International Journal of Research in Engineering and Management Sciences (IJREMS)
E-ISSN: 3107-7439

Research Article
VOL.: 1, Issue: 2, July 2025

AI and Blockchain Integration for Sustainable Supply Chain Transparency: Challenges and Opportunities

[1]Vaskula Srikanth

*[*1]Assistant Professor, Department of Information Technology Chaitanya Bharathi Institute of Technology (CBIT), Telangana, India*

Email: srikanth.us8@gmail.com

Orcid ID: https://orcid.org/0009-0006-6171-1238

ABSTRACT:

The global supply chain is a complicated chain and it has the suppliers, manufactures, distributors and the consumers. The old systems have been associated with inefficiencies, lack of real time information, visibility that leads to fraud, delays and environmental wastages. AI and Blockchain technologies provide the opportunities to make the supply chains more visible and sustainable. blockchain-based decentralized immutable ledger can be used to provide secure verifiable data along the chain and AI can be used to optimise the processes and predict demand and inefficiencies. When the latter arrives in combination, traceability is boosted, fraud is driven to minimum and ethical sourcing plus sustainability are encouraged. The given paper establishes AIs and Blockchain combination and mentions such advantages of the partnership as real-time monitoring or predictive analytics. Nevertheless, the issue of data confidentiality, size and legal issues need to be taken care of in order to have a successful implementation. The industry has case studies and examples of their application that can give some idea of how they have been applied in practice and some idea of how the obstacles to adoption can be lessened and how sustainable practice can be achieved.

Keywords: Artificial intelligence, Blockchain, Supply chain transparency, Sustainability, Integration of technology

Received Date: 5 July 2025**; Accepted Date:** 15 July 2025**; Published Date:** 20 July 2025.

Introduction

Blockchain and Artificial Intelligence are the two technologies that, when intersect, will likely change the supply chain management in numerous ways, in particular, by allowing transparency, efficiency, and sustainability (Reddy, 2019). The outdated paradigm of the supply chain that operates on the principle of the absence of visibility and centralized systems proves to be more exposed to the risks, such as fraud, inefficiencies, and environmental impact, and the new categories of solutions need to have an opportunity to eliminate such fundamental weaknesses (Khanna et al., 2022). Blockchain technology had the potential to develop end-to- end traceability appropriately because of the decentralized secure unchangeable ledger system that reduced the risks of frauds and made all the participants of the entire supply chain ecosystem more responsible (Khanna et al., 2022). Meanwhile,

the Artificial Intelligence is introducing the advanced data analytics, which is enabling the organizations to anticipate the future trends, most efficient logistical routes as well as automating the processes that are challenging and making the operations more competent and timelier (He et al., 2024). However, together with each other, the two revolutionary technologies can open the doors to a new level of transparencyand, consequently, in real-time, the origin, condition, and ownership of the product can become traceable, which will allow all the participants of the supply chain system to build more trust and collaboration (Karaduman & G ulhas, 2025).

Background of the Study

The artificial intelligence is implemented to primarily discrete and task-based environments that also encompass the predictive inventory care besides the data analysis and data processing tasks (Shen et al., 2024). Despite the fact that the increasing interest is being created in the field of artificial intelligence in regard to the supply chain management, some gaps were found in the previous literature reviews that did not enable the undertaking to gain a more comprehensive vision of the field (Teixeira et al., 2025). Among the most valuable consequences of a contemporary supply chain is adjustment to extremely dynamic operations, and the worldwide economy is becoming increasingly competitive (Riahi et al., 2021). Blockchain in conjunction with a supply chain system allows generating an immutable and transparent ledger that fully records the journey of a product, and a blockchain-based paradigm shifts allows making reliable and verifiable information concerning the origin of a good, its processing steps, and its effect on the environment visible to all the parties (Khanna et al., 2022). Such broad transparency will be among the essential elements of trust-building and responding to integrity of supply chain (Khanna et al., 2022)

Table 1: Comparison of Traditional Supply Chain vs. AI and Blockchain-Integrated Supply Chain

Aspect	Traditional Supply Chain	AI and Blockchain-Integrated Supply Chain
Data Management	Often fragmented and siloed	Real-time, transparent, and secure data with decentralized ledger
Visibility	Limited visibility into processes and operations	Full transparency across the entire supply chain
Security	Vulnerable to fraud, data breaches, and manipulation	High security through encryption and blockchain immutability
Traceability	Difficult to trace the movement of goods and materials	Enhanced traceability with real-time tracking through blockchain
Operational Efficiency	Slow processes, prone to human errors	Optimized operations through AI-driven automation and decision-making
Supply Chain Coordination	Dependent on intermediaries and manual intervention	Decentralized, autonomous, and self-regulated systems using smart contracts
Fraud and Counterfeit Prevention	High risk of fraud and counterfeit goods	Reduced fraud and counterfeit risks with verified data and provenance tracking
Sustainability	Often lacks focus on sustainability and ethical sourcing	Promotes sustainability with ethical sourcing and environmental tracking through AI and Blockchain

Cost Efficiency	Higher operational and administrative costs	Reduced costs through automation, transparency, and optimized decision-making

Justification

The movement towards artificial intelligence and Blockchain technologies are colliding, and it is a game-changing opportunity to reengineer supply chain management as the world needs more visibility, responsibility, and sustainability to become ever-more sophisticated (Shen et al., 2024). The causes of the failure of the businesses to meet the demand along with the regulatory requirements imposed as a consequence of the consumer demand have been tracked down to inefficiency and the lack of transparency that the traditional supply chain systems were aligned with (Awasthi, 2024). The blockchain technology can provide all the stakeholders with a single source of truth, a decentralized immutable ledger system when integrity and traceability of the data across the entire supply chain is encompassed (Thakur, 2023). The described transparency can even be supplemented by the AI that will be able not only to optimize operations but also predict potential upheavals and proposing activities that will lead to more informed decisions (Reddy, 2019). With the AI algorithms and the intended data on the different sources, the companies can be potentially capable of having a better picture of their occurrences in the supply chain, the possibility to improve them, and the risks to avoid even before they occur (Chen, 2023). This is because this kind of integration is far more stubborn in demonstrating ethical sourcing and sustainability practices than the capacity to track the products back to the origin and to the consumer (Chen, 2023).

Purposes of the Study

- To address the importance of the AI and Blockchain combination in the improvement of the supply chain visibility.
- To discover the primary advantages of AI and Blockchain in supply chain activities.
- To deal with the concerns which are inferential to the implementation of such technologies to the real-life supply chains.
- To assess how AI and Blockchain have a chance to enhance sustainability practices within the supply chains.
- To offer recommendations as per how the barriers to the acceptance of AI and Blockchain in the supply chain management can be overcome.

Literature Review

Blockchain and artificial intelligence are the technologies that can drive the network revolution in the supply chain management due to a higher degree of transparency, security and efficiency. Immutability, by definition, blockchain, in conjunction with decentralized ledger system, creates a secure basis to follow the products and transactions through the multi- faceted webs of supply with data integrity and provenance (Awasthi, 2024). It is the variation of the distributed ledger technology allowing to establish a common, auditable ledger of all activities along the supply chain, including the sourcing of the raw materials to the final delivery that reduces the opportunity of fraud, counterfeiting, and data manipulation (Khanna et al., 2022; Reddy, 2019). The variants of the AI algorithms that preferably position the augmented data processing and decision-making to the foreground and allow optimizing the supply chain processes in real-time, predicting the demands, and identifying the abnormalities are machine learning and predictive analytics (Vyas et al., 2022). These technologies are synergistic and will form an incredible ecosystem of supply chain innovation that will make most industries more efficient, such as agriculture, healthcare, and finance (Adel, 2024). blockchain AI With the help of a vast amount of information relayed by all the nodes on the blockchain, AI algorithms will find patterns, outline possible disruptions, and optimize the location of resources (Shen et al., 2024).

Material and Methodology

The considered work is based on the qualitative research methodology because the literature and cases, as well as the industry reports, are considered to explore the opportunities of the AI and Blockchain supply chain management combination. The potential of their application in the different industries, including agriculture, retail, and logistics are discussed in the process of the understanding of

how the technologies already are used to offer increased degrees of transparency and sustainability. In addition to this, there is also a comparative analysis that can be seen to symmetrize the advantages and drawbacks of using AI and Blockchain as a pair, mainly regarding the consequences, in the aspect of efficiency, traceability, and eco-friendliness.

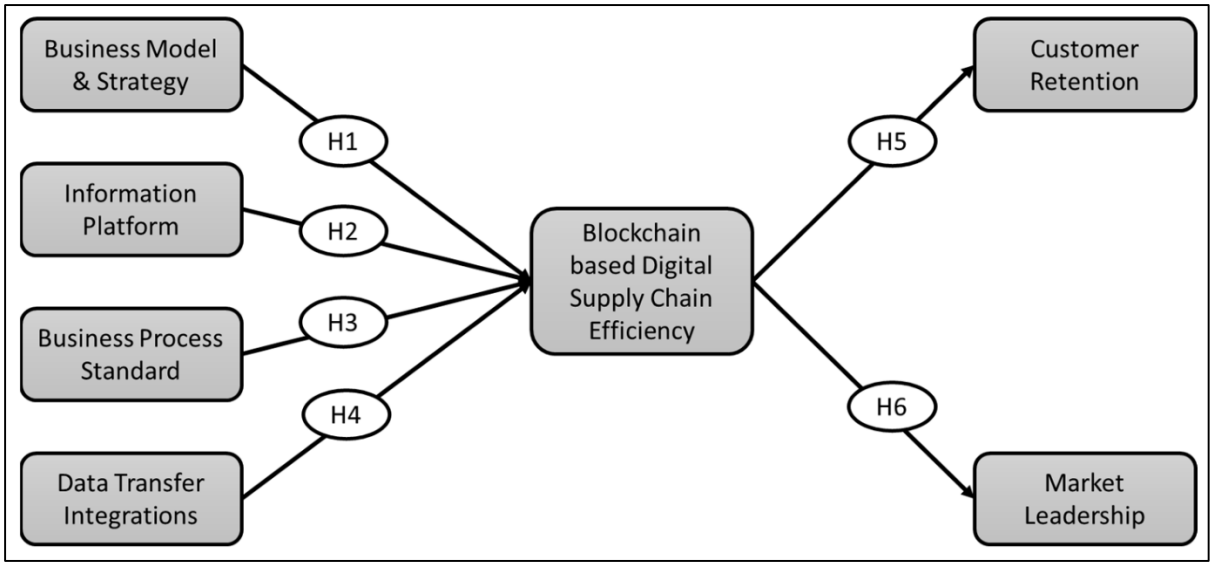
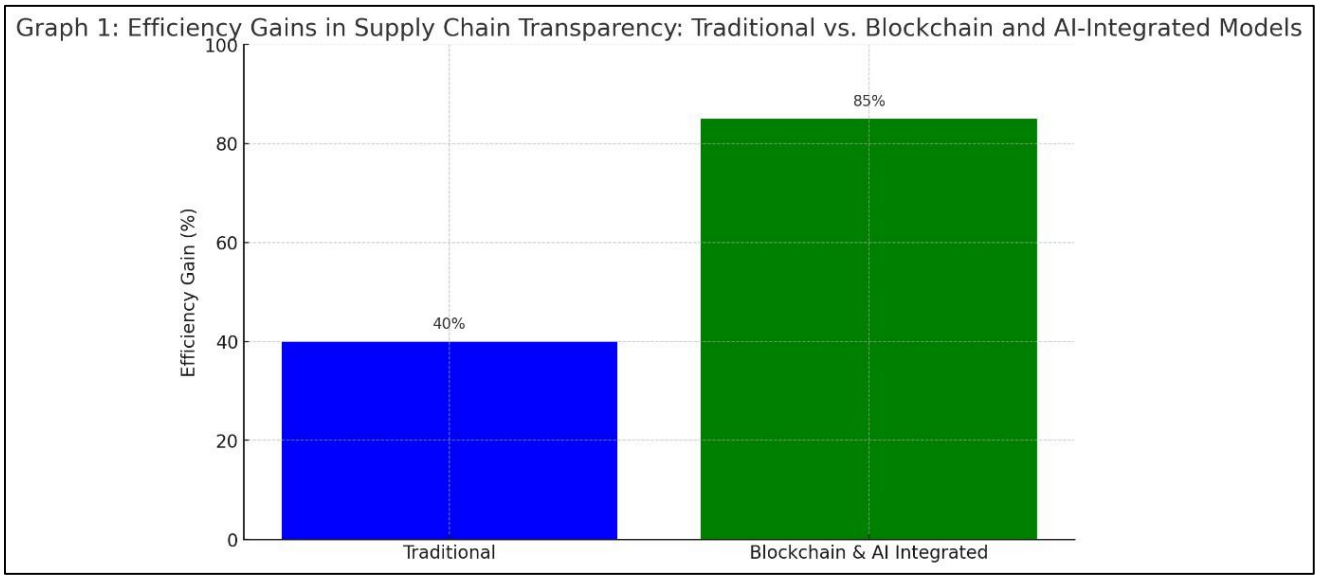


Figure 1: Blockchain and AI Integration in Supply Chain Management

Results and Discussion

AI and Blockchain have high chances of boosting the transparency of the supply chains. Blockchain allows seeing every one of the transactions on the supply chain and they cannot be modified and AI can be used on the supply chain processes to optimise them by analysing vast measured of data. Combining traceability ability, reduction in fraud and enhancement of sustainability are some of the capabilities of some of these technologies.



Graph 1: Efficiency Gains in Supply Chain Transparency: Traditional vs. Blockchain and AI-Integrated Models

However, there still exist certain apprehensions in the sphere of the data privacy, scale and regulatory

problems. The last concern to earn the designation of a regular use is the security of the transmission of the information to the Blockchain networks and its ability to comply with the privacy policies is unmatched. Second, the technicality which shrouds the application of the AI and Blockchain systems could be a challenge to the firms which lack the technical expertise. Still, AI and Blockchain integration presupposes the considerable innovations in the supply chains. The companies that will succeed in deploying such types of technologies will be in the position of having won the competitive edge since they would be in a position to maximise the transparency, efficiencies and sustainability of operations.

Study Limitations

Artificial Intelligence and the blockchain technology are the two technologies that, in combination, can potentially form a paradigm shift and transform the many industries due to the heightened efficiency of the business processes, the automation of the decision- making trust, and the data security (Pandl et al., 2020). Nevertheless, the existing information is already in the shade of the theoretical frameworks and conceptual models, which are already integrated with the existing literature and the first case studies and are pending to be - empirically tested (Kumar et al., 2022). These papers, however, are somewhat informative in regard to the future utility of the AI-blockchain conjunction, even though they are largely lacking in empirical research, not to mention actual implementations that they could use to evaluate the practical implication and challenge of such a broad integration (Adel, 2024; Yuan et al., 2025).

Future Scope

To make the synergetic merger of the Artificial Intelligence and blockchain technologies in the supply chain ecosystems come true, the future research in the field must be aimed at creating the standardized frameworks, which describe the unambiguous rules of interoperability, data sharing, and system management (Riad et al., 2024). These frameworks should revolve around complexities related to interconnection of various systems which should be rendered seamless in view of communication as well as data-flow/information across the chain supply network (Vyas et al., 2022). Specifically, the conventional application programming interfaces, data formats, and consensus mechanisms to assist with which secure and efficient data sharing between AI-based systems and blockchain can be realised need to be established (Chen, 2023).

Conclusion

AI and Blockchain can be a game changer in the endeavor to achieve more transparent, sustainable and efficient supply chains. Despite the fact that it has few problems such as information privacy, scalability and regulatory problems, the prospect of the technologies in helping to facilitate the supply chain related activities of companies that are keen on streamlining their operations makes it a desirable solution. By reacting to these concern, the companies will be able to create more open, efficient and sustainable supply chains that will subsequently give them competitive advantage in the market.

References

1. He, J., Min, F., & Fan, Y. (2024). Digital transformation and supply chain efficiency improvement: An empirical study from a- share listed companies in China. PLoS ONE, 19(4). https://doi.org/10.1371/journal.pone.03021 33
2. Karaduman, O., & Gülhas, G. (2025). Blockchain-Enabled Supply Chain Management: A Review of Security, Traceability, and Data Integrity Amid the
3. EvolvingSystemic Demand. Applied Sciences, 15(9), 5168. https://doi.org/10.3390/app15095168
4. Khanna, A., Jain, S., Burgio, A., Bolshev, V., & Панченко, B. (2022). Blockchain- Enabled Supply Chain platform for Indian Dairy Industry: Safety and Traceability. Foods, 11(17), 2716. https://doi.org/10.3390/foods11172716
5. Reddy, V. V. (2019). Enhancing Supply Chain Management Using Blockchain Technology. International Journal of Engineering and Advanced Technology, 8(6), 4657.https://doi.org/10.35940/ijeat.f9141.08861 9
6. Chen, Y.-H. (2023). Integrating Explainable Artificial Intelligence and Blockchain to Smart

Agriculture with Decision Making and Improved Security. https://doi.org/10.2139/ssrn.4446597 Riad, M., Naïmi, M., & Okar, C. (2024). Enhancing Supply Chain Resilience Through Artificial Intelligence: Developing a Comprehensive Conceptual Framework for AI Implementation and Supply Chain Optimization. Logistics, 8(4), 111. https://doi.org/10.3390/logistics8040111

7. Shanmugam, L., Tillu, R., & Jangoan, S. (2023). Privacy-Preserving AI/ML Application Architectures: Techniques, Trade-offs, and Case Studies. Journal of Knowledge Learning and Science Technology ISSN 2959-6386 (Online), 2(2), 398. https://doi.org/10.60087/jklst.vol2.n2.p420
8. Vyas, S., Shabaz, M., Pandit, P., Parvathy, L. R., & Ofori, I. (2022). Integration of Artificial Intelligence and Blockchain Technology in Healthcare and Agriculture. Journal of Food Quality, 2022, 1. https://doi.org/10.1155/2022/4228448
9. Yuan, F., Zuo, Z., Jiang, Y., Shu, W., Tian, Z., Ye, C., Yang, J., Mao, Z., Huang, X., Gu, S., & Peng, Y. (2025). AI-Driven Optimization of Blockchain Scalability, Security, and Privacy Protection. Algorithms, 18(5), 263. https://doi.org/10.3390/a18050263
10. Adel, N. (2024). The Impact of Digital Literacy and Technology Adoption on Financial Inclusion in Africa, Asia, and Latin America. Heliyon, 10(24). https://doi.org/10.1016/j.heliyon. 2024.e40 951
11. Choi, N., & Kim, H. (2024). Technological Convergence of Blockchain and Artificial Intelligence: A Review and Challenges. Electronics, 14(1), 84. https://doi.org/10.3390/electronics1401008 4
12. Kumar, S., Lim, W. M., Sivarajah, U., & Kaur, J. (2022). Artificial Intelligence and Blockchain Integration in Business: Trends from a Bibliometric-Content Analysis. Information Systems Frontiers. https://doi.org/10.1007/s10796-022-10279- 0
13. Pandl, K. D., Thiebes, S., Schmidt- Kraepelin, M., & Sunyaev, A. (2020). On the Convergence of Artificial Intelligence and Distributed Ledger Technology: A Scoping Review and Future Research Agenda. arXiv (Cornell University). https://doi.org/10.48550/arxiv.2001.11017
14. Rashid, A. B., & Kausik, M. A. K. (2024). AI Revolutionizing Industries Worldwide: A Comprehensive Overview of Its Diverse Applications. Hybrid Advances, 7, 100277. https://doi.org/10.1016/j.hybadv.2024.100 277
15. Riahi, Y., Saikouk, T., Gunasekaran, A., & Badraoui, I. (2021). Artificial intelligence applications in supply chain: A descriptive bibliometric analysis and future research directions. Expert Systems with Applications, 173, 114702. https://doi.org/10.1016/j.eswa.2021.11470 2
16. Shen, J., Bu, F., Ye, Z., Zhang, M., Ma, Q., Yan, J., & Huang, T. (2024). Management of drug supply chain information based on “artificial intelligence + vendor managed inventory” in China: perspective based on a case study. Frontiers in Pharmacology, 15. https://doi.org/10.3389/fphar.2024.137364 2
17. Teixeira, A. R., Ferreira, J. V., & Ramos, L. (2025). Intelligent Supply Chain Management: A Systematic Literature Review on Artificial Intelligence Contributions. Information, 16(5), 399. https://doi.org/10.3390/info16050399
18. Awasthi, S. (2024). Artificial Intelligence in Supply Chain Management. Journal of Student Research, 13(1). https://doi.org/10.47611/jsrhs.v13i1.5996
19. Thakur, A. (2023). Market trends and analysis of blockchain technology in supply chain. Frontiers in Blockchain, 6. https://doi.org/10.3389/fbloc.2023.114259 9