Application of Blockchain Technology in Optimizing E-tailer Supply Chain Costs: Public and Consortium Blockchains

Sahani Rathnasiri, Sardar M. N. Islam
Institute of Sustainable Industries and Liveable Cities, Victoria University, Australia
liyanawaduge.rathnasiri@live.vu.edu.au, Sardar.Islam@vu.edu.au

Pritee Ray
Department of Operations Management, Indian Institute of Management Ranchi, Jharkhand, India
pritee.r@iimranchi.ac.in

Abstract

Blockchain technology implementation is becoming an increasing trend in supply chain operations around the globe. However, the blockchain costs and its impact on the supply chain operational outcomes are still unclear in the literature. Specially, online retail (e-tailer) supply chains can derive significant benefits from blockchain implementation, as they heavily rely on accurate information and proper information sharing among the supply chain members, who are located distantly and externally. The rapid sales growth in the e-tailer supply chains further reinforces the importance of identifying the costs of implementing a blockchain system to derive insights for strategic decisions to improve the operational effectiveness of these supply chains. Therefore, we investigate the cost determinants of public and consortium blockchains in an operational framework of the e-tailer supply chain. The findings emphasize that the transaction fee is a determining factor, and the public blockchain operations are costly in long term operations than the consortium blockchain operations.

Keywords
Blockchain technology, Consortium blockchain, Cost minimization, E-tailer supply chain, Public blockchain

1. Introduction
E-commerce supply chain operations are growing at an exponential rate around the globe due to the lifestyle changes of consumers towards online shopping, thus enabling a large number of e-tailing networks (Li et al. 2020). The present global pandemic skyrocketed the online retailing as consumers have shifted towards online shopping even for the basics such as groceries (Savage 2020). It also generates extreme levels of uncertainty for the e-commerce supply chain operations, along with the increased demand levels (Elrhim and Elsayed 2020). Therefore, e-commerce supply chains require innovative strategies to improve and streamline the operations, which can be obtained by implementing disruptive technologies such as blockchain. Blockchain is one of the best disruptive technologies, which has the potential to enhance the supply chain business processes and transform the traditional operations towards improved supply chain performances (Wamba et al. 2020). The inherent features of blockchain such as decentralized operations, immutable data storage and management create an impact on the supply chain relationships, data management, and enhanced visibility of the supply chain operations (Wang et al. 2019). For e-commerce supply chains, effective information sharing is an essential requirement, as the operations mainly rely on the information than the physical attributes, which blockchain technology showcase a promising impact. The exponential growth of the e-tailer networks increases competition among the supply chains, thereby emphasizing the need for minimizing costs while streamlining the processes (Strand and Strandänger 2016). Even though the benefits of blockchain are widely identified, the investigations of blockchain applications in the supply chains are still in primary stages (Queiroz et al. 2019, Schmidt and Wagner 2019, Wamba and Queiroz 2020) and the knowledge related to the implications of blockchain in supply chain management is scant (Treiblmaier 2018). Moreover, no study is found in the literature, which explores the cost analysis of blockchain implementation in supply chain networks.

Blockchains are segregated into three main frameworks based on their operational setting and the level of decentralization as public, private and consortium blockchains (Zheng et al. 2017, Dib et al. 2018). The different blockchain systems incorporate varied operational aspects, which generate diverse operational costs of implementation and management. Therefore, it is imperative to know the blockchain management and operational costs in public, private and consortium blockchain frameworks. In supply chain operations, multiple organizations operate, which creates the necessity to provide peer-to-peer operation for all supply chain members; therefore, consortium blockchain and public blockchains are more suited than the private blockchains (Manupati et al. 2020). Based on all these facts, in this study, we investigate the impact of different blockchain systems and their costs on minimizing the e-tailer costs and thereby improving the supply chain performances through this study. We analyze what the main cost parameters that are affecting e-tailer supply chain costs in public and consortium blockchain frameworks. We adopt optimization modeling approach in identifying the costs in both public and consortium blockchains and compare the results to derive implications from the models on the operational decisions of the e-tailer supply chains.

This study derives significant theoretical and pragmatic contributions. Firstly, the findings from this study generate new knowledge in the field of supply chain management as we discuss the blockchain costs and its implications towards e-tailer supply chain operations, which is not explored in the previous literature. Secondly, the model implications derive the important cost determinants of the blockchain implementation within the e-tailer supply chain operations and further augment the knowledge related to blockchain system implementation and business operations. The findings of this study produce significant insights for decision-makers in the actual e-tailer organizations related to blockchain costs and their impact on improving their supply chain operations.

2. Literature Review

2.1 Characteristics of the blockchain system

Blockchain is first introduced with the cryptocurrency-based money exchange system by Satoshi Nakamoto in 2008 (Liu and Li 2019). However, it has gained wide attention in the later years from industry practitioners in different fields such as finance, healthcare, supply chain, logistics, etc. (Helo and Shamsuzzoha 2020). There are critical attributes, which define the uniqueness of blockchain architecture (Table 1) that enables the operational effectiveness of supply chains.

Table 1. Main attributes of the blockchain system

Attribute	Description
Decentralization	Peer to peer network with data shared through all participants of the system and validated without a central authority. Therefore, the blockchain acts as a Distributed Ledger.
Anonymity	Identity of the user remains anonymous.
Immutability	Data stored in the blockchain is verified and validated through the Cryptographic mechanism, and therefore, data cannot be tampered or altered.
Persistency	The capability of quick validation of transaction and admitted transactions into the system cannot be deleted.
Auditability	Quickly verifiable transactions and the capability to track the transaction from the inception

Source: (Zheng et al. 2017, Perboli et al. 2018)

Blockchain acts as a distributed ledger, which holds all information about transactions that occurred within the supply chain, in a chain of blocks and operated in a decentralized setting (Dolgui et al. 2019). It enables a higher level of transparency and traceability of the data circulation within the supply chain. As the information in each block is verified with a consensus mechanism, the information cannot be altered and therefore, the blockchain is immutable from external parties (Subramanian 2017). Blockchain systems can also safeguard the players, who share their sensitive information, thus enabling a trusted and secure operational setting for supply chain operations. Therefore, asymmetric information among supply chain members gets reduced (Nakasumi 2017).

Smart contracts are essential aspects amalgamated with blockchain systems. The smart contract is automatically executed when the contract clauses, terms and conditions are met in which these conditions and clauses are pre-written into the computer program (Dib et al. 2018, Mao et al. 2019, Zheng et al. 2020). The smart contract eliminates the "Trusted Third Party", who manages the conventional contract and, therefore, allows cost reduction and peer-to-peer operation within the blockchain system (Hu et al. 2019, Zheng et al. 2020).

2.2 Analysis of Blockchain Applications in Supply Chain Studies

The literature related to blockchain and supply chain management indicates an increasing trend even though blockchain is not a widely applied application by supply chain organizations (Bai and Sarkis 2020). Literature related to blockchain applications in supply chain management are primarily focused on the improvements related to the transparency, trust, information sharing, traceability and tracking.

Bai and Sarkis (2020) investigated the blockchain adaptation in resolving transparency issues of sustainable supply chain operations, where the findings illustrate a framework for supply chain decision-makers to derive an appraisal model based on blockchain implementation. Wamba et al. (2020) have analyzed the determinants of blockchain adoption to the supply chain outcomes through empirical data gathered in India and the USA context. The findings of this study indicate that the blockchain improves supply chain performances, and the main determinants are knowledge sharing and trading partner pressure. The relationship between the blockchain enablers and the agriculture supply chain are discussed by Kamble et al. (2020) based on an empirical analysis. They have identified 20 blockchain enablers and found that the traceability is the most significant blockchain enabler for the agriculture supply chain operations. Longo et al. (2019) have analyzed how to improve trust and information sharing by deploying a public blockchain system, where the authors have considered an Etherem like UnicalCoin blockchain system. Within the analysis of the simulation of their study, transaction fees are taken as an important factor of blockchain operations.

Several studies have incorporated smart contract development to improve supply chain operations. Wang et al. (2020) have designed a smart contract to enhance the traceability and information sharing of precast construction supply chains considering ordering, delivery, production costs, where the smart contract conditions are analyzed through algorithms. Dolgui et al. (2019) have designed a smart contract to improve flow shop scheduling of supply chain operations using optimal control-based algorithms. Manupati et al. (2020) designed a smart contract within a consortium blockchain framework for a sustainable supply chain operation in effectively managing emission costs. However, the authors did not consider the implementation and management costs of blockchain in their model.

Nevertheless, no evidence is found in the literature that has investigated the blockchain costs and its impact on operational outcomes such as cost optimization in the e-commerce supply chains. Furthermore, no study is found in the literature related to the comparison of the blockchain costs between public and consortium blockchain operations, which is an important area to investigate as these blockchain systems have different implications. Therefore, we explore how the blockchain costs in public and consortium blockchains affect the overall supply chain costs of the e-tailer supply chains.

3. E-tailer Supply Chain Model

We formulate an optimization model considering the operational and blockchain costs of the small/medium scale e-tailer supply chain including a single e-tailer, multiple suppliers and Third-party Logistics (3PL) operators. The e-tailer receives the demand according to the customer orders, and then the e-tailer place the order to the relevant suppliers. The suppliers manufacture or obtain the required order quantity from their inventory, and then the Third-party Logistics (3PL) operators deliver goods to the customer's doorstep. We include blockchain costs into this operational setting and analyze the cost determinants of public and consortium blockchain systems. The model objectives are formulated based on cost minimization. In this analysis, we consider three suppliers (S1, S2, S3) and two 3PL operators (3PL 1, 3PL 2) within a multi-period operational framework (Figure 1).

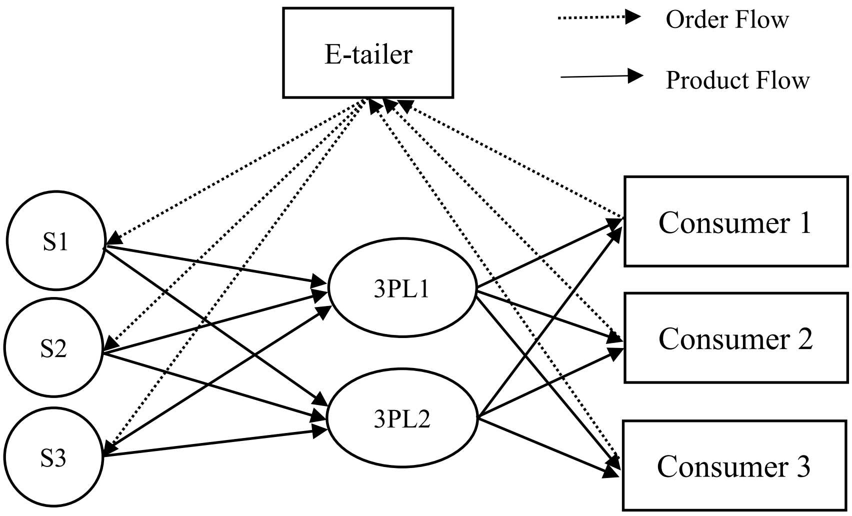

Figure 1. The operational flow of the e-tailer supply chain

The objective function of the above e-tailer supply chain is formulated based on the operational costs and the blockchain costs as below.

$$Minimize\ C_{total} = \left[\begin{array}{l} \sum_{i=1}^{i=12}\sum_{s=1}^{s=3}\left[\left\{\left(C_{i,s}^{m}\cdot a_{i,s}\right)+\left(C_{i,s}^{I}\cdot b_{i,s}\right)+C_{i,s}^{\text{var}}+\left(C_{i,s}^{tra}\cdot n_{i,s}\right)\right\}\right] \\ +\sum_{i=1}^{i=12}\sum_{d=1}^{d=2}\left[\left\{\left(C_{i,d}^{D}\cdot d_{i,s}\right)+C_{i,d}^{\text{var}}+\left(C_{i,d}^{tra}\cdot d_{i,s}\right)\right\}\right] \\ +\sum_{i=1}^{i=12}\left[\left\{\left(P_{i,s}^{S}\cdot n_{i,s}\right)+\left(P_{i,d}^{D}\cdot d_{i,s}\right)+C_{i,e}^{\text{var}}+C^{Investment}+C_{i,e}^{tra}\left(n_{i,s}+d_{i,s}\right)\right\}\right] \end{array} \right] \quad [1]$$

Subject to:

$$b_{i,s} = a_{i,s} - n_{i,s} \quad [2]$$

$$\sum_{i=1}^{i=12}\sum_{s=1}^{s=3} n_{i,s} \geq D_i \quad [3]$$

$$\sum_{i=1}^{i=12}\sum_{d=1}^{d=2} d_{i,s} \geq D_i \quad [4]$$

<u>Sets</u>

i = Number of periods ($i = (1,2,..........12)$)

s = Number of suppliers

d = Number of 3PL operators

<u>Parameters</u>

$C_{i,s}^{m}$ = The manufacturing cost per unit of the supplier s in each period i

$C_{i,s}^{I}$ = The inventory holding cost per unit of the supplier s in each period i

$C_{i,d}^{D}$ = The delivery cost per unit of the 3PL operator d in each period i

$C_{i,s}^{\text{var}}$ = The blockchain system management cost of the supplier s in each period i

$C_{i,d}^{\text{var}}$ = The blockchain system management cost of the 3PL operator d in each period i

$C_{i,e}^{\text{var}}$ = The blockchain system management cost of e-tailer in each period i

$C_{i,s}^{tra}$ = The transaction fee paid by the supplier s in each period i

$C_{i,d}^{tra}$ = The transaction fee paid by the 3PL operator d in each period i

$C_{i,e}^{tra}$ = The transaction fee paid by the e-tailer in each period i

$C^{Investment}$ = The investment costs of the blockchain system

$P_{i,s}^{S}$ = Unit ordering cost paid by the e-tailer to product supplier s in each period i

$P_{i,d}^{D}$ = Unit service fee paid by the e-tailer to the 3PL operator d in each period i

D_i = Consumer demand in each period i

Variables

$a_{i,s}$ = The number of units manufactured in each period i by the supplier s

$b_{i,s}$ = The inventory level in each period i by the supplier s

$n_{i,s}$ = The order quantity levels in each period i by the supplier s

$d_{i,s}$ = The delivery quantities in each period by the 3PL operator d

C_{total} = The total e-tailer supply chain cost

We consider that the e-tailer bears the blockchain investment costs as he is the main link to the online supply chain operations. The blockchain system management costs include the cloud storage costs, onboarding costs, equipment and system maintenance costs. In this study, the public blockchain platform is based on Ethereum, and the consortium blockchain is a cloud-based operating system developed based on client requirements. The transaction fees in the public and consortium blockchain are vastly different. In the Ethereum blockchain operations, the transaction fee is determined based on gas price and the amount of gas spent on the transactions. In this model, we have only considered financial payments as the transactions, which, therefore, require a comparatively lesser gas amount for processing (Rimba et al. 2018). The transaction fee of the consortium blockchain is determined based on the variable operational costs related to transactions (e.g., Audit costs, cloud storage costs per GB) (Ernst & Young 2019).

4. Data and Results Analysis

We gather data related to blockchain costs from Ernst & Young (2019). It includes the blockchain investment costs, system maintenance costs as well as the transaction costs. The data are related to real-world operational requirements, and the costs are differentiated based on transaction volume, transaction size, consensus protocol and the node hosting method. We obtain Ether gas prices of the Ethereum blockchain from the Ether Gas Station (https://ethgasstation.info/), which also has been referred by Longo et al. (2019) in their study. We analyze the results based on 12 years of data. As the model is a Mixed Integer Linear Programming model, we use an optimization solver tool to conduct computer experiments and derive the results. We programmed the model using AMPL and solved using GUSEK (Version 4.65), on Windows 10, a 64-bit operating system with 8 GB RAM. GUSEK is open-source, free software, which is widely used in resolving large scale linear programming and mixed-integer linear programming problems (http://gusek.sourceforge.net/gusek.html). It uses Branch and Cut method to generate optimal solutions, and accordingly, output files are created.

Based on the optimal solutions generated for the consortium and public blockchain models, the results indicate that the $C_{total}(Public) > C_{total}(Consortium)$. However, no significant difference between $C_{total}(Public)$ and $C_{total}(Consortium)$ is derived in this numerical illustration based on the 12 years of data, which needs to be further explored to identify the reasons for this result (Figure 2). The results suggest that the public blockchain implemented supply chain costs are 2% higher than the consortium blockchain implemented supply chain. One of the main reasons is that the public blockchain investment costs are lesser in Ethereum as it is an open-source operational platform than the consortium blockchain, which will be specially developed for the requirement of the supply chain. However, transaction fees are comparatively higher in the Ethereum platform (Average 4 times higher than the transaction fees of consortium blockchain in the numerical illustration), which depends on the Gas price on the current Ethereum market.

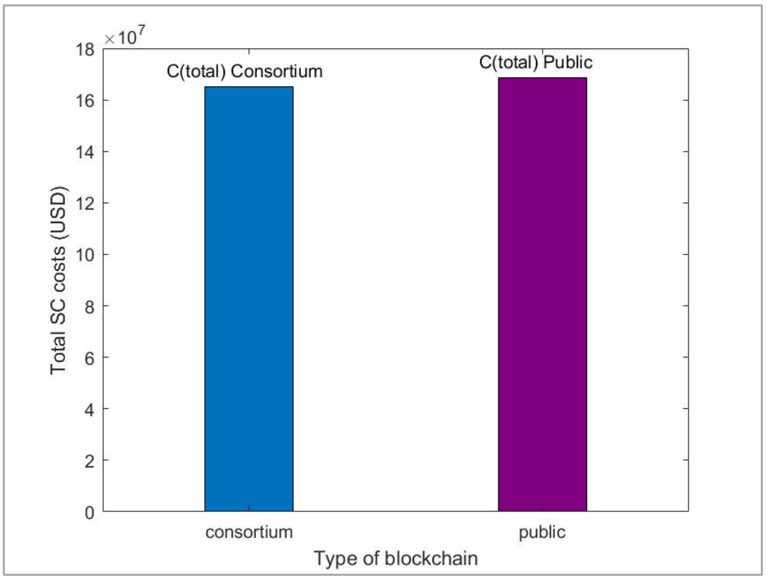

Figure 2. Total supply chain costs comparison of the public and consortium blockchain systems

We have further analyzed the individual players' total costs, where we observe that the highest impact of the blockchain costs is on 3PL operators (14% increase in public blockchain than the consortium blockchain). In comparison, it has only increased by 1% for the suppliers and 2% for the e-tailer in the public blockchain. As the operational costs of the 3PL operators are comparatively lower than the suppliers in the numerical data used for this study, the impact of blockchain system costs generates a higher effect on the total costs of 3PL operators. Therefore, when the supply chain members have lower operational costs, the impact of transaction fees and blockchain system management costs has a more substantial influence on the total supply chain costs.

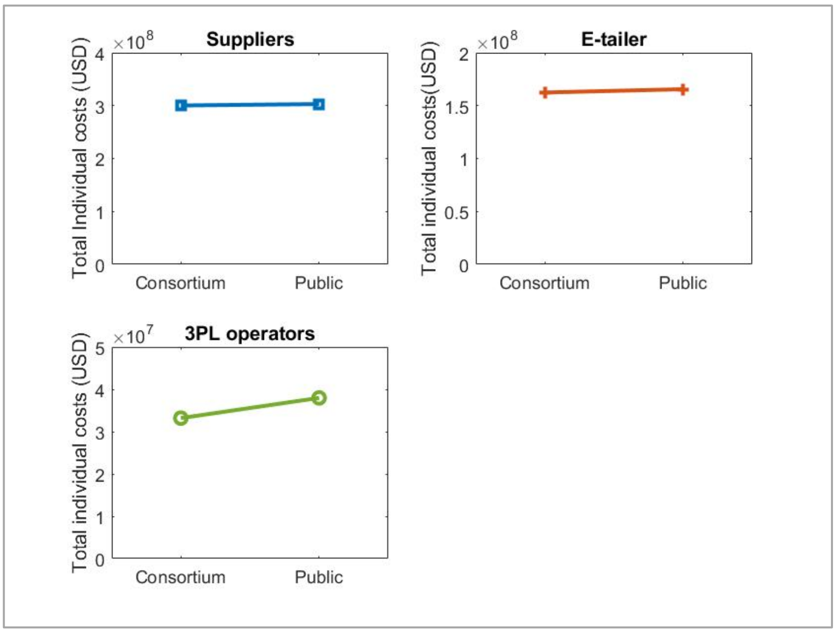

Figure 3. Comparison of total individual costs of the suppliers, e-tailer and the 3PL operators

Next, we have performed a sensitivity analysis to explore the impact of transaction fees on the supply chain costs of the Ethereum blockchain system. As transaction fees are determined based on the gas prices of the market, it is imperative to identify the impact of transaction fee on the total supply chain costs.

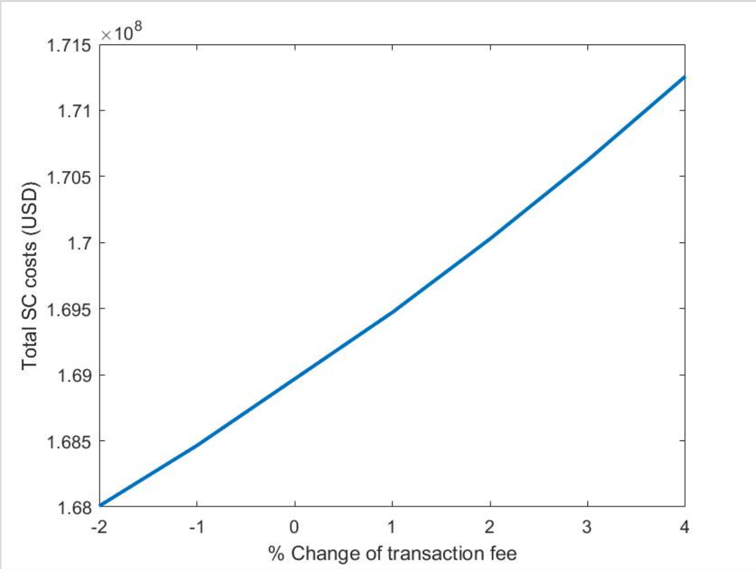

Figure 4. Impact of the transaction fee of public blockchains on the total costs of the e-tailer supply chain

The transaction fee affects the total supply chain costs (Figure 4), and accordingly, supply chain costs increases if the gas prices increase over time in public blockchains. In contrast, the transaction fee is getting reduced over time in consortium blockchain systems, as it depends on the internal variable costs of the system. Therefore, in the long run, public blockchain adoption is costly for e-tailer supply chains than the consortium blockchain operations.

5. Conclusion

This paper investigates the impact of blockchain implementation on the e-tailer supply chain costs, considering the public and consortium blockchain settings, as these supply chains are searching for technology-based innovation for their supply chain improvements. The blockchain investment costs, blockchain system management costs and transaction fees are considered in both blockchain systems, and we integrated them within a multi-period operational framework to analyze the impact. The results indicate that the public blockchain adopted supply chain costs are higher than the consortium adopted blockchain system; however, it does not showcase a significant difference. The main reasons are the transaction fees, and the investment costs of the public and consortium systems as the transaction fee is higher in the public blockchain system while the investment cost is lower. However, the transaction fee of a public blockchain like Ethereum has a positive relationship with the total supply chain costs as it depends on the gas price, which can either fluctuate over the years or increase/decrease. Therefore, the transaction fee is a significant cost determinant, which differentiates the outcomes of the e-tailer supply chain operations. As this study has not considered the actual data, the findings of this study can be applied to actual e-tailer organizational settings through which e-tailer organizations can derive organizational implications in the future. Furthermore, we can adopt the findings of this study in other supply chain sectors such as manufacturing, 4PL and 5PL supply chains to study the impact of blockchain costs on their supply chain outcomes.

References

Bai, C. and Sarkis, J. A supply chain transparency and sustainability technology appraisal model for blockchain technology. *International Journal of Production Research*: 1-21,2020.

Dib, O., Brousmiche, K.-L., Durand, A., Thea, E. and Hamida, E. B. Consortium blockchains: Overview, applications and challenges. *International Journal On Advances in Telecommunications* 11(1&2),2018.

Dolgui, A., Ivanov, D., Potryasaev, S., Sokolov, B., Ivanova, M. and Werner, F. Blockchain-oriented dynamic modelling of smart contract design and execution in the supply chain. *International Journal of Production Research*: 1-16,2019.

Elrhim, M. A. and Elsayed, A. The Effect of COVID-19 Spread on the E-Commerce Market: The Case of the 5 Largest E-Commerce Companies in the World. *SSRN*, http://dx.doi.org/10.2139/ssrn.3621166,2020.

Ernst & Young Total Cost of Ownership for Blockchain Solutions. https://www.ey.com/Publication/vwLUAssets/ey-total-cost-of-ownership-for-blockchain-solutions/$File/ey-total-cost-of-ownership-for-blockchain-solutions.pdf,2019.

Helo, P. and Shamsuzzoha, A. Real-time supply chain—A blockchain architecture for project deliveries. *Robotics and Computer-Integrated Manufacturing* 63: 101909,2020.

Hu, W., Fan, Z. and Gao, Y. Research on Smart Contract Optimization Method on Blockchain. *IT Professional* 21(5): 33-38,2019.

Kamble, S. S., Gunasekaran, A. and Sharma, R. Modeling the blockchain enabled traceability in agriculture supply chain. *International Journal of Information Management* 52,2020.

Li, M., Shao, S., Ye, Q., Xu, G. and Huang, G. Q. Blockchain-enabled logistics finance execution platform for capital-constrained E-commerce retail. *Robotics and Computer-Integrated Manufacturing* 65: 101962,2020.

Liu, Z. and Li, Z. A blockchain-based framework of cross-border e-commerce supply chain. *International Journal of Information Management* 52,2019.

Longo, F., Nicoletti, L., Padovano, A., d'Atri, G. and Forte, M. Blockchain-enabled supply chain: An experimental study. *Computers & Industrial Engineering* 136: 57-69,2019.

Manupati, V. K., Schoenherr, T., Ramkumar, M., Wagner, S. M., Pabba, S. K. and Inder Raj Singh, R. A blockchain-based approach for a multi-echelon sustainable supply chain. *International Journal of Production Research* 58(7): 2222-2241,2020.

Mao, D., Hao, Z., Wang, F. and Li, H. Novel automatic food trading system using consortium blockchain. *Arabian Journal for Science and Engineering* 44(4): 3439-3455,2019.

Nakasumi, M. *Information sharing for supply chain management based on block chain technology*. 2017 IEEE 19th Conference on Business Informatics (CBI), IEEE,2017.

Perboli, G., Musso, S. and Rosano, M. Blockchain in logistics and supply chain: A lean approach for designing real-world use cases. *IEEE Access* 6: 62018-62028,2018.

Queiroz, M. M., Telles, R. and Bonilla, S. H. Blockchain and supply chain management integration: a systematic review of the literature. *Supply Chain Management: An International Journal*,2019.

Rimba, P., Tran, A. B., Weber, I., Staples, M., Ponomarev, A. and Xu, X. Quantifying the cost of distrust: Comparing blockchain and cloud services for business process execution. *Information Systems Frontiers*: 1-19,2018.

Savage, M. (2020). Online retail COVID-19 impact: e-commerce skyrockets. Retrieved 20 May 2020, https://www.the-future-of-commerce.com/2020/04/20/online-retail-covid-19-impact-e-commerce-skyrockets/, from https://www.the-future-of-commerce.com/2020/04/20/online-retail-covid-19-impact-e-commerce-skyrockets/.

Schmidt, C. G. and Wagner, S. M. Blockchain and supply chain relations: A transaction cost theory perspective. *Journal of Purchasing and Supply Management* 25(4): 100552,2019.

Strand, J. and Strandänger, L. A case study on how an e-tailer can use a multiple criteria ABC analysis to identify risk in the selection of suppliers. Stockholm.2016.

Subramanian, H. Decentralized blockchain-based electronic marketplaces. *Communications of the ACM* 61(1): 78-84,2017.

Treiblmaier, H. The impact of the blockchain on the supply chain: a theory-based research framework and a call for action. *Supply Chain Management: An International Journal* 23(6): 545-559,2018.

Wamba, S. F. and Queiroz, M. M. Blockchain in the operations and supply chain management: Benefits, challenges and future research opportunities. *International Journal of Information Management* 52: 1-9,2020.

Wamba, S. F., Queiroz, M. M. and Trinchera, L. Dynamics between blockchain adoption determinants and supply chain performance: An empirical investigation. *International Journal of Production Economics*, (229): 1-15,2020.

Wang, Y., Han, J. H. and Beynon-Davies, P. Understanding blockchain technology for future supply chains: a systematic literature review and research agenda. *Supply Chain Management: An International Journal* 24(1): 62-84,2019.

Wang, Z., Wang, T., Hu, H., Gong, J., Ren, X. and Xiao, Q. Blockchain-based framework for improving supply chain traceability and information sharing in precast construction. *Automation in Construction* 111: 103063,2020.

Zheng, Z., Xie, S., Dai, H.-N., Chen, W., Chen, X., Weng, J. and Imran, M. An overview on smart contracts: Challenges, advances and platforms. *Future Generation Computer Systems* 105: 475-491,2020.

Zheng, Z., Xie, S., Dai, H., Chen, X. and Wang, H. *An overview of blockchain technology: Architecture, consensus, and future trends*. 2017 IEEE international congress on big data (BigData congress), IEEE,2017.

Biographies

Sahani Rathnasiri is a final year PhD student in the Institute for Sustainable Industries and Livable Cities, Victoria University, Australia. She holds a Master's degree in Management from Cardiff Metropolitan University, UK and a Bachelor's degree in Supply Chain and Logistics Management from the University of Moratuwa, Sri Lanka. Her research interests are mainly related to applications of supply chain and logistics management and optimization.

Dr. Pritee Ray is an Assistant Professor in the area of Operations Management at the Indian Institute of Management Ranchi. She obtained her Ph.D. degree from IIT Kharagpur in the area of supply chain risk management. She has published her research work in top tiers International Journals such as EJOR, ANOR etc and several International Conferences. She also acts as ad-hoc reviewer in many international journals and conferences. She worked in academia for more than eight years. Her research and teaching interests include supply chain risk management, game theory, operations research, operations management.

Prof. Sardar M. N. Islam is a Professor at Victoria University's Institute of Sustainable Industries and Liveable Cities, Australia. He was a Professor of Business, Economics and Finance from 2007 to 2017, and has had many years of academic work experience in teaching, supervision, and multi-disciplinary research. He has published extensively across a broad range of disciplines. His research has attracted international acclaim, leading to a number of appointments as a Visiting or Adjunct Professor in accounting, industrial engineering, finance, economics and management in several different countries.