Proceedings of the International Conference on Industrial Engineering and Operations Management
Publisher: IEOM Society International, USA DOI: 10.46254/AF6.20250223
Published: April 8, 2025

Designing a Blockchain Framework for Optimized Supply Chain Management

Lebhar Ikram
PhD Researcher - Industrial Engineering
ENSAM-Meknes School of Engineering
University Moulay Ismail
Morocco
lebharikram@gmail.com

Dadda Afaf
Full Professor of Industrial Engineering
ENSAM-Meknes School of Engineering
University Moulay Ismail, Morocco
a.dadda@ensam.umi.ac.ma

Lhachimi Ilyas and Imioussaka Zakarya
Industrial Engineering Students
ENSAM-Meknes School of Engineering
University Moulay Ismail, Morocco
ilyaslhachimi@gmail.com, zakariaimiou0@gmail.com

Ezzine Latifa
Full Professor of Industrial Engineering
ENSAM-Meknes School of Engineering
University Moulay Ismail, Morocco
latifae@yahoo.com

Abstract

As blockchain technology advances, numerous businesses have expressed strong interest in their capacity to promote trust among different parties without relying on centralized authorities. While the success of cryptocurrencies validates blockchain's decentralized value storage, its use in industrial contexts, such as supply chain management, is still in its early stages. Industrial ecosystems with a varied stakeholder base continue to experiment with private blockchains. However, many business blockchain projects have failed to acquire traction owing to bad design, insufficient stakeholder incentives, or circumstances where blockchain was not required. This highlights the importance of a thorough framework that assists blockchain designers in determining whether blockchain is applicable and guiding them through the process of building an effective corporate solution. The current research on blockchain designs is limited and mainly focuses on specialized applications. This article presents a Supply Chain Blockchain Design Framework (SCBDF), which provides a methodical approach to identifying viable blockchain use cases while also outlining the architectural features required for a multi-industry enterprise blockchain ecosystem.

Keywords
Blockchain Technology (BCT), Supply Chain Management, Digitalization

Introduction:

Numerous organizations participate in industrial collaborations that necessitate the sharing of transaction records, private data, and microtransactions. This collaborative landscape is widespread in many industries, including automotive and supply chain ecosystems. A significant problem in facilitating these relationships is the building of a strong trust foundation, which is required to ensure that sensitive records, audits, and accounting processes are managed reliably. Obtaining this degree of confidence necessitates both technical and business concerns.

Historically, corporate partnerships relied on three types of trust. The first one is the peer-to-peer trust, formed through established relationships, as those among long-term business partners. The second firm is based on legal frameworks and established procedures, which can be time-consuming and expensive, often necessitating judicial intervention to solve conflicts. The third type involves putting trust in a centralized entity, which can be anything from a financial institution to a digital platform. Although dependence on such third-party middlemen has aided the internationalization of many businesses, it also brings risks. Centralized control over information and resources can result in potential failures and breaches, needing complex auditing procedures and legal agreements.

In response to these issues, BCT became known as a game-changing fourth form of trust, decentralizing the storage of data and transaction records among different nodes. This major development enables players to rely on cryptographically secure transaction histories in distributed ledger technology (DLT) via consensus processes, fostering confidence among network participants. Each node runs the same version of the blockchain, increasing stability and transparency. Moreover, BCT enables smart contracts that automate the rules controlling transactions, settlements, and accounts.

Despite the promising potential of blockchain, many companies have failed to gain traction post-launch, mainly because current systems frequently lack a genuine trust deficit, reducing the need for blockchain interventions. Furthermore, enterprise blockchain ecosystems are typically created around quickly changing technologies that continue to compete for dominance. Designing these ecosystems requires traversing a vast set of architectural options, including business logic, consensus algorithms, smart contract frameworks, and tokenomics.
This paper introduces the Supply Chain Blockchain Design Framework (SCBDF), a methodology which is currently in the design stage, intended to help practitioners identify viable use cases for blockchain technology in supply chain, and aims to improve interoperability among existing platform participants while also encouraging collaboration across varied stakeholder environments.

2. Literature review:

BCT is a chain of interconnected, secured blocks that may contain all transaction details. Welfare (2019) provides both brief and thorough descriptions of Blockchain in his book "Commercializing Blockchain: Strategic Applications in the Real World." He describes Blockchain as "a trusted and efficient way of sharing data and transactions," and goes on to say, "Blockchain technology can be viewed as a distributed ledger of information, which maintains a continuously growing list of records, called blocks, secured from tampering and changes". Initially associated with cryptocurrency, Althabatah (2023) explained that BCT has evolved into a transformational force across multiple industries, holding tremendous potential in procurement and supply chain management. Masudin (2022) defined Blockchain as a decentralized and immutable ledger system, drastically altering the dynamics of information management. The immutable ledger technology ensures supply chain transparency, traceability, and security, addressing long-standing issues.

According to Saxena (2024), for procurement businesses to remain nimble in the face of a slew of interactions and transactions across several processes, BCT appears as an appropriate option, giving a solid foundation of trust, seamless communication, and increased value. As a part of Industry 4.0, it distinguishes apart from digital breakthroughs such as IoT, AI/ML, big data, and additive manufacturing due to its unprecedented importance in assuring visibility, accountability, and auditing within complicated procurement and supply chain contexts. Its properties as a transparent and irreversible distributed ledger considerably contribute to its practical significance for procurement, which is the business function most exposed to interactions with a wide range of internal and external stakeholders. Bang (2024) highlighted that blockchain's reliability improves industrial processes by allowing for automated decision-making and enhancing harmonization across stakeholders in the procurement value chain.

The design of BCT systems is based on a layered architecture:
Hardware Layer: This is the bottommost layer of a blockchain system. While most blockchain systems can be deployed without any specialized hardware, hardware can make the computation more efficient, provide extra security of the storage and computing environment (Arnone 2024).Data Storage Layer: when it comes to storing data, keeping it safe from modifications, and making it traceable, this is the most important part of a blockchain system. It is also responsible for providing availability and durability of data.

Communication Layer: Any blockchain system needs a mechanism for disseminating the transactions and blocks between the participants. This is especially important for large-scale permissionless blockchain systems. Chen (2024)) & Ada (2021) explained that the granularity of dissemination, protocol of communication, ordering guarantees, privacy and security guarantees, and propagation time are related to this layer. All computing devices participating in the deployment of a blockchain system can be divided into two categories according to their involvement in the dissemination: core nodes constituting the blockchain network and ‘‘client’’ computing devices.

Data Manipulation Layer: The main responsibilities of this layer include updating the blockchain and offering a search functionality for data. Since an update must be a coordinated decision in a decentralized environment with a lack of trust between individual participants, the consensus protocol plays a central role in all blockchain systems.
Contract Layer: Bandhu (2022) highlighted that BCT systems provide the ability to define contracts for creating and enforcing the rules among the participants of the network. This layer deals with executing transactions within the contract, as well as programming languages and execution environments. Application Layer: This is an abstraction of the application built atop a BCT system. While its specific design is outside the scope of a blockchain system, it defines the requirements that a blockchain system needs to satisfy (Li 2023).

3.Developing the Supply Chain Blockchain Design Framework (SCBDF)

After studying literature, the development of blockchain frameworks for supply chain management is a relatively new and underexplored topic. Our article bridges this gap introduces a Supply Chain Blockchain Design Framework (SCBDF), specifically tailored to address inefficiencies in e-procurement within supply chains. By leveraging BCT, SCBDF seeks to enhance transparency, efficiency, and traceability in procurement processes. This scientific approach will outline the strategic planning, technological integration, and optimization phases necessary for designing a robust blockchain framework.

3.1. Strategic Planning and Business Alignment for Supply Chain

a) Define Stakeholders and Use Cases
The first step involves identifying key stakeholders such as suppliers, manufacturers, distributors, and procurement entities. Understanding their roles enables the development of specific use cases including procurement transparency, supplier verification, and automated purchase order processing. This ensures that the blockchain implementation targets the unique needs of the supply chain ecosystem (Global market for blockchain technology, 2018-2025).

b) Align Blockchain Implementation with Supply Chain Goals
The BCT should be aligned with the supply chain’s goals—primarily in e-procurement—focusing on transparency, efficiency, and traceability. By establishing Key Performance Indicators (KPIs), such as reduced procurement cycle times and cost savings (Chen,2024), the blockchain system’s impact on the supply chain can be effectively measured and enhanced over time.

c) Assess Feasibility, Technology, and Legal Compliance
A critical step in developing the SCBDF is evaluating the feasibility of blockchain integration, considering technological scalability, transaction efficiency, and legal compliance. BCT must handle high transaction volumes and support smart contracts while maintaining data security and seamless integration with existing systems. Legal considerations, especially surrounding the enforceability of smart contracts, must also be addressed (Srivastava, 2023).

d) Establish Cooperation Agreements and Engage in Supply Chain Initiatives
Cooperation agreements with e-procurement platform providers, suppliers, and regulatory bodies are essential for fostering innovation and developing industry standards. Engagement in supply chain initiatives contributes to establishing best practices and widespread adoption of BCT-based e-procurement solutions.

3.2. Designing and Structuring Layers for Supply Chain

a) Analyze Physical Assets and Integrate Technological Support
Blockchain-enabled procurement begins with analyzing physical assets, such as inventory and supplier relationships, and integrating technologies like IoT for real-time tracking. IoT devices enhance inventory visibility, monitor supplier performance, and automate procurement processes, reducing errors and delays (Parkhi, 2024).

b) Develop E-Procurement Applications, Services, and APIs
Custom applications and services are developed to support e-procurement processes, such as automated purchase order creation and supplier onboarding. These services allow real-time procurement analytics, and bid management,

and support collaboration among stakeholders. APIs are essential to ensure interoperability between the BCT system and external platforms.

c) Define and Configure Digital Assets and Cyber-Physical Connectors
Digital assets, including procurement contracts and supplier profiles, are integrated into the BCT. Cyber-physical connectors link these digital assets to the physical supply chain, providing transparency and auditability throughout the procurement lifecycle (Balasubramanian, 2022). This ensures that digital and physical elements are in sync, creating a seamless procurement process.

3.3. Implementation of Blockchain Components for E-Procurement

a) Choose and Implement a Consensus Protocol
The choice of consensus protocol is crucial for maintaining the integrity of e-procurement transactions. Protocols such as Proof of Stake (PoS) can be implemented to ensure that transactions are processed efficiently and securely, ensuring agreement among participants in the network (Arnone, 2024).

b) Set Up Distributed Ledger Systems, Hash Functions, and Encryption
A distributed ledger system is implemented to store procurement transactions securely. Hash functions and encryption techniques are applied to protect sensitive data, such as procurement contracts and supplier information, ensuring data integrity throughout the procurement cycle.

c) Configure a Peer-to-Peer Network with Propagation and Verification Mechanisms
A decentralized peer-to-peer network is established to facilitate secure communication and information sharing among procurement stakeholders. Propagation mechanisms ensure timely dissemination of information, while verification mechanisms maintain the authenticity of shared data across the network (Li, 2023)
d) Deploy Infrastructure Components, Including IoT Integration
The infrastructure for e-procurement is deployed with virtual machines and containers that support blockchain nodes. IoT devices are integrated into the system to enhance real-time monitoring capabilities for inventory management and supplier performance.

4. Integration and Optimization for E-Procurement

a) Ensure Cohesion and Interoperability
It is essential to ensure that the various layers of the blockchain-based procurement system work together seamlessly (Parkhi, 2024). Data flow and communication between these layers should be continuously validated to ensure interoperability and system efficiency.

b) Optimize Framework for Scalability and Real-World Application
Optimization focuses on enhancing system performance, scalability, and responsiveness to real-world procurement challenges. Identifying and addressing bottlenecks ensures that the BCT solution remains efficient and adaptable.

c) Conduct Testing, Evaluation, and Refinement
Rigorous testing is performed to evaluate the BCT solution against KPIs, such as cycle time reduction and cost savings (Althabatah, 2023). Feedback from e-procurement participants is vital for refining the system and ensuring it meets business objectives.

d) Monitor Performance and Adapt to Evolving Needs
Continuous monitoring of the BCT solution allows for real-time adjustments based on performance metrics. The system is designed to adapt to changing business needs, regulatory updates, and technological advancements, ensuring its long-term relevance and functionality.

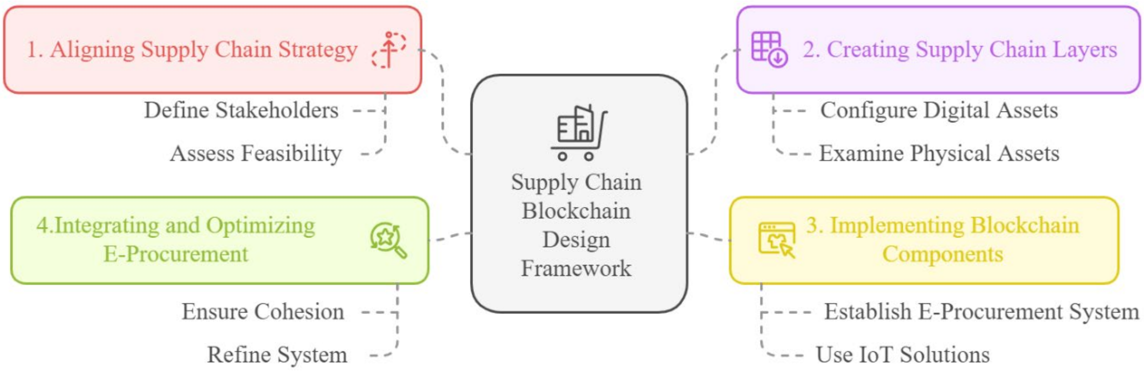

Figure 1. Supply Chain Blockchain Design Framework

5.Conclusion:

To conclude, our study consists in developing a BCT design framework applied to supply chain management, tailored to enhance efficiency, transparency and resilience. The novel framework addresses the critical challenges including data security, traceability and operational inefficiency. Our current research phase is devoted to refining the design in order to ensure its scalability and adaptability across various supply chain ecosystems.

As the system is actually in the design phase, future studies will focus on its practical applications in real supply chain scenarios. This should include testing the framework to approve its effectiveness and determining areas of optimization. Moreover, our ongoing work includes rigorous testing to assess its performance under a variety of operational conditions.

By providing insights into the practical implementation and outcomes, future research will contribute to the advancement of BCT-enabled supply chain systems. These steps will pave the way for a robust, reliable solution that aligns with industry needs and promotes sustainable practices in supply chain management.

References:

Ada N et al. Blockchain technology for enhancing traceability and efficiency in automobile supply chain—a case study. Sustain 13(24):1–21,(2021) . https://doi.org/10.3390/su132413667

Althabatah, A., Yaqot, M., Menezes, B., & Kerbache, L. , "Transformative Procurement Trends: Integrating Industry 4.0 Technologies for Enhanced Procurement Processes". Logistics, 7(3), (2023). https://doi.org/10.3390/logistics7030063

Arnone, G. , Blockchain Technology: The Backbone of Cryptocurrencies. In: Navigating the World of Cryptocurrencies. Contributions to Finance and Accounting. Springer, Cham,(2024). . https://doi.org/10.1007/978-3-031-69176-8_2

Balasubramanian S, Akila IS , Blockchain implementation for agricultural food supply chain using hyperledger fabric. J Intell Fuzzy Syst 43(5):5387–5398,(2022) . https://doi.org/10.3233/JIFS-211265

Bandhu KC, Litoriya R, Lowanshi P, Jindal M, Chouhan L, Jain S , Making drug supply chain secure traceable and efficient: a blockchain and smart contract-based implementation. Multimed Tools (2022) , Appl. https://doi.org/10.1007/s11042-022-14238-4

Bang, L.K. et al. (, Revolutionizing Organic Product Traceability: Utilizing Smart Contracts, NFT, IPFS and Distributed Ledgers for Transparent Organic Products Supply Chains. In: Saeed, K., Dvorský, J. (eds) Computer Information Systems and Industrial Management. CISIM 2024. Lecture Notes in Computer Science, vol 14902. Springer, Cham, 2024). . https://doi.org/10.1007/978-3-031-71115-2_13

Chen, Q., Chen, X., Li, S. et al. Blockchain-enabled supply chain finance model: a study of the dual-channel closed-loop supply chain of electronic products. Ann Oper Res 343, 87–124 (2024). https://doi.org/10.1007/s10479-024-06320-x

Global market for blockchain technology 2018-2025 | , Statista. (n.d.). Retrieved September 25, (2022) , from https://www.statista.com/statistics/647231/worldwideblockchain-technology-market-size/.

Li, S., Zhou, T., Yang, H., & Wang, P. , Blockchain-based secure storage and access control scheme for supply chain ecological business data: A case study of the automotive industry. Sensors (Basel), 23(16), 7036, .(2023). https://doi.org/10.3390/s23167036

Masudin, I., Rahmatullah, B. B., Agung, M. A., Dewanti, I. A., & Restuputri, D. P. , "Traceability System in Halal Procurement: A Bibliometric Review". Logistics, 6(4),(2022). . https://doi.org/10.3390/logistics6040067

M., Sehrawat, R., Daim, T., Shaygan, A, Technology assessment: Enabling Blockchain in hospitality and tourism sectors. Technol. Forecast. Soc. Chang. 169 (May), 120810, .(2021). https://doi.org/10.1016/j.techfore.2021.120810.

Parkhi, S., Karande, K., Purohit, Y. , Blockchain's Efficacy in Removing Obstacles for Humanitarian Supply Chains. In: Al Mubarak, M., Hamdan, A. (eds) Innovative and Intelligent Digital Technologies; Towards an Increased Efficiency. Studies in Systems, Decision and Control, vol 564. Springer, Cham, (2024). . https://doi.org/10.1007/978-3-031-70399-7_14

Saxena, R., Sharma, S., Saini, K.P., Agarwal, S. , From Greenwashing to Green Finance: Blockchain as a Catalyst for Transparency and Impact. In: Sharma, V., Gupta, M., Arora, N., Rocha, A. (eds) Blockchain's Transformative Potential of Financial Technology for Sustainable Futures. Information Systems Engineering and Management, vol 17. Springer, Cham, (2024). . https://doi.org/10.1007/978-3-031-70219-8_10

Srivastava, S. , : Prospective application of blockchain in mutual fund industry. In: Nayyar, A., Naved, M., Rameshwar, R. (eds.) New Horizons for Industry 4.0 in Modern Business. Contributions to Environmental Sciences & Innovative Business Technology. Springer, Cham, (2023). https://doi.org/10.1007/978-3-031-20443-2_6

Werbach, K. , The Blockchain and the New Architecture of Trust. The MIT Press.(2018). https://doi.org/10.7551/mitpress/11449.001.0001

Welfare A, (, "Commercializing Blockchain: Strategic Applications in the Real World". Wiley: Chichester 1st edition, UK,2019). .

Zaman, S. , A Systematic Review of ERP And CRM Integration For Sustainable Business And Data Management in Logistics And Supply Chain Industry. Frontiers in Applied Engineering and Technology, 1(01), 204–221,(2024). . https://doi.org/10.70937/faet.v1i01.36

Biographies:

Ikram LEBHAR is a Ph.D. Researcher at ENSAM School (Ecole Nationale Supérieure d'Arts et Métiers de Meknès), Moulay Ismaïl University, Morocco. She is an Industrial Engineer specializing in International Logistics. She received her Engineering Degree in Industrial Engineering in 2021 from ESITH School of Casablanca (Ecole Supérieure des Industries du Textile et Habillement), Morocco. Her research interest includes digital transformation applied to Industry 4.0 and the optimization of the global supply chain.

Afaf DADDA is a Professor at the Department of Industrial Engineering, ENSAM School (Ecole Nationale Supérieure d'Arts et Métiers de Meknès), Moulay Ismaïl University, Morocco. She obtained her Engineering Degree in Industrial Engineering in 2004 and her Ph.D. Degree in 2016 from the ENSAM-school, Moulay Ismaïl University, Morocco. Her current research focuses on decision support systems, artificial intelligence, renewable energy, and digital transformation applied to Industry 4.0.

Ilyas LHACHIMI is an Industrial Engineer who graduated in 2024 from ENSAM School (Ecole Nationale Supérieure d'Arts et Métiers de Meknès), Moulay Ismaïl University, Morocco.

Zakarya IMIOUSSAKA is an Industrial Engineer who graduated in 2024 from ENSAM School (Ecole Nationale Supérieure d'Arts et Métiers de Meknès), Moulay Ismaïl University, Morocco.

Latifa EZZINE is a Professor at the Department of Industrial Engineering, ENSAM School (Ecole Nationale Supérieure d'Arts et Métiers de Meknès), Moulay Ismaïl University, Morocco. She obtained her Ph.D. Degree in 2010 from the Faculty of Sciences, Moulay Ismaïl University, Morocco. Her current research focuses on statistics and artificial intelligence, modeling and optimization, control systems and telecommunications