to facilitate the widespread adoption of AI and blockchain in supply chains.

Finally, the review aims to provide actionable insights and recommendations for businesses and policymakers. By synthesizing the findings from the literature, this review will offer practical frameworks for implementing AI and blockchain solutions in supply chain management. The goal is to highlight best practices and success stories that can guide organizations in leveraging these technologies to enhance their supply chain operations. Moreover, this review will emphasize the importance of strategic planning, continuous innovation, and cross-industry collaboration in achieving long-term supply chain security and transparency.

This review seeks to provide a comprehensive analysis of the integration of AI and blockchain in supply chain management. By addressing the objectives outlined above, this review aims to contribute to the growing body of knowledge on supply chain innovation and provide valuable insights for practitioners and researchers. The integration of AI and blockchain holds great promise for creating resilient, transparent, and secure supply chains that can withstand the challenges of the modern global economy.

1.4 Clarification of the review's aims and scope, specifically examining how the integration of AI and blockchain can enhance supply chain security and transparency

The purpose of this review is to explore the integration of Artificial Intelligence (AI) and blockchain technologies in enhancing supply chain security and transparency. In an era marked by rapid digital transformation and globalization, supply chains have become increasingly complex and susceptible to various risks, including fraud, counterfeiting, and cyber-attacks. The convergence of AI and blockchain technologies offers promising solutions to these challenges, ensuring that supply chains remain resilient, secure, and transparent. This review aims to provide a thorough analysis of how these advanced technologies can be leveraged to address current vulnerabilities in supply chain management.

The scope of this review encompasses a detailed examination of the existing literature on supply chain security and transparency, focusing on the potential applications of AI and blockchain. The integration of these technologies is anticipated to revolutionize supply chain operations by providing robust mechanisms for data analysis, real-time tracking, and verification of goods and transactions. The review will critically assess the effectiveness of AI and blockchain in mitigating risks and enhancing operational efficiency within supply chains.

One of the primary aims of this review is to elucidate the current challenges faced by supply chains in terms of security and transparency. As supply chains extend across multiple geographies and involve numerous stakeholders, they are prone to disruptions and fraudulent activities. The increasing complexity of modern supply chains increases their vulnerability to disruptions, which can have significant financial and operational repercussions. By identifying these challenges, this review sets the stage for evaluating how AI and blockchain can provide effective solutions.

Another key objective of this review is to investigate the potential of AI in optimizing supply chain processes. AI technologies, including machine learning and predictive analytics, have the capability to analyze large datasets and generate actionable insights. AI can greatly enhance decision-making in supply chain management by providing accurate demand forecasts, optimizing inventory levels, and identifying potential disruptions. This review will explore various AI applications in supply chain management, demonstrating their potential to improve operational efficiency and resilience.

The role of blockchain technology in ensuring supply chain transparency and security is also a focal point of this review. Blockchain's decentralized and immutable ledger system offers a secure platform for recording and verifying transactions. Blockchain can provide unparalleled transparency and traceability in supply chains, helping to detect and prevent fraud, reduce counterfeiting, and ensure compliance with regulatory standards. This review will examine how blockchain can be integrated into supply chain management to create a verifiable and tamper-proof record of product movements and transactions.

Furthermore, this review aims to analyze the synergistic effects of integrating AI and blockchain technologies in supply chain management. The combination of AI's data processing capabilities and blockchain's secure transaction records can lead to more informed decision-making, reduced risks, and enhanced efficiency. The integration of AI and blockchain can result in significant improvements in supply chain operations by providing stakeholders with reliable and transparent data. This review will evaluate case studies and empirical evidence to illustrate the benefits of this integration.

Additionally, this review seeks to address the challenges and barriers to the adoption of AI and blockchain in supply chain management. Despite their potential, these technologies face several implementation hurdles, including high costs, technological complexity, and resistance to change. The integration of AI requires substantial investments in infrastructure and expertise. This review will discuss these challenges and propose strategies for overcoming them to facilitate the widespread adoption of AI and blockchain in supply chains.

Finally, the review aims to provide actionable insights and recommendations for businesses and policymakers. By synthesizing the findings from the literature, this review will offer practical frameworks for implementing AI and blockchain solutions in supply chain management. The goal is to highlight best practices and success stories that can guide organizations in leveraging these technologies to enhance their supply chain operations. Moreover, this review will emphasize the importance of strategic planning, continuous innovation, and cross-industry collaboration in achieving long-term supply chain security and transparency.

This review seeks to provide a comprehensive analysis of the integration of AI and blockchain in supply chain management. By addressing the objectives outlined above, this review aims to contribute to the growing body of knowledge on supply chain innovation and provide valuable insights for practitioners and researchers. The integration

of AI and blockchain holds great promise for creating resilient, transparent, and secure supply chains capable of withstanding the challenges of the modern global economy.

1.5 Current Challenges in Supply Chain Management

Supply chain management (SCM) has become an increasingly complex and vital aspect of modern business operations, driven by globalization and technological advancements. Despite these advancements, SCM faces numerous challenges that threaten its efficiency and reliability. These challenges include disruptions, fraud, counterfeiting, and a lack of transparency, each of which can have significant financial and operational repercussions. Addressing these issues requires innovative solutions, such as the integration of Artificial Intelligence (AI) and blockchain technologies, which offer the potential to revolutionize SCM by enhancing security and transparency.

One of the most pressing challenges in SCM is the vulnerability to disruptions. Global supply chains are intricate networks that span multiple geographies and involve numerous stakeholders, making them susceptible to various types of disruptions. Supply chain disruptions can result from natural disasters, geopolitical tensions, and global health crises, such as the COVID-19 pandemic. These disruptions can cause significant delays, increased costs, and loss of revenue, underscoring the need for resilient supply chain systems that can withstand and quickly recover from such events.

Another significant challenge is the prevalence of fraud and counterfeiting within supply chains. The global nature of modern supply chains provides opportunities for malicious actors to introduce counterfeit products and engage in fraudulent activities. Counterfeit goods pose a substantial threat to industries such as pharmaceuticals, electronics, and luxury goods, compromising product integrity and consumer safety. The financial losses associated with counterfeit products are considerable, and the damage to brand reputation can be long-lasting.

The lack of transparency in supply chains further exacerbates these challenges. Transparency refers to the visibility and traceability of products and processes throughout the supply chain, ensuring that stakeholders have access to accurate and real-time information. Transparency is critical for building trust among stakeholders, ensuring regulatory compliance, and promoting sustainable practices. However, traditional supply chains often lack the necessary infrastructure to provide this level of visibility, making it difficult to track product origins, movements, and handling.

In addition to these issues, SCM must contend with the complexity of managing vast amounts of data generated by modern supply chain operations. The sheer volume of data can overwhelm traditional data management systems, leading to inefficiencies and errors. Efficient data management is crucial for optimizing supply chain processes, from demand forecasting and inventory management to logistics and distribution. However, many organizations struggle to effectively harness and analyze this data, resulting in suboptimal decision-making and operational inefficiencies.

The integration of AI and blockchain technologies offers promising solutions to these challenges by enhancing supply chain security and transparency. AI technologies, such as machine learning and predictive analytics, can analyze large datasets to generate actionable insights, improve decision-making, and optimize various supply chain processes. For example, AI-driven predictive analytics can identify potential disruptions before they occur, allowing organizations to take proactive measures to mitigate risks.

Blockchain technology, with its decentralized and immutable ledger system, provides a secure platform for recording and verifying transactions. Blockchain can provide unparalleled transparency and traceability in supply chains, helping to detect and prevent fraud, reduce counterfeiting, and ensure compliance with regulatory standards. By creating a verifiable and tamper-proof record of product movements and transactions, blockchain can enhance trust among stakeholders and improve the overall integrity of supply chains.

The combination of AI and blockchain technologies can create a synergistic effect, further enhancing supply chain security and transparency. The integration of AI and blockchain can lead to more informed decision-making, reduced risks, and improved efficiency across the supply chain. AI can process and analyze the vast amounts of data generated by blockchain, providing insights that can optimize supply chain operations. Meanwhile, blockchain can provide a secure and transparent platform for sharing these insights among stakeholders.

Despite their potential, the adoption of AI and blockchain in SCM faces several implementation challenges, including high costs, technological complexity, and resistance to change. Key barriers to blockchain adoption include scalability issues and the need for cross-industry collaboration. Similarly, the integration of AI requires substantial investments in infrastructure and expertise. Addressing these challenges will be crucial for the widespread adoption of these technologies in supply chains.

SCM faces numerous challenges that threaten its efficiency and reliability, including disruptions, fraud, counterfeiting, and a lack of transparency. The integration of AI and blockchain technologies offers promising solutions to these challenges by enhancing supply chain security and transparency. By addressing the current vulnerabilities and inefficiencies in traditional SCM, these technologies can create more resilient, ethical, and sustainable supply chains. As industries continue to evolve in response to global challenges, the adoption of AI and blockchain will be crucial for ensuring the security and transparency of supply chains, ultimately benefiting businesses, consumers, and the broader economy.

1.6 Discussion on the current challenges faced by supply chains in terms of security breaches, lack of transparency, and data integrity

In the contemporary global economy, supply chains are the lifelines of commerce, ensuring the seamless movement of goods and services across borders. However, the increasing complexity and globalization of supply chains have introduced a plethora of challenges that threaten their efficiency, reliability, and security. Among the most pressing issues are security breaches, lack of transparency, and data integrity concerns. Addressing these challenges is crucial for maintaining the robustness of supply chains and safeguarding against potential disruptions.

Security breaches in supply chains have become increasingly common, posing significant risks to businesses and economies. The interconnected nature of modern supply chains means that a security breach at any point can have cascading effects throughout the network. These breaches can result from various factors, including cyber-attacks, physical theft, and insider threats. For instance, cyber-attacks targeting supply chain management systems can lead to the loss of sensitive information, financial losses, and disruption of operations. The growing reliance on digital technologies in supply chain management has made these systems attractive targets for cybercriminals, highlighting the need for robust security measures.

Lack of transparency is another critical challenge that undermines the efficiency and trustworthiness of supply chains. Transparency in supply chains refers to the visibility and traceability of products and processes from the point of origin to the final destination. Without adequate transparency, it becomes difficult for stakeholders to verify the authenticity of products, monitor compliance with regulatory standards, and ensure ethical sourcing practices. The absence of transparency can lead to issues such as counterfeit products, fraud, and unethical practices, which can have severe reputational and financial implications for businesses.

Data integrity is equally vital in the context of supply chains, as accurate and reliable data are essential for effective decision-making and operations. Supply chains generate vast amounts of data at every stage, from procurement and manufacturing to logistics and distribution. However, ensuring the accuracy, completeness, and consistency of this data is a significant challenge. Data integrity issues can arise from manual data entry errors, system malfunctions, and intentional manipulation of data. These issues can lead to inaccurate demand forecasts, inventory mismanagement, and suboptimal logistics planning, ultimately affecting the overall efficiency of the supply chain.

The integration of advanced technologies such as Artificial Intelligence (AI) and blockchain offers promising solutions to these challenges. AI can enhance supply chain security by providing advanced analytics and predictive capabilities that help identify potential security threats before they materialize. AI-driven systems can analyze patterns and anomalies in real-time data, enabling proactive measures to mitigate security risks. Additionally, AI can improve transparency by automating the tracking and monitoring of products throughout the supply chain, ensuring that stakeholders have access to accurate and up-to-date information.

Blockchain technology, with its decentralized and immutable ledger system, addresses the challenges of transparency and data integrity. Blockchain provides a secure platform for recording and verifying transactions, ensuring that all stakeholders have a single source of truth. By creating an unalterable record of every transaction, blockchain enhances transparency, traceability, and accountability in supply chains. Moreover, blockchain's inherent security features protect against data tampering and unauthorized access, thereby safeguarding data integrity.

The combination of AI and blockchain technologies can create a synergistic effect, further enhancing supply chain security, transparency, and data integrity. Integrating AI with blockchain can provide a comprehensive solution that leverages the strengths of both technologies. AI can process and analyze the vast amounts of data generated by blockchain, offering insights that optimize supply chain operations. Meanwhile, blockchain can ensure the security and integrity of the data, providing a robust foundation for AI-driven analytics.

Despite their potential, the adoption of AI and blockchain in supply chains faces several implementation challenges. Key barriers to blockchain adoption include scalability issues and the need for cross-industry collaboration. Similarly, the integration of AI requires significant investments in infrastructure and expertise. Addressing these challenges will be crucial for the widespread adoption of these technologies in supply chains.

Supply chains face significant challenges related to security breaches, lack of transparency, and data integrity. The integration of AI and blockchain technologies offers promising solutions to these challenges by enhancing security, transparency, and data integrity. By addressing the current vulnerabilities and inefficiencies in traditional supply chain management, these technologies can create more resilient, ethical, and sustainable supply chains. As industries continue to evolve in response to global challenges, the adoption of AI and blockchain will be crucial for ensuring the security and transparency of supply chains, ultimately benefiting businesses, consumers, and the broader economy.

1.7 Overview of Methodological Approach: A brief overview of the methodological approach adopted for the systematic review, including data sourcing, search strategies, and criteria for study selection

This systematic review adopts a rigorous and structured methodological approach to investigate the integration of Artificial Intelligence (AI) and blockchain technologies in enhancing supply chain security and transparency. The approach encompasses comprehensive data sourcing, meticulous search strategies, and stringent criteria for study selection, ensuring that the review is thorough, credible, and relevant.

The data sourcing process involved identifying relevant literature from a variety of academic databases and sources. Key databases included Google Scholar, PubMed, Scopus, IEEE Xplore, and Web of Science. These databases were selected due to their extensive collections of peer-reviewed articles, conference papers, and industry reports. The search was not limited to any specific timeframe to capture a wide range of studies, from foundational research to the latest advancements in AI and blockchain applications in supply chains.

The search strategies were meticulously crafted to ensure comprehensive coverage of the topic. Boolean operators were employed to refine search queries, combining keywords such as "Artificial Intelligence," "AI," "blockchain," "supply chain security," "supply chain transparency," and "data integrity." For example, a typical search string might be "AI AND blockchain AND supply chain AND security OR transparency." This approach helped in retrieving a diverse set of articles that address various aspects of the topic.

In addition to database searches, reference lists of selected articles were reviewed to identify additional relevant studies. This snowballing technique ensured that significant works cited in key papers were not overlooked. The search strategies were periodically revised based on initial findings to refine the focus and improve the relevance of retrieved articles.

The criteria for study selection were established to ensure the inclusion of high-quality and pertinent research. The primary inclusion criteria were: (1) studies that focus on the application of AI and blockchain technologies in supply chains, (2) studies that discuss the impact of these technologies on supply chain security and transparency, (3) peer-reviewed journal articles, conference papers, and reputable industry reports, and (4) studies published in English. Exclusion criteria included: (1) studies that do not specifically address AI or blockchain in the context of supply chains, (2) articles that are opinion-based or lack empirical evidence, and (3) publications in languages other than English.

The selection process involved several stages to ensure rigor and consistency. Initially, titles and abstracts of retrieved articles were screened to determine their relevance based on the inclusion and exclusion criteria. Articles that met the criteria proceeded to the next stage, where full texts were reviewed. This stage involved a more detailed assessment to verify that the studies indeed focused on the integration of AI and blockchain technologies in supply chains and provided empirical or substantial theoretical insights.

To minimize bias and enhance the reliability of the review, a second reviewer independently assessed a random sample of the articles. Discrepancies between reviewers were resolved through discussion and consensus, ensuring that only studies meeting the stringent criteria were included in the final analysis.

Data extraction from the selected studies was carried out using a standardized form to capture key information systematically. This included details such as study objectives, methodologies, sample sizes, main findings, and conclusions. The extracted data were then synthesized to identify common themes, trends, and gaps in the literature.

The methodological approach also involved assessing the quality of the included studies. Criteria for quality assessment included the clarity of objectives, robustness of the methodology, appropriateness of the data analysis techniques, and the validity of the conclusions. High-quality studies were given more weight in the synthesis process, while studies with significant limitations were considered with caution.

This systematic review employs a comprehensive and rigorous methodological approach to examine the integration of AI and blockchain technologies in enhancing supply chain security and transparency. The meticulous data sourcing, well-defined search strategies, and stringent criteria for study selection ensure the inclusion of high-quality and relevant research. This methodological rigor provides a robust foundation for drawing credible and insightful conclusions about the potential and challenges of applying AI and blockchain in supply chains.

2 Literature Review

2.1 Overview of AI in Supply Chain Security: Exploration of the fundamental principles and features of AI technologies used in supply chain security, including machine learning, anomaly detection, and predictive analytics

Artificial Intelligence (AI) technologies have revolutionized various domains of business operations, including supply chain security, by enhancing efficiency and mitigating risks through advanced data processing and analysis. This literature review explores the fundamental principles and features of AI technologies utilized in supply chain security, focusing on machine learning, anomaly detection, and predictive analytics.

AI-driven machine learning algorithms play a pivotal role in supply chain security by enabling systems to learn from data patterns and make decisions autonomously. According to Liu and Zhang (2020), machine learning models such as neural networks and decision trees are extensively employed to analyze historical data and predict potential security breaches in supply chains. These models process vast amounts of data from diverse sources, including logistics, inventory management, and transaction records, to detect anomalies and identify suspicious activities.

Anomaly detection is another critical AI application in supply chain security, aimed at identifying deviations from expected patterns that may indicate security threats or operational inefficiencies. Research by Ma, W., 2020 emphasizes the use of anomaly detection techniques, such as clustering algorithms and statistical analysis, to detect unusual behaviors in supply chain operations. By continuously monitoring data streams, AI-powered anomaly detection systems can promptly flag anomalies and trigger alerts for immediate investigation and response.

Moreover, predictive analytics powered by AI enables proactive risk management in supply chain security. According to Oyewole, A.T, et al (2024), predictive analytics models leverage historical data and real-time information to forecast potential disruptions or vulnerabilities in supply chains. These models apply advanced statistical methods and machine learning algorithms to analyze complex relationships within supply chain networks and anticipate future security challenges. (Tirkolae, E.B, et al, 2021).

The integration of AI technologies in supply chain security not only enhances operational efficiency but also strengthens resilience against various threats, including cyber-attacks, theft, and natural disasters. This study underscores the importance of AI-driven predictive maintenance in preventing equipment failures and ensuring continuous supply chain operations. By predicting maintenance needs based on sensor data and operational parameters, AI systems help minimize downtime and optimize resource utilization (Queiroz, M.M. and Telles, R., 2018).

Furthermore, AI's ability to process and analyze unstructured data, such as social media feeds and sensor data, provides valuable insights into emerging security risks and consumer sentiments. This capability enables supply chain managers to make informed decisions and adapt quickly to dynamic market conditions

AI technologies, including machine learning, anomaly detection, and predictive analytics, are instrumental in enhancing supply chain security by improving detection capabilities, predicting risks, and optimizing operational resilience. Future research should focus on refining AI algorithms, integrating multi-source data, and addressing ethical considerations to further advance the effectiveness and reliability of AI-driven solutions in supply chain security.

2.2 Overview of Blockchain in Supply Chain Transparency: Analysis of the key features of blockchain technology that enhance supply chain transparency, such as decentralized ledgers, immutability, and smart contracts

Blockchain technology has emerged as a transformative tool in enhancing supply chain transparency, characterized by its key features such as decentralized ledgers, immutability, and smart contracts. These attributes collectively contribute to more transparent, efficient, and secure supply chain operations, addressing long-standing challenges in the industry.

A decentralized ledger is a core component of blockchain technology, providing a distributed and immutable record of transactions. This decentralized nature eliminates the need for a central authority, thereby reducing the risk of data tampering and enhancing trust among supply chain participants (Kshetri, 2018). Each participant in the supply chain network has access to the same data, ensuring that information is consistent and transparent across all nodes (Sabeti et al., 2019). The decentralized ledger also facilitates real-time tracking of goods and materials, allowing stakeholders to monitor the movement and status of products at every stage of the supply chain. This transparency is crucial for identifying inefficiencies, preventing fraud, and ensuring compliance with regulatory requirements (Carson et al., 2018).

Immutability is another significant feature of blockchain technology that bolsters supply chain transparency. Once a transaction is recorded on the blockchain, it cannot be altered or deleted, creating a permanent and tamper-proof record (Wang et al., 2019). This immutability ensures the integrity of data, as any attempt to alter the information would be evident to all participants in the network. The secure and unchangeable nature of blockchain records builds trust among stakeholders, as they can be confident that the data is accurate and has not been manipulated (Tian, 2016). This level of trust is particularly important in industries where product authenticity and traceability are critical, such as pharmaceuticals, food, and luxury goods (Kamath, 2018).

Smart contracts are self-executing contracts with the terms of the agreement directly written into code. They automatically enforce and execute contractual obligations when predefined conditions are met (Tapscott & Tapscott, 2017). In the context of supply chains, smart contracts can automate processes such as payments, order fulfillment, and quality inspections, reducing the need for manual intervention and minimizing the risk of errors or disputes (Mending et al., 2018). For instance, a smart contract could trigger an automatic payment to a supplier once the delivery of goods is confirmed, ensuring timely and accurate transactions (Kouhizadeh & Sarkis, 2018). The transparency and efficiency provided by smart contracts enhance the overall reliability and responsiveness of supply chain operations (Christidis & Devetsikiotis, 2016).

Blockchain technology also supports greater accountability and traceability within supply chains. By providing a detailed and immutable record of each transaction, blockchain enables stakeholders to trace the origin and journey of products throughout the supply chain (Kumar et al., 2020). This traceability is particularly valuable in addressing issues such as counterfeiting, product recalls, and ethical sourcing. For example, in the food industry, blockchain can track the path of produce from farm to table, ensuring that consumers have access to information about the provenance and safety of their food (Tian, 2017). Similarly, in the pharmaceutical industry, blockchain can help verify the authenticity of drugs and prevent the circulation of counterfeit products (Mettler, 2016).

The adoption of blockchain technology in supply chains also promotes sustainability by providing transparency into the environmental and social impact of production processes (Sabeti et al., 2019). Companies can use blockchain to monitor and report on their sustainability practices, such as carbon emissions, water usage, and labor conditions, thereby enhancing their accountability to consumers and regulators. This transparency can drive more sustainable business practices and support the achievement of corporate social responsibility goals.

The key features of blockchain technology—decentralized ledgers, immutability, and smart contracts—significantly enhance supply chain transparency. By providing a secure, transparent, and efficient way to record and manage transactions, blockchain addresses many of the challenges faced by traditional supply chain systems. Its ability to ensure data integrity, automate processes, and enhance traceability makes it a valuable tool for improving the efficiency, accountability, and sustainability of supply chain operations. The continued adoption and development of blockchain technology are likely to further transform supply chain management, driving greater transparency and trust among stakeholders.

2.3 Integration of AI and Blockchain in Supply Chains: Examination of how AI and blockchain can be integrated to provide comprehensive solutions for supply chain security and transparency

The integration of Artificial Intelligence (AI) and blockchain technology in supply chains presents a comprehensive approach to enhancing security and transparency. This fusion leverages the strengths of both technologies, providing robust solutions to longstanding challenges in supply chain management.

AI is renowned for its ability to analyze vast amounts of data, detect patterns, and make predictive decisions. When integrated with blockchain technology, which offers decentralized, immutable, and transparent ledgers, the synergy between these technologies can significantly enhance supply chain operations (Kouhizadeh et al., 2021). AI can process the data recorded on the blockchain to provide real-time insights and predictive analytics, enabling proactive decision-making and enhancing operational efficiency (Min, 2019). This integration allows for improved demand forecasting, inventory management, and fraud detection, thereby increasing overall supply chain resilience.

One of the primary benefits of integrating AI with blockchain in supply chains is the enhancement of security. Blockchain's immutability ensures that once data is recorded, it cannot be altered or tampered with, providing a secure and reliable record of transactions (Casino et al., 2019). AI can further enhance this security by continuously monitoring the blockchain for any anomalies or suspicious activities. For example, AI algorithms can detect patterns indicative of fraudulent behavior or cyber-attacks, allowing for immediate intervention and mitigation (Gai et al., 2017). This combination of AI and blockchain thus creates a more secure environment for supply chain transactions, reducing the risk of fraud and cyber threats (Zhang et al., 2020).

Transparency is another significant advantage of integrating AI and blockchain in supply chains. Blockchain's decentralized ledger ensures that all participants have access to the same data, promoting transparency and trust among stakeholders (Nawari & Ravindran, 2019). AI can enhance this transparency by providing real-time analytics and reporting, enabling stakeholders to track the movement of goods and materials at every stage of the supply chain (Kamilaris et al., 2019). This real-time visibility is crucial for ensuring compliance with regulatory requirements and for maintaining the integrity of the supply chain (Saber et al., 2019). Additionally, AI can analyze historical data stored on the blockchain to identify trends and insights that can inform strategic decision-making and improve supply chain performance (Lohmer & Lasch, 2020).

The integration of AI and blockchain also facilitates the automation of supply chain processes through smart contracts. Smart contracts are self-executing contracts with the terms of the agreement directly written into code. They automatically enforce and execute contractual obligations when predefined conditions are met. AI can enhance the functionality of smart contracts by adding intelligence and automation capabilities. For instance, AI can be used to monitor and verify the conditions required for the execution of smart contracts, ensuring that transactions are processed accurately and efficiently (Kouhizadeh et al., 2021). This automation reduces the need for manual intervention, minimizes the risk of errors, and increases the speed and reliability of supply chain transactions (Min, 2019).

Another critical application of AI and blockchain integration in supply chains is in the area of traceability and provenance. Blockchain provides a secure and immutable record of the origin and journey of products, which is essential for ensuring product authenticity and safety (Casino et al., 2019). AI can enhance traceability by analyzing the data on the blockchain to track the movement of goods and materials in real-time, providing detailed insights into the supply chain (Kamilaris et al., 2019). This capability is particularly valuable in industries where traceability is critical, such as pharmaceuticals, food, and luxury goods (Nawari & Ravindran, 2019). For example, in the food industry, AI can be used to monitor and analyze data on the blockchain to ensure that products are sourced and processed in accordance with safety standards, reducing the risk of contamination and ensuring consumer safety (Saber et al., 2019).

The integration of AI and blockchain technology offers significant potential for enhancing security and transparency in supply chains. By leveraging the strengths of both technologies, supply chain operations can be made more efficient, secure, and transparent. AI's ability to analyze data and make predictive decisions, combined with blockchain's decentralized and immutable ledger, provides a powerful tool for addressing the challenges of supply chain management. The continued development and adoption of AI and blockchain integration are likely to further transform supply chain practices, driving greater efficiency, security, and transparency.

2.4 Case Studies of AI and Blockchain Implementation in Supply Chains: Examination of specific case studies where AI and blockchain have been successfully implemented to enhance supply chain security and transparency

The integration of Artificial Intelligence (AI) and blockchain technology in supply chains has been demonstrated through several case studies, showcasing their potential to enhance security and transparency. This section examines specific examples where these technologies have been successfully implemented, providing insights into their practical applications and benefits.

One notable case study is IBM's Food Trust blockchain platform, which integrates AI to enhance food supply chain transparency and safety. The platform uses blockchain to create an immutable record of the journey of food products from farm to table. This traceability ensures that all participants in the supply chain can access the same information, enhancing trust and accountability. AI algorithms analyze this data to identify patterns and predict potential issues, such as contamination risks or supply chain disruptions. The integration of AI and blockchain in the IBM Food Trust platform has improved the ability to quickly trace and recall contaminated products, thereby enhancing food safety and reducing the risk of widespread foodborne illnesses.

Another significant example is the implementation of AI and blockchain by Walmart in its supply chain operations. Walmart has partnered with IBM to leverage the Food Trust blockchain platform to track the provenance of food products. This system has significantly reduced the time required to trace the origin of food items from days to mere seconds. AI technologies further enhance this process by automating data analysis and providing real-time insights into supply chain operations. For instance, AI can monitor the conditions under which perishable goods are transported and stored, ensuring compliance with safety standards and reducing spoilage. The combination of AI and blockchain has thus enabled Walmart to improve supply chain transparency, efficiency, and safety, demonstrating the practical benefits of these technologies in a real-world setting.

In the pharmaceutical industry, the integration of AI and blockchain has been pivotal in combating counterfeit drugs. A case study involving the MediLedger project, a blockchain-based network, illustrates this application. MediLedger uses blockchain to create a secure and immutable record of drug transactions, ensuring that only authorized entities can add or modify information. AI technologies are employed to analyze these records and detect anomalies that may indicate counterfeit activities. For example, AI algorithms can identify suspicious patterns in the supply chain, such as unexpected changes in the origin or destination of drug shipments. By combining AI and blockchain, MediLedger enhances the security and transparency of the pharmaceutical supply chain, reducing the prevalence of counterfeit drugs and ensuring the safety of patients.

The fashion industry has also seen successful implementations of AI and blockchain to enhance supply chain transparency. A prominent example is the partnership between LVMH, ConsenSys, and Microsoft to develop the Aura blockchain platform. This platform tracks the provenance and authenticity of luxury goods, providing consumers with verified information about the origin and history of their purchases. AI technologies are integrated into the Aura platform to analyze supply chain data and provide insights into production processes, ensuring compliance with ethical sourcing and sustainability standards. This integration not only enhances transparency but also helps brands protect their reputation and build trust with consumers.

In the automotive industry, the combination of AI and blockchain has been used to improve the transparency and efficiency of supply chain operations. A case study involving the automaker BMW highlights the successful implementation of these technologies. BMW has developed a blockchain platform, PartChain, to track and verify the provenance of automotive parts throughout the supply chain. AI algorithms analyze the data recorded on the blockchain to optimize inventory management, predict maintenance needs, and ensure the authenticity of parts. This integration has enhanced the traceability and reliability of BMW's supply chain, reducing the risk of counterfeit parts and improving overall operational efficiency.

The integration of AI and blockchain technology in supply chains has been demonstrated through various successful case studies across different industries. These examples illustrate how the combination of AI and blockchain can enhance supply chain security and transparency by providing immutable records, real-time insights, and automated processes. The continued adoption and development of these technologies are likely to further transform supply chain management, driving greater efficiency, trust, and accountability in supply chain operations.

3 Benefits and Challenges

3.1 Advantages of AI and Blockchain Integration in Supply Chains: Discussion on the benefits of integrating AI and blockchain in supply chains, including improved security, enhanced transparency, real-time tracking, and data integrity.

The integration of Artificial Intelligence (AI) and blockchain technology in supply chains offers numerous advantages, including improved security, enhanced transparency, real-time tracking, and data integrity. These benefits can significantly transform supply chain management by addressing persistent challenges and fostering more efficient and reliable operations.

One of the primary advantages of integrating AI and blockchain in supply chains is the enhancement of security. Blockchain technology provides a decentralized and immutable ledger, ensuring that once data is recorded, it cannot be altered or tampered with (Casino, Dasaklis & Patsakis, 2019). This immutability is crucial for maintaining the integrity of supply chain data, as it prevents unauthorized modifications and ensures that all participants have access to the same trustworthy information. AI further enhances security by continuously monitoring the blockchain for any anomalies or suspicious activities (Gai et al., 2020). For instance, AI algorithms can detect patterns indicative of fraudulent behavior or cyber-attacks, allowing for immediate intervention and mitigation. This combination of AI and blockchain thus creates a more secure environment for supply chain transactions, reducing the risk of fraud and cyber threats (Zhang et al., 2018).

Enhanced transparency is another significant benefit of integrating AI and blockchain in supply chains. Blockchain's decentralized ledger ensures that all participants have access to the same data, promoting transparency and trust among stakeholders (Nawari & Ravindran, 2019). This transparency is crucial for ensuring compliance with regulatory requirements and for maintaining the integrity of the supply chain. AI can further enhance transparency by providing real-time analytics and reporting, enabling stakeholders to track the movement of goods and materials at every stage of the supply chain (Kamilaris et al., 2019). Real-time visibility into supply chain operations allows for better decision-making and can help identify and address issues promptly, thereby improving overall supply chain efficiency (Saber et al., 2019).

The integration of AI and blockchain also facilitates real-time tracking of goods and materials throughout the supply chain. Blockchain provides a secure and immutable record of each transaction, allowing stakeholders to trace the origin and journey of products (Kshetri, 2021). AI enhances this capability by analyzing the data on the blockchain to provide real-time insights and predictive analytics. For example, AI algorithms can monitor the conditions under which perishable goods are transported and stored, ensuring compliance with safety standards and reducing spoilage (Tian, 2016). Real-time tracking also enables more accurate demand forecasting and inventory management, as AI can predict potential disruptions and adjust supply chain operations accordingly (Min, 2019). This capability is particularly valuable in industries where timely and accurate information is critical, such as food and pharmaceuticals.

Data integrity is another crucial benefit of integrating AI and blockchain in supply chains. The immutable nature of blockchain ensures that all data recorded on the ledger is accurate and cannot be altered (Casino et al., 2019). This feature is essential for maintaining the integrity of supply chain data, as it provides a single source of truth for all participants. AI enhances data integrity by automating data analysis and verification processes. For instance, AI can be used to verify the accuracy of data inputs, identify discrepancies, and ensure that only authorized entities can modify the information (Kouhizadeh, Sarkis & Zhu, 2021). This automation reduces the risk of human error and ensures that supply chain data remains reliable and accurate.

However, despite these significant benefits, the integration of AI and blockchain in supply chains also presents several challenges. One of the main challenges is the complexity of integrating these technologies into existing supply chain systems. Many organizations may lack the technical expertise and resources required to implement and manage AI and blockchain solutions effectively. Additionally, the integration process can be time-consuming and costly, requiring significant investments in technology and infrastructure (Behnke & Janssen, 2020). Organizations must carefully consider these factors and develop comprehensive implementation strategies to ensure successful integration.

Another challenge is the issue of data privacy and security. While blockchain provides a secure and immutable record of transactions, the decentralized nature of the technology can raise concerns about data privacy and access control (Gai et al., 2017). Organizations must implement robust security measures to protect sensitive data and ensure that only authorized entities can access the information. Additionally, AI algorithms must be designed and trained to handle sensitive data responsibly and ethically, minimizing the risk of data breaches and misuse (Zhang et al., 2018).

The integration of AI and blockchain technology in supply chains offers numerous benefits, including improved security, enhanced transparency, real-time tracking, and data integrity. These advantages can significantly transform supply chain management by addressing persistent challenges and fostering more efficient and reliable operations (Udeh, E.O, et al, 2024). However, organizations must also consider the challenges associated with integrating these technologies, including the complexity of implementation and the need for robust data privacy and security measures. By carefully addressing these challenges and leveraging the strengths of AI and blockchain, organizations can unlock the full potential of these technologies and drive greater efficiency, trust, and accountability in supply chain operations.

3.2 Implementation Challenges: Identification of the challenges associated with integrating AI and blockchain in supply chains, such as technical complexities, scalability, and regulatory issues

The integration of Artificial Intelligence (AI) and blockchain technology in supply chains presents significant potential benefits, but it also comes with a range of implementation challenges. These challenges include technical complexities, scalability issues, and regulatory concerns, all of which must be addressed to fully realize the advantages of these technologies.

One of the primary challenges in integrating AI and blockchain technology in supply chains is the technical complexity involved. Both AI and blockchain are sophisticated technologies that require a high level of expertise to implement and manage effectively. AI involves complex algorithms and machine learning models that need to be trained on large datasets, while blockchain technology requires a robust and secure infrastructure to maintain its decentralized ledger. The integration of these technologies necessitates a deep understanding of both fields and the ability to merge them seamlessly. This complexity can be a significant barrier for organizations, particularly those that lack the necessary technical skills and resources.

Scalability is another significant challenge in the integration of AI and blockchain in supply chains. Blockchain technology, while secure and transparent, can struggle with scalability issues due to its decentralized nature. Each transaction must be verified by multiple nodes in the network, which can slow down processing times and limit the number of transactions that can be handled simultaneously. This can be particularly problematic in large-scale supply chain operations that require the processing of vast amounts of data in real-time. AI can help to mitigate some of these scalability issues by optimizing the processing and analysis of data, but the fundamental limitations of blockchain technology must still be addressed. Solutions such as off-chain transactions and layer-two scaling techniques are being explored, but these are still in the development stages and not yet widely adopted.

Regulatory issues also pose a significant challenge to the integration of AI and blockchain in supply chains. The regulatory landscape for these technologies is still evolving, with many jurisdictions lacking clear guidelines and standards for their use. This uncertainty can create legal and compliance risks for organizations looking to implement AI and blockchain solutions. For example, data privacy regulations such as the General Data Protection Regulation (GDPR) in the European Union impose strict requirements on how personal data can be collected, stored, and processed. Blockchain's immutable nature can conflict with these regulations, as it is difficult to modify or delete data once it has been recorded on the blockchain. AI algorithms must also be designed to comply with data privacy laws, ensuring that they do not infringe on individuals' rights or expose sensitive information.

Another regulatory challenge is the lack of standardization in the implementation of AI and blockchain technologies. Without industry-wide standards and protocols, it can be difficult to ensure interoperability between different systems and platforms. This can hinder the seamless integration of AI and blockchain into existing supply chain operations and limit the ability to share data across different networks. Efforts are being made to develop standards for blockchain technology, such as the International Organization for Standardization (ISO) blockchain standards, but these are still in the early stages and not yet widely adopted.

In addition to these challenges, there are also concerns about the ethical implications of integrating AI and blockchain in supply chains. AI algorithms can sometimes produce biased or unfair outcomes if they are not trained on representative datasets or if they are designed without considering ethical principles. Blockchain technology, while providing transparency and security, can also raise concerns about surveillance and data privacy. Organizations must consider these ethical issues and ensure that their AI and blockchain solutions are designed and implemented in a way that respects individuals' rights and promotes fairness and accountability. (Scott, A.O, et al, 2024).

While the integration of AI and blockchain technology in supply chains offers significant potential benefits, it also presents a range of implementation challenges. Technical complexities, scalability issues, and regulatory concerns are among the key obstacles that must be addressed to fully leverage these technologies. Organizations must invest in the

necessary expertise and resources to overcome these challenges and develop robust, scalable, and compliant AI and blockchain solutions. By doing so, they can unlock the full potential of these technologies and drive greater efficiency, security, and transparency in their supply chain operations.

3.3 Strategic Solutions: Insights into strategies and best practices for overcoming the challenges of integrating AI and blockchain into supply chain management

Integrating Artificial Intelligence (AI) and blockchain into supply chain management offers transformative potential but also presents significant challenges. Addressing these challenges requires strategic solutions and best practices that can help organizations leverage these technologies effectively. This section provides insights into strategies and best practices for overcoming the technical complexities, scalability issues, and regulatory concerns associated with integrating AI and blockchain in supply chains.

To address the technical complexities of integrating AI and blockchain, organizations must invest in developing a skilled workforce. This involves hiring experts with specialized knowledge in AI, blockchain, and supply chain management. Training existing employees to understand and work with these technologies is equally important. Continuous education and professional development programs can help build the necessary expertise within the organization, ensuring that staff are well-equipped to handle the complexities of integration.

Another strategic solution is to adopt a phased implementation approach. Implementing AI and blockchain in supply chains can be a complex and resource-intensive process. By breaking the implementation into smaller, manageable phases, organizations can focus on achieving specific milestones, making it easier to manage and mitigate risks. This approach allows for iterative learning and adaptation, enabling organizations to refine their strategies and technologies based on real-world experiences and feedback.

To address scalability issues, organizations can explore hybrid blockchain solutions. Hybrid blockchains combine the benefits of both public and private blockchains, offering greater scalability and flexibility. Public blockchains provide transparency and security, while private blockchains offer control and efficiency. By leveraging hybrid solutions, organizations can manage the trade-offs between scalability and security more effectively. Additionally, implementing layer-two scaling solutions, such as off-chain transactions and sidechains, can enhance the scalability of blockchain networks.

Optimizing AI algorithms for scalability is another critical strategy. AI models should be designed to handle large volumes of data efficiently. Techniques such as distributed computing and parallel processing can help improve the performance and scalability of AI algorithms. Organizations can also leverage cloud-based AI services, which offer scalable computing resources and advanced AI capabilities, to support their supply chain operations.

Regulatory compliance is a significant concern when integrating AI and blockchain in supply chains. To navigate the evolving regulatory landscape, organizations should engage with regulators and industry bodies early in the implementation process. This proactive engagement can help organizations stay informed about regulatory developments and ensure that their solutions comply with current and future regulations. Collaborating with regulators can also provide valuable insights into best practices and standards for using AI and blockchain in supply chains.

Developing and implementing robust data governance frameworks is essential for ensuring compliance with data privacy and security regulations. Organizations must establish clear policies and procedures for data collection, storage, and processing, ensuring that they align with legal and ethical standards. Implementing advanced encryption techniques and access control mechanisms can help protect sensitive data and ensure that only authorized individuals can access and modify the information. (Scott, A.O, et al, 2024).

Standardization is another critical aspect of successful AI and blockchain integration. Establishing industry-wide standards and protocols can help ensure interoperability between different systems and platforms. Organizations should actively participate in standardization efforts and collaborate with industry peers to develop and adopt common standards. This collaboration can facilitate seamless data sharing and integration, enhancing the overall efficiency and effectiveness of supply chain operations.

Addressing ethical concerns is also crucial for the successful integration of AI and blockchain in supply chains. Organizations must ensure that their AI models are trained on diverse and representative datasets to avoid biased outcomes. Implementing transparent AI algorithms that can be audited and explained can help build trust and

accountability. Organizations should also establish ethical guidelines for using AI and blockchain, ensuring that these technologies are deployed responsibly and in a manner that respects individuals' rights.

While the integration of AI and blockchain technology in supply chains offers significant potential benefits, it also presents various challenges. By adopting strategic solutions and best practices, organizations can overcome these challenges and effectively leverage these technologies. Investing in a skilled workforce, adopting phased implementation approaches, exploring hybrid blockchain solutions, optimizing AI algorithms, engaging with regulators, establishing data governance frameworks, promoting standardization, and addressing ethical concerns are critical steps toward successful integration. These strategies can help organizations unlock the full potential of AI and blockchain, driving greater efficiency, security, and transparency in supply chain operations.

4 Future Directions

4.1 Emerging Trends in AI and Blockchain for Supply Chains: Speculation on future trends and innovations in AI and blockchain that could further enhance supply chain security and transparency

The future of supply chain management is poised for significant transformation with the continued evolution and integration of Artificial Intelligence (AI) and blockchain technology. As these technologies advance, several emerging trends and innovations are expected to further enhance supply chain security and transparency. This section explores these trends and speculates on their potential impact.

One of the most promising emerging trends is the development of AI-powered predictive analytics combined with blockchain's immutable records. Predictive analytics uses AI algorithms to analyze historical data and predict future trends, enabling supply chain managers to make more informed decisions. When integrated with blockchain, predictive analytics can leverage the secure and transparent data provided by the blockchain to improve accuracy and reliability. This combination can help organizations anticipate supply chain disruptions, optimize inventory management, and enhance demand forecasting, ultimately leading to more resilient and efficient supply chains.

Another significant trend is the use of decentralized AI models within blockchain networks. Traditional AI models often rely on centralized data processing, which can be a bottleneck in terms of scalability and security. Decentralized AI models distribute the computational workload across the blockchain network, enhancing scalability and reducing the risk of data breaches. These models can process data locally at each node, maintaining data privacy and security while providing real-time insights. This approach is particularly beneficial for large-scale supply chains that require high levels of data processing and security.

The integration of Internet of Things (IoT) devices with AI and blockchain is also expected to revolutionize supply chain management. IoT devices can collect real-time data on the condition and location of goods as they move through the supply chain. When this data is recorded on a blockchain, it creates a transparent and immutable record of the entire supply chain process. AI can analyze this data to provide real-time monitoring and alerts, ensuring that goods are transported and stored under optimal conditions. This integration can enhance traceability, reduce losses, and improve overall supply chain efficiency.

Smart contracts, which are self-executing contracts with the terms of the agreement directly written into code, represent another key innovation. The future will likely see more sophisticated smart contracts that leverage AI to automate and optimize a wide range of supply chain processes. For example, AI can monitor conditions specified in the smart contract, such as delivery times or quality standards, and automatically execute payments or other actions when these conditions are met. This automation reduces the need for manual intervention, minimizes the risk of errors, and enhances the efficiency and transparency of supply chain transactions.

Moreover, the concept of federated learning is gaining traction as a method to enhance AI models while maintaining data privacy. Federated learning involves training AI models across multiple decentralized devices or servers holding local data samples, without exchanging them. This method, combined with blockchain, ensures that data privacy is maintained while still benefiting from the insights generated by AI. In supply chain management, federated learning can enable collaborative data analysis across different stakeholders without compromising the confidentiality of their data, fostering a more cooperative and efficient supply chain ecosystem.

The rise of quantum computing also holds significant potential for AI and blockchain in supply chains. Quantum computing can process complex calculations at unprecedented speeds, which can enhance the capabilities of AI models and improve the efficiency of blockchain networks. Although still in the experimental stages, quantum computing could

revolutionize supply chain analytics, enabling real-time optimization of logistics, predictive maintenance, and enhanced security through advanced cryptographic techniques.

In addition to technological advancements, the future will likely see the establishment of more comprehensive regulatory frameworks for AI and blockchain. As governments and international organizations recognize the potential and risks associated with these technologies, they are expected to develop regulations that promote their safe and ethical use in supply chains. These regulations will provide clearer guidelines for compliance, data privacy, and security, helping organizations navigate the complexities of integrating AI and blockchain technologies.

The integration of AI and blockchain technology in supply chains is set to advance significantly with the emergence of new trends and innovations. Predictive analytics, decentralized AI models, IoT integration, smart contracts, federated learning, and quantum computing are among the key developments that will enhance supply chain security and transparency. As these technologies evolve, they will provide more robust, efficient, and secure supply chain solutions, transforming the way organizations manage their operations. The continued collaboration between industry stakeholders and regulatory bodies will be crucial in addressing the challenges and maximizing the benefits of these emerging technologies.

4.2 Opportunities for Advancement and Integration: Exploration of opportunities for advancing AI and blockchain technologies and integrating them with other emerging technologies to create more robust and efficient supply chains

The integration of Artificial Intelligence (AI) and blockchain technology in supply chains presents numerous opportunities for advancement, particularly when combined with other emerging technologies. This section explores these opportunities, emphasizing the potential to create more robust, efficient, and transparent supply chains.

One significant opportunity lies in the convergence of AI, blockchain, and the Internet of Things (IoT). IoT devices can collect vast amounts of real-time data from various points along the supply chain, such as sensors on shipping containers, warehouse monitoring systems, and tracking devices on delivery vehicles. When this data is recorded on a blockchain, it creates an immutable and transparent ledger that can be accessed by all stakeholders. AI can then analyze this data to optimize supply chain operations, predict maintenance needs, and enhance overall efficiency. The integration of these technologies can lead to more proactive supply chain management, where potential issues are identified and addressed before they escalate into significant problems.

Another promising area is the use of AI and blockchain to enhance supply chain sustainability. Blockchain's ability to provide transparent and immutable records can help verify the sustainability claims of products and materials. AI can analyze these records to ensure that suppliers adhere to environmental and social governance (ESG) standards. For example, AI algorithms can assess the carbon footprint of various supply chain activities and recommend strategies for reducing emissions. This integration can help companies meet regulatory requirements and consumer demand for sustainable practices, while also improving their corporate social responsibility (CSR) profiles.

The advancement of smart contracts presents further opportunities for integrating AI and blockchain in supply chains. Smart contracts are self-executing agreements where the terms are directly written into code. They can automate various supply chain processes, such as payments, order fulfillment, and compliance checks. AI can enhance smart contracts by providing dynamic decision-making capabilities based on real-time data. For instance, AI can monitor weather conditions, traffic patterns, and other external factors to adjust delivery schedules automatically, ensuring that supply chain operations remain efficient and responsive to changing conditions.

The development of decentralized AI models is another key opportunity. Traditional AI models often rely on centralized data processing, which can be a bottleneck in terms of scalability and security. Decentralized AI models distribute the computational workload across the blockchain network, enhancing scalability and reducing the risk of data breaches. These models can process data locally at each node, maintaining data privacy and security while providing real-time insights. This approach is particularly beneficial for large-scale supply chains that require high levels of data processing and security.

Quantum computing represents a frontier for AI and blockchain integration in supply chains. Quantum computing can process complex calculations at unprecedented speeds, enhancing the capabilities of AI models and improving the efficiency of blockchain networks. Although still in the experimental stages, quantum computing could revolutionize supply chain analytics, enabling real-time optimization of logistics, predictive maintenance, and enhanced security.

through advanced cryptographic techniques. The integration of quantum computing with AI and blockchain could unlock new levels of performance and reliability in supply chain management.

Federated learning is gaining traction as a method to enhance AI models while maintaining data privacy. Federated learning involves training AI models across multiple decentralized devices or servers holding local data samples, without exchanging them. This method, combined with blockchain, ensures that data privacy is maintained while still benefiting from the insights generated by AI. In supply chain management, federated learning can enable collaborative data analysis across different stakeholders without compromising the confidentiality of their data, fostering a more cooperative and efficient supply chain ecosystem.

The integration of AI and blockchain with 5G technology offers another opportunity for advancing supply chain management. 5G provides high-speed, low-latency connectivity, which is essential for real-time data transmission and analysis. With 5G, AI algorithms can process and respond to data more quickly, and blockchain transactions can be verified and recorded in near real-time. This high-speed connectivity can enhance the responsiveness and agility of supply chain operations, allowing for more precise tracking and management of goods and materials.

The integration of AI and blockchain technology in supply chains, combined with other emerging technologies such as IoT, quantum computing, federated learning, and 5G, presents significant opportunities for advancement. These technologies can enhance supply chain transparency, efficiency, and sustainability by providing real-time data analysis, automating processes, and ensuring data security. As these technologies continue to evolve, their integration will likely lead to more robust and resilient supply chains, capable of meeting the complex demands of the global market. The continued exploration and implementation of these opportunities will be crucial for organizations seeking to optimize their supply chain operations and gain a competitive edge in the industry.

5 Conclusion

The integration of Artificial Intelligence (AI) and blockchain technology in supply chain management presents transformative potential for enhancing security, transparency, and efficiency. This comprehensive review has explored the key benefits and challenges of integrating these technologies, examined case studies of successful implementations, and speculated on future trends and opportunities. The findings highlight the significant advancements that AI and blockchain can bring to supply chains, as well as the strategic solutions needed to overcome the associated challenges.

The key findings from this review underscore the multifaceted advantages of integrating AI and blockchain into supply chains. These technologies collectively enhance security by providing a decentralized and immutable ledger for transactions, coupled with AI's ability to monitor and detect anomalies. Transparency is significantly improved as blockchain ensures that all stakeholders have access to the same, unalterable data, while AI provides real-time analytics and reporting. Real-time tracking capabilities are bolstered through the use of IoT devices, which feed data into blockchain systems that AI can analyze to optimize operations. Data integrity is maintained through blockchain's immutable records, and AI algorithms ensure that data is consistently accurate and reliable.

However, integrating AI and blockchain into supply chains is not without its challenges. Technical complexities arise due to the sophisticated nature of these technologies, requiring specialized knowledge and skills for effective implementation and management. Scalability issues are also a concern, particularly for blockchain networks, which can struggle with processing large volumes of transactions quickly. Regulatory and compliance challenges further complicate the landscape, as the legal framework for these technologies is still evolving and often lacks clear guidelines.

Despite these challenges, the future holds promising opportunities for the advancement and integration of AI and blockchain in supply chains. The convergence of these technologies with other emerging innovations such as IoT, quantum computing, federated learning, and 5G can create more robust and efficient supply chain systems. IoT devices can provide real-time data collection, blockchain ensures data integrity and transparency, and AI analyzes this data to optimize operations. Quantum computing could revolutionize supply chain analytics by enabling faster and more complex computations, while federated learning enhances AI models' performance without compromising data privacy. The high-speed, low-latency connectivity of 5G can further enhance the responsiveness and agility of supply chain operations.

The strategic solutions discussed in this review are critical for overcoming the challenges of integrating AI and blockchain into supply chains. Developing a skilled workforce, adopting phased implementation approaches, exploring hybrid blockchain solutions, and optimizing AI algorithms for scalability are essential steps. Engaging with regulators

and establishing robust data governance frameworks can help navigate regulatory challenges, while promoting standardization and addressing ethical concerns ensure responsible and effective use of these technologies.

The integration of AI and blockchain technology in supply chain management offers significant potential benefits, including enhanced security, transparency, and efficiency. The strategic solutions and future opportunities discussed in this review provide a roadmap for organizations seeking to leverage these technologies to optimize their supply chain operations. As AI and blockchain continue to evolve, their integration with other emerging technologies will likely lead to more robust and resilient supply chains, capable of meeting the complex demands of the global market. Organizations that invest in these technologies and adopt strategic solutions to overcome the associated challenges will be well-positioned to gain a competitive edge in the industry. The continued exploration and implementation of these opportunities will be crucial for driving innovation and excellence in supply chain management.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

References

- [1] Behnke, K. and Janssen, M.F.W.H.A., 2020. Boundary conditions for traceability in food supply chains using blockchain technology. *International Journal of Information Management*, 52, p.101969. DOI: 10.1016/j.ijinfomgt.2019.05.025
- [2] Carson, B., Romanelli, G., Walsh, P. and Zhumaev, A., 2018. Blockchain beyond the hype: What is the strategic business value. *McKinsey & Company*, 1, pp.1-13.
- [3] Casino, F., Dasaklis, T.K. and Patsakis, C., 2019. A systematic literature review of blockchain-based applications: Current status, classification and open issues. *Telematics and informatics*, 36, pp.55-81. DOI: 10.1016/j.telpol.2019.101888.
- [4] Christidis, K. and Devetsikiotis, M., 2016. Blockchains and smart contracts for the internet of things. *IEEE access*, 4, pp.2292-2303. DOI: 10.1109/ACCESS.2016.2566339
- [5] Francisco, K. and Swanson, D., 2018. The supply chain has no clothes: Technology adoption of blockchain for supply chain transparency. *Logistics*, 2(1), p.2. DOI: 10.3390/logistics2010002
- [6] Gai, K., Qiu, M., Sun, X. and Zhao, H., 2017. Security and privacy issues: A survey on FinTech. In *Smart Computing and Communication: First International Conference, SmartCom 2016, Shenzhen, China, December 17-19, 2016, Proceedings 1* (pp. 236-247). Springer International Publishing. DOI: 10.1016/j.jnca.2020.01.003
- [7] Grimm, J.H., Hofstetter, J.S. and Sarkis, J., 2014. Critical factors for sub-supplier management: A sustainable food supply chains perspective. *International journal of production economics*, 152, pp.159-173. DOI: 10.1016/j.ijpe.2013.12.011.
- [8] Ivanov, D. and Dolgui, A., 2020. Viability of intertwined supply networks: extending the supply chain resilience angles towards survivability. A position paper motivated by COVID-19 outbreak. *International journal of production research*, 58(10), pp.2904-2915. DOI: 10.1080/00207543.2020.1750727.
- [9] Kamath, R., 2018. Food traceability on blockchain: Walmart's pork and mango pilots with IBM. *The Journal of the British Blockchain Association*, 1(1).
- [10] Kamilaris, A., Fonts, A. and Prenafeta-Boldú, F.X., 2019. The rise of blockchain technology in agriculture and food supply chains. *Trends in food science & technology*, 91, pp.640-652. DOI: 10.1016/j.tifs.2019.07.034
- [11] Kouhizadeh, M. and Sarkis, J., 2018. Blockchain practices, potentials, and perspectives in greening supply chains. *Sustainability*, 10(10), p.3652. DOI: 10.3390/su10103652
- [12] Kouhizadeh, M., Saberi, S. and Sarkis, J., 2021. Blockchain technology and the sustainable supply chain: Theoretically exploring adoption barriers. *International journal of production economics*, 231, p.107831. DOI: 10.1016/j.ijpe.2020.107831.
- [13] Kshetri, N., 2018. 1 Blockchain's roles in meeting key supply chain management objectives. *International Journal of information management*, 39, pp.80-89. DOI: 10.1016/j.ijinfomgt.2017.12.005.
- [14] Kshetri, N., 2018. 1 Blockchain's roles in meeting key supply chain management objectives. *International Journal of information management*, 39, pp.80-89. DOI: 10.1016/j.ijinfomgt.2017.12.005

- [15] Kumar, A., Liu, R. and Shan, Z., 2020. Is blockchain a silver bullet for supply chain management? Technical challenges and research opportunities. *Decision Sciences*, 51(1), pp.8-37. DOI: 10.1111/deci.12396
- [16] Lohmer, J. and Lasch, R., 2020. Blockchain in operations management and manufacturing: Potential and barriers. *Computers & Industrial Engineering*, 149, p.106789. DOI: 10.1016/j.cie.2020.106789
- [17] Ma, W., 2020. Analysis of anomaly detection method for Internet of things based on deep learning. *Transactions on Emerging Telecommunications Technologies*, 31(12), p.e3893.
- [18] Mackey, T.K., Kuo, T.T., Gummadi, B., Clauson, K.A., Church, G., Grishin, D., Obbad, K., Barkovich, R. and Palombini, M., 2019. 'Fit-for-purpose?'—challenges and opportunities for applications of blockchain technology in the future of healthcare. *BMC medicine*, 17, pp.1-17.
- [19] Mendling, J., Weber, I., Aalst, W.V.D., Brocke, J.V., Cabanillas, C., Daniel, F., Debois, S., Ciccio, C.D., Dumas, M., Dustdar, S. and Gal, A., 2018. Blockchains for business process management—challenges and opportunities. *ACM Transactions on Management Information Systems (TMIS)*, 9(1), pp.1-16. DOI: 10.1145/3183367
- [20] Mettler, M., 2016, September. Blockchain technology in healthcare: The revolution starts here. In 2016 IEEE 18th international conference on e-health networking, applications and services (Healthcom) (pp. 1-3). IEEE. DOI: 10.1109/HealthCom.2016.7749510
- [21] Min, H., 2010. Artificial intelligence in supply chain management: theory and applications. *International Journal of Logistics: Research and Applications*, 13(1), pp.13-39. DOI: 10.1080/13675560902736537.
- [22] Min, H., 2019. Blockchain technology for enhancing supply chain resilience. *Business Horizons*, 62(1), pp.35-45. DOI: 10.1016/j.bushor.2018.08.012
- [23] Montecchi, M., Plangger, K. and Etter, M., 2019. It's real, trust me! Establishing supply chain provenance using blockchain. *Business Horizons*, 62(3), pp.283-293. DOI: 10.1016/j.bushor.2019.01.008
- [24] Nawari, N.O. and Ravindran, S., 2019. Blockchain and the built environment: Potentials and limitations. *Journal of Building Engineering*, 25, p.100832. DOI: 10.1016/j.job.2019.100832
- [25] Oyewole, A.T., Okoye, C.C., Ofodile, O.C. and Ejairu, E., 2024. Reviewing predictive analytics in supply chain management: Applications and benefits. *World Journal of Advanced Research and Reviews*, 21(3), pp.568-574.
- [26] Queiroz, M.M. and Telles, R., 2018. Big data analytics in supply chain and logistics: an empirical approach. *The International Journal of Logistics Management*, 29(2), pp.767-783.
- [27] Saberi, S., Kouhizadeh, M., Sarkis, J. and Shen, L., 2019. Blockchain technology and its relationships to sustainable supply chain management. *International journal of production research*, 57(7), pp.2117-2135. DOI: 10.1080/00207543.2018.1533261.
- [28] Scott, A.O., Amajuoyi, P. and Adeusi, K.B., 2024. Advanced risk management models for supply chain finance. *Finance & Accounting Research Journal*, 6(6), pp.868-876.
- [29] Tapscott, A. and Tapscott, D., 2017. How blockchain is changing finance. *Harvard Business Review*, 1(9), pp.2-5.
- [30] Tian, F., 2016, June. An agri-food supply chain traceability system for China based on RFID & blockchain technology. In 2016 13th international conference on service systems and service management (ICSSSM) (pp. 1-6). IEEE. DOI: 10.1109/ICSSSM.2017.7996119
- [31] Tian, F., 2017, June. A supply chain traceability system for food safety based on HACCP, blockchain & Internet of things. In 2017 International conference on service systems and service management (pp. 1-6). IEEE. DOI: 10.1109/ICSSSM.2017.7996119
- [32] Tirkolaei, E.B., Sadeghi, S., Mooseloo, F.M., Vandchali, H.R. and Aeni, S., 2021. Application of machine learning in supply chain management: a comprehensive overview of the main areas. *Mathematical problems in engineering*, 2021(1), p.1476043.
- [33] Udeh, E.O., Amajuoyi, P., Adeusi, K.B. and Scott, A.O., 2024. Blockchain-driven communication in banking: Enhancing transparency and trust with distributed ledger technology. *Finance & Accounting Research Journal*, 6(6), pp.851-867.
- [34] Wang, Y., Han, J.H. and Beynon-Davies, P., 2019. Understanding blockchain technology for future supply chains: a systematic literature review and research agenda. *Supply Chain Management: An International Journal*, 24(1), pp.62-84. DOI: 10.1108/SCM-03-2018-0148
- [35] Zhang, P., Schmidt, D.C., White, J. and Lenz, G., 2018. Blockchain technology use cases in healthcare. In *Advances in computers* (Vol. 111, pp. 1-41). Elsevier.