



Blockchain in operations and supply Chain Management

Ali Emrouznejad¹ · Soumyadeb Chowdhury² · Prasanta Kumar Dey³

Published online: 30 June 2023

© The Author(s), under exclusive licence to Springer Science+Business Media, LLC, part of Springer Nature 2023

Blockchain technology (BCT) has emerged as an enabling technology that can provide traceability, provenance, and transparency in business operations across complex global supply chain ecosystems, where leanness, agility, and speed are crucial, in addition to achieving social sustainability. It is considered one of the most disruptive technologies representing a decentralized environment for transactions, self-executing digital contracts (smart contracts), and intelligent asset management over the Internet, providing a single view to the entities (users) involved in the transaction. Therefore, the key characteristics of BCT will significantly impact organizational governance, supply-chain relationships, operations strategy, digital transformation pathway, and existing supply-chain business models. When integrated with other technologies such as the Internet of Things, big data analytics, and artificial intelligence (AI), BCT will help increase the efficiency of the supply chain through agile data-driven decision-making based on high-quality data (stored in Blockchain), and further facilitating supply chain transparency that will also afford product traceability, authenticity, and legitimacy. This will enhance sub-supplier transparency, which will alleviate social sustainability problems in multi-tier supply networks.

Despite the potential of BCT for the field of Operations and Supply Chain Management (OSCM), it has thus far received extremely limited attention in the OSCM literature, except for a few studies reporting a systematic review of literature reflecting on the characteristics of the technology, potential drivers in a business environment, and technical challenges to deploy it. However, empirical evidence and research on developing new models and contemporary tools to assess several elements related to the technology, including but not limited to performance, organizational readiness, risk assessment, operations strategy, integration with existing ERP systems and supply chain business models, will facilitate deeper understanding of the benefits offered by the technology. This, in turn, will help managers

✉ Ali Emrouznejad
a.emrouznejad@surrey.ac.uk

¹ Surrey Business School, University of Surrey, Guildford, UK

² TBS Business School, Toulouse, France

³ Aston Business School, Aston University, Birmingham, UK

and relevant decision-makers systematically assess the impact of BCT on their respective organization and supply chain model. Furthermore, research into the application of BCT within the OSCM literature will require examining the relevance of existing theories and either developing new theories or extending existing theories that will facilitate a better understanding of this contemporary phenomenon and its impact on supply chain relationships, operations strategy, workforce management, business partnerships, value creation, social legislations, and business transparency.

This volume on “Blockchain in Operations and Supply Chain Management” of *Annals of Operations Research* features 16 research articles by esteemed authors. The opening of the volume includes a review article that provides a critical analysis of how blockchain and AI are integrated into the supply chain. The authors, *Charles, Emrouznejad, and Gherman (2023)*, present a comprehensive overview of the current literature on the topic, focusing on the use cases of blockchain and AI in supply chain management. They seek to answer important questions such as what current studies exist on this topic, what current applications of blockchain and AI are being utilized in the supply chain, and what areas of future research are necessary. Through their analysis, they have identified significant studies that have contributed to the development and growth of knowledge in the field of supply chain management through the integration of blockchain and AI.

The second article in this volume focuses on the impact of BCT on trust levels in the supply chain. *Yavaprabhas, Pournader, and Seurig (2023)* introduced supply chain models that are trusted by blockchain to investigate and comprehend the formation and distribution of trust among all participants in the supply chain ecosystem. This is followed by an article from *Xia, Zeng, Xing, Zhan, Hua Tan, and Kumar (2023)* who proposed and demonstrated the effectiveness of a mixed-integer programming model for blockchain-enabled fleet sharing. The model aims to achieve optimal drone routing to enhance supply chain sustainability. In the fourth article, *Vafadarnikjoo, Badri Ahmadi, Liou, Botelho, and Chalvatzis (2023)* examined the barriers to BCT adoption in manufacturing supply chains. Based on their findings, they suggested a set of action points to promote the acceptance and validation of this technology in emerging markets. By doing so, the research provides a pathway to successfully adopt BCT within supply chains and develop strategies aligned with the critical productivity mission of organizations.

This volume continues with an article from *Tsolakis, Schumacher, Dora, and Kumar (2023)*, who empirically studied the tuna fish supply chain in Thailand to explore and examine the impact of the co-implementation of AI and BCT to enhance operational performance and achieve sustainability. This research has proposed a unified framework that can assist organizations within the supply chain network to capture critical data. By doing so, organizations can effectively leverage the integration of AI and BCT. This is followed by an article from *Yadav, Singh, Raut, and Cheikhrouhou (2023)*. The authors have revealed that BCT will facilitate real-time information availability, supply chain transparency and traceability to achieve sustainable food security in the Indian agricultural supply chain. The research reveals the interrelationship between BCT adoption drivers, which will help to prioritize the context of using the technology to enhance communication and collaboration between supply chain partners, and in the same vein develop policies to empower the adopters within the supply chain network. In a similar context, *Samad, Sharma, Ganguly, Fosso Wamba, and Jain (2023)* classify BCT enablers as prominent, influencing, and resulting, and provide a decision-making framework for organizations operating in logistics

supply chains, where BCT has been popular. The authors provided a systematic avenue for organizations by introducing a decision-making framework to understand the rationale for adopting BCT (depending on the context and use-case), and the potential impact of the adoption (by mapping the relationships between the various forms of enablers to help prioritize the key BCT features to leverage within the selected use-cases).

The eighth article in this volume, authored by *Nayal, Raut, Narkhede, Priyadarshinee, Panchal, and Gedam (2023)* reveals that green and lean practices, supply chain integration, supply chain risks, internal and external conditions, regulatory support, innovation capability, and cost will positively influence BCT adoption, which will lead to sustainability performance within the agricultural supply chain in India. As a result, the research provides guidance on how organizations can implement BCT to achieve sustainability. In the same area but focusing on risk factors, *Narwane, Raut, Mangla, Dora, and Narkhede (2023)* have identified risk factors and their interrelationships resulting from the integration of big data analytics and blockchain technology in manufacturing supply chains. This information can assist managers in tactical and strategic policymaking. The research emphasizes that understanding the relationships between the various risk factors involved in BCT implementation is critical for productive and sustainable adoption of the technology.

In the tenth article, *Liu, Zhao, Lyu, and Yue (2023)* discuss the relationship between blockchain services and the strategic choices of competing firms and investigate the conditions for combining documental circulation by blockchain service. The research implies that BCT can improve service experience in documental activities, particularly for small firms, and constructs a game theory model to obtain optimal results for using blockchain services in documental activities. An article written by *Chaudhuri, Bhatia, Kayikci, Fernandes, and Fosso-Wamba (2023)* explores the strategies and factors that facilitate achieving social sustainability and mitigating risks in the supply chain. The importance of behavioural mechanisms to facilitate the purposeful adoption of BCT was studied through interviews with key stakeholders in four real-life BCT projects. Additionally, *Ghaemi Asl, Adekoya, and Rashidi (2023)* studied the dynamic connectedness and returns spillover between DLT stocks and sectoral stock returns for twelve sectors using quantile coherency and dynamic connectedness approaches. This research helps policymakers frame strategies that can empower technological firms with performance benefits and solidify the assurance for investors on investment benefits and safety.

Article thirteen in this volume shows that firm size is a key influencing factor in BCT adoption because large organizations have the resources and capabilities to manage and mitigate implementation risks, and therefore should develop strategic initiatives to implement the technology within the supply chain ecosystem, bringing smaller firms on board. In this article, authors *Chittipaka, Kumar, Sivarajah, Bowden, and Mohan Baral (2023)* employed the technology-organization-environment (TOE) framework and demonstrated that all eleven dimensions of the theoretical framework will influence the decision to adopt BCT within supply chains. Subsequently, *Dwivedi, Agrawal, Paul, and Pratap (2023)* in the next article, examined the organizational readiness to adopt blockchain within the manufacturing industries for product recovery systems, and in doing so, provided an impact-relations map unearthing the impact and correlation between the challenges. Their findings were supported by propositions, which will help operations managers to benchmark performance in blockchain-enabled supply chains.

The last two articles in this volume centre on BCT adoption and its role in evaluating and controlling the supply chain. Chowdhury, Rodriguez-Espindola, Dey, and Budhwar (2023) present a framework that can assist operations managers to assess the feasibility and need for BCT adoption, particularly for managing supply chain risks, and factors that will facilitate BCT adoption in this context. The research suggests that resilient supply chain practices and user-friendly implementation will facilitate BCT adoption in business operations plagued by volatility, uncertainty, complexity, and ambiguity. In the last article, Kamble, Gunasekaran, Subramanian, Ghadge, Belhadi, and Venkatesh (2023) study BCT adoption in the automotive industry employing dynamic capability as the theoretical lens and suggest that the technology can provide a competitive advantage through collaboration and reconfiguration in the supply chain upstream and downstream, contributing to sustainable supply chain performance.

In conclusion, we would like to express our gratitude to all the authors and reviewers who contributed to the success of this volume. While we regret that we were unable to include all submitted manuscripts, we hope that the feedback provided to the authors proved beneficial for their future work. We also want to extend our appreciation to Professor Endre Boros, Editor-in-Chief of *Annals of Operations Research*, for granting us the opportunity and providing us with unwavering support throughout the preparation of this volume.

In summary, blockchain and AI technologies are rapidly evolving, opening new avenues for working with data that were previously unimaginable. They are setting the pace of innovation and introducing a radical shift in every industry. On their own, blockchain and AI are cutting-edge technologies, but when combined, they can be truly revolutionary, of course, as long as such integration is underpinned by a problem-centric thinking approach. Each of them has the potential to improve the other's capabilities, allowing for better oversight and accountability.

Hence, we believe that the articles in this volume provide empirical evidence showing the significance of BCT to achieve sustainability and resilience through real-time information sharing, strengthening relationships between stakeholders, guiding transparent information flow, and providing frameworks to help translate theoretical knowledge into practical implementation. While the adoption of blockchain is still at a nascent stage from practitioners' perspectives, although there has been an exponential rise in research on the topic in operations and supply chain management, we propose the following research agenda.

1. Future studies need to examine the real-life implementation of blockchain across various business sectors to understand which dimensions of the technology are difficult to implement from an organizational perspective. Additionally, studies should comprehensively identify the critical success factors to assess productive implementation of the technology.
2. While many existing studies have focused on the features of the technology and their implications on business operations to achieve productivity, sustainability, and resilience, it is pivotal to comprehensively examine which business operations, functions, activities, and sectors will reap the most benefits. The uptake of technology to support specific scenarios and use-cases requires clarity and further investigation.
3. Research should also turn its attention to applications of blockchain technology such as smart contracts within the OSCM domain to examine the relevance of existing operations research optimization models and the need to either integrate or evolve these

- models in that context. For example, how can tools enabled by blockchain facilitate multistakeholder relationships in international business ecosystems?
4. The role of blockchain technology to achieve supply chain resilience and the factors that will drive these warrants further exploration. In this context, studies should consider what strategies organizations within the supply chain should employ to achieve resilience through the adoption of blockchain applications, and conversely, how blockchain can inhibit supply chain resilience.
 5. Supply chain diligence is an emerging topic, and the impact of blockchain tools and platforms to achieve due diligence (i.e., with the aim of preventing or ending certain human rights or environmental violations) needs to be examined. Such studies should provide evidence of how this technology can help companies comply with policies and regulations and make all the information auditable and accountable.
 6. Research is also gaining momentum on the impact of blockchain technology to achieve sustainable development goals. More studies should examine this theme to critically understand how the technology can facilitate addressing specific SDGs and at what cost. For example, instead of just examining sustainability performance, studies that provide clear evidence on implications towards selected SDGs will help in developing cases where, how, and why the technology can be adopted.
 7. A question that has arisen in recent years is why BCT implementation is failing and why organizations are sceptical to adopt it. This theme needs to be critically explored to better understand the role of different stakeholders and strategies to enable organizations to adopt the technology. This underscores the need to go beyond examining drivers and barriers but conduct in-depth analysis of failed implementations.
 8. Blockchain analytics is also an emerging theme that will leverage Industry 4.0 technologies such as Internet of Things, cloud computing, business analytics, and AI. The utility, relevance, and application of blockchain analytics are an uncharted territory for organizations. Therefore, studies should understand the interplay between the integration of these technologies and unearth a framework that will facilitate data-driven agile decision-making using the data recorded in blockchains.

References

- Charles, V., Emrouznejad, A., & Gherman, T. (2023). A critical analysis of the integration of blockchain and artificial intelligence for supply chain. *Annals of Operations Research*. <https://doi.org/10.1007/s10479-023-05169-w>.
- Chaudhuri, A., Bhatia, M. S., Kayikci, Y., Fernandes, K. J., & Fosso-Wamba, S. (2023). Improving social sustainability and reducing supply chain risks through blockchain implementation: Role of outcome and behavioural mechanisms. *Annals of Operations Research*. <https://doi.org/10.1007/s10479-021-04307-6>.
- Chittipaka, V., Kumar, S., Sivarajah, U., Bowden, J. L. H., & Baral, M. M. (2023). Blockchain Technology for Supply Chains operating in emerging markets: An empirical examination of technology-organization-environment (TOE) framework. *Annals of Operations Research*. <https://doi.org/10.1007/s10479-022-04801-5>.
- Chowdhury, S., Rodriguez-Espindola, O., Dey, P., & Budhwar, P. (2023). Blockchain technology adoption for managing risks in operations and supply chain management: Evidence from the UK. *Annals of Operations Research*. <https://doi.org/10.1007/s10479-021-04487-1>.
- Dwivedi, A., Agrawal, D., Paul, S. K., & Pratap, S. (2023). Modeling the blockchain readiness challenges for product recovery system. *Annals of Operations Research*. <https://doi.org/10.1007/s10479-021-04468-4>.

- Ghaemi Asl, M., Adekoya, O. B., & Rashidi, M. M. (2023). Quantiles dependence and dynamic connect- edness between distributed ledger technology and sectoral stocks: Enhancing the supply chain and investment decisions with digital platforms. *Annals of Operations Research*. <https://doi.org/10.1007/s10479-022-04882-2>.
- Kamble, S. S., Gunasekaran, A., Subramanian, N., Ghadge, A., Belhadi, A., & Venkatesh, M. (2023). Block- chain technology's impact on supply chain integration and sustainable supply chain performance: Evidence from the automotive industry. *Annals of Operations Research*. <https://doi.org/10.1007/s10479-021-04129-6>.
- Liu, J., Zhao, H., Lyu, Y., & Yue, X. (2023). The provision strategy of blockchain service under the sup- ply chain with downstream competition. *Annals of Operations Research*. <https://doi.org/10.1007/s10479-022-05034-2>.
- Narwane, V. S., Raut, R. D., Mangla, S. K., Dora, M., & Narkhede, B. E. (2023). Risks to big data analyt- ics and blockchain technology adoption in supply chains. *Annals of Operations Research*. <https://doi.org/10.1007/s10479-021-04396-3>.
- Nayal, K., Raut, R. D., Narkhede, B. E., Priyadarshinee, P., Panchal, G. B., & Gedam, V. V. (2023). Ante- cedents for blockchain technology-enabled sustainable agriculture supply chain. *Annals of Operations Research*. <https://doi.org/10.1007/s10479-021-04423-3>.
- Samad, T. A., Sharma, R., Ganguly, K. K., Wamba, S. F., & Jain, G. (2023). Enablers to the adoption of block- chain technology in logistics supply chains: Evidence from an emerging economy. *Annals of Operations Research*. <https://doi.org/10.1007/s10479-022-04546-1>.
- Tsolakis, N., Schumacher, R., Dora, M., & Kumar, M. (2023). Artificial intelligence and blockchain imple- mentation in supply chains: A pathway to sustainability and data monetisation? *Annals of Operations Research*. <https://doi.org/10.1007/s10479-022-04785-2>.
- Vafadarnikjoo, A., Badri Ahmadi, H., Liou, J. J., Botelho, T., & Chalvatzis, K. (2023). Analyzing block- chain adoption barriers in manufacturing supply chains by the neutrosophic analytic hierarchy process. *Annals of Operations Research*. <https://doi.org/10.1007/s10479-021-04048-6>.
- Xia, Y., Zeng, W., Xing, X., Zhan, Y., Tan, K. H., & Kumar, A. (2023). Joint optimisation of drone rout- ing and battery wear for sustainable supply chain development: A mixed-integer programming model based on blockchain-enabled fleet sharing. *Annals of Operations Research*. <https://doi.org/10.1007/s10479-021-04459-5>.
- Yadav, V. S., Singh, A. R., Raut, R. D., & Cheikhrouhou, N. (2023). Blockchain drivers to achieve sus- tainable food security in the Indian context. *Annals of Operations Research*. <https://doi.org/10.1007/s10479-021-04308-5>.
- Yavaprabhas, K., Pournader, M., & Seuring, S. (2023). Blockchain as the “trust-building machine” for sup- ply chain management. *Annals of Operations Research*. <https://doi.org/10.1007/s10479-022-04868-0>.

Publisher's Note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.