Acquisition Research Program | Acquisition Research Symposium

2021-05-10

Blockchain for a Resilient, Efficient, and Effective Supply Chain: Evidence from Cases

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http://hdl.handle.net/10945/68166

SYM-AM-21-103

Excerpt from the Proceedings of the Eighteenth Annual Acquisition Research Symposium

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May 11–13, 2021

Published: May 10, 2021

The research presented in this report was supported by the Acquisition Research Program of the Graduate School of Defense Management at the Naval Postgraduate School.

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Blockchain for a Resilient, Efficient, and Effective Supply Chain: Evidence from Cases

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Abstract

In the modern acquisition, it is unrealistic to consider single entities as producing and delivering a product independently. Acquisitions usually take place through supply networks. Resiliency, efficiency, and effectiveness of supply networks directly contribute to the acquisition system's resiliency, efficiency, and effectiveness. All the involved firms form a part of a supply network essential to producing the product or service. The decision-makers have to look for new methodologies for supply chain management. Blockchain technology introduces new methods of decentralization and delegation of services, which can transform supply chains and result in a more resilient, efficient, and effective supply chain.

This research aims to review and analyze the selected current blockchain technology adoptions to enhance the resiliency of supply network management by facilitating collaboration and communication among suppliers and support the decision-making process. In the first part of this study, we discuss the limitations and challenges of the supply chain system that can be addressed by integrating blockchain technology. In the final part, we analyze multiple blockchain-based supply chain use cases to identify how the main features of blockchain are suited best for supply network management.

Keywords: supply chain, blockchain, supply network, resilience, acquisition

Introduction

The Department of Defense (DOD) spending on goods and services has grown significantly since the Fiscal Year (FY) 2000 to well over $250 billion annually (Walker, 2006). The process of DoD supply chain includes all government and private-sector organizations, processes, and systems that individually or collectively play a role in planning for, acquiring, maintaining, or delivering material resources for military or other operations conducted in support of U.S. national defense interests (Reay, 2000). The supply chain complexities, which create significant challenges throughout the networks, arise from various factors, such as changes in customer expectations, multiple market channels, and international markets. Access to the latest technologies in various fields can be a great support in supply chain management. Innovations, including digitalization and industry 4.0, have developed new paradigms, principles, and models in supply network management. Through the literature review by (Ivanov et al., 2019), the digital technologies include big data analytics, advanced manufacturing technologies with sensors, decentralized agent-driven control, advanced robotics, augmented reality, advanced tracking and tracing technologies, and additive manufacturing. The development of the digital supply chain and smart operations are facilitated using Internet of Things (IoT), cyber-physical systems, and smart products. Blockchain technology is attracting a rising level of interest reflected by Google trends that returned 21.6 million Google queries for blockchain released on January 10, 2017 (Fosso Wamba et al., 2018). However, there is a need for novel models to support supply chain management in the future (Ivanov et al., 2019).

Resiliency, a vital feature for the viability of supply chains, is defined to be a measure of the persistence of systems and of their ability to absorb change and disturbance and still maintain the same relationships between populations or state variables (Holling, 1973). The common resiliency metrics for the supply network system are availability, connectivity, and accessibility, which can be improved by the decentralized, distributed, and fault-tolerant features of blockchain technology. The highly resilient architecture and distributed nature of blockchain technology make it an interesting platform to defend against attacks and preserve the integrity of the identity network (Shrier et al., 2016).

This study proposes applying blockchain technology, which can address many of the mentioned technological challenges and enhance supply network management. This study includes a systematic literature review of the current most critical challenges of supply chain and supply networks in the Literature Review section. The Block Chain in Supply Chain section covers the solutions that can be provided by utilizing blockchain technology for the supply network challenges identified from the academic and grey literature. Several use cases that applied blockchain technology in supply chain management are analyzed in the Case Studies section, followed by a conclusion in the last section.

Literature Review

In this section, the limitations and challenges of the supply chain system that can be addressed by integrating blockchain technology are identified through the literature, and the blockchain-based solutions are mapped to those challenges.

A systematic literature review is an efficient tool for summarizing the results of existing studies and assessing consistency among previous studies. It provides a systematized approach to identify current challenges, new methodologies, and research avenues (Queiroz et al., 2019). This study provides a systematic literature review on the current supply chain challenges and limitations in a supply network. For this purpose, the Web of Science database is used. Table 1 shows the details of the papers that were extracted by each keyword. In the next step, papers that were relevant to the topic were selected for full paper reading in addition to relevant papers that were selected from Google Scholar, ISI journals, and conference papers. The third step included assessing the quality of the selected paper, and lastly, final papers were selected as the references for this report. The protocols followed for this systematic literature review include 1. determining Web of Science and Google Scholar as the main research databases, and 2. only considering the English language journal publications for this review. The data extractions details are defined and can be seen in Table 1.

Table 1. Literature Review Structure

Database	**Total # of results**	**Number Selected of papers**
Web of Science	3217 + 338	29
Google Scholar	132	127
Total	3687	156

The three keywords that were used for the Web of Science database are *supply network challenge*, *blockchain technology*, and the combination of *supply chain challenges* AND *blockchain*, as shown in Figure 1.

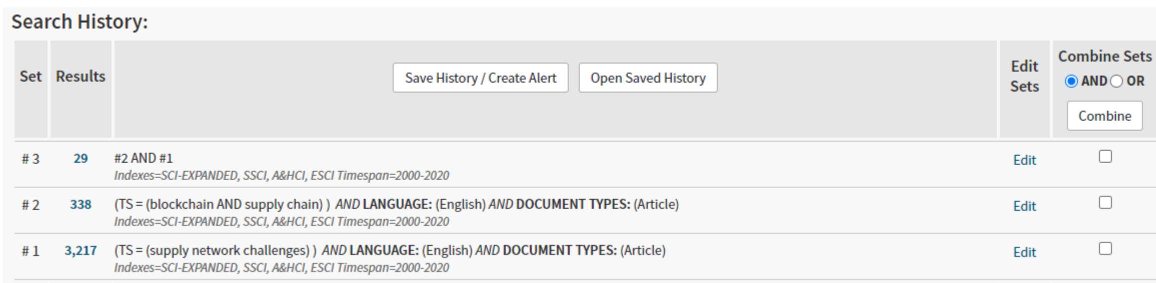

Figure 1. Keyword Search History

The articles in the supply chain field include a broad area of applications and theories. Hence, this study has narrowed down the content search to three main categories of technologies, theories, and applications (see Table 2).

Table 2. Search Content Categories

Content Categories	
Main technologies	Blockchain technology, smart contracts, modeling, & simulation
Main theories	Conceptual, reviews, frameworks, and case studies
Blockchain application area	Supply chain network

The study retained 29 articles out of the combination of 3,217 papers with the topic of supply network challenges, and 338 papers with both topics of blockchain and supply chain up to summer in the two decades of 2000–2020 (see Figure 1). The report categorizes the blockchain applicability in supply network challenges into four areas: communication, transparency, data and information, and performance.

The region-based literature analysis revealed that *supply network challenges* is a popular topic in different regions across the world. Figure 2 shows the distribution of papers in different countries within the past two decades; most articles were published in the United States, followed by China and England.

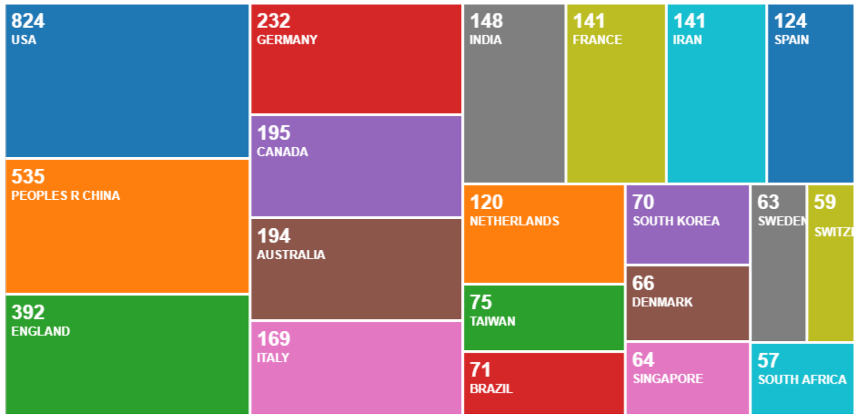

Figure 2. Supply Network Challenges Paper Region Distribution

On the other hand, the systematic review shows that the interest in research in the field of supply networks has gained more attention recently, as depicted in Figure 3. In 2019, there were around 500 articles published related to supply network challenges.

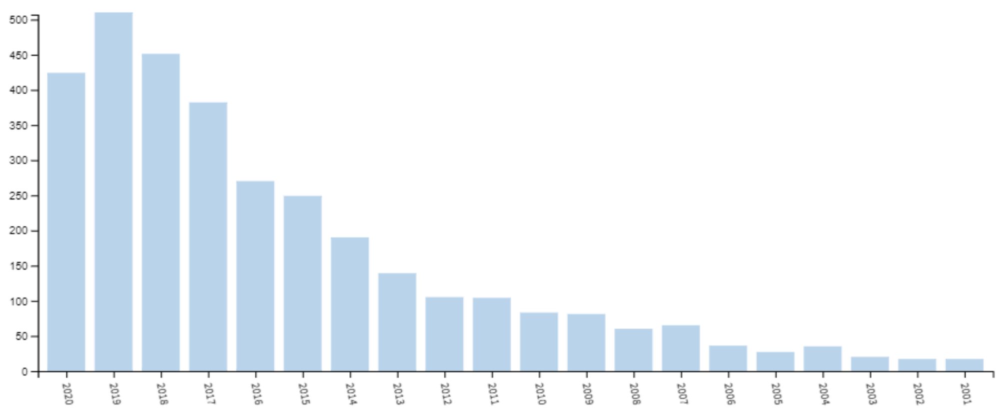

Figure 3. Supply Network Challenges Publication (2001–2020)

Supply Chain Network Management

A supply chain is a network of multiple businesses and relationships (Lambert & Cooper, 2000) considered as a complex system due to having multiple levels and numerous facilities at each level (Beamon, 1999). Supply chain management is a system capable of rational planning, management, and control of the supply chain and the logistics. It enables the stakeholders to accurately monitor and provide real-time responses to the supply chain issues (Yoo & Won, 2018). The evolution of supply chain management was studied by Fawcett and Magnan (2002) and is shown in Table 3. It is rooted back to the 1950s and 1960s, where the focus was on minimizing the production cost. In the 1970s, material requirement planning was developed. In the 1980s, the global competition developed management programs such as Just-In-Time that forced firms to offer low-cost, high-quality, and reliable products with greater flexibility in the design. In the 1990s, the outsourcing of non-core operations was introduced as a solution to reduce or transfer some of the risks, which developed more interactions and integrations among different involved parties in a supply network. The changes shift the focus to more collaborations and performance management of a supply network for the success of a firm. Lastly, with the advent of new technologies, the concentration is more on creativity, improving collaboration, and communication among the stakeholders.

Table 3. Supply Chain Management Evolution Era (Fawcett & Magnan, 2002)

Era	Description
Creation Era	In the 1980s, the supply chain term was coined by an American industry consultant.
Integration Era	Through the 1960s–1990s, the electronic data interchange system was developed and led to enterprise resource planning systems.
Globalization Era	The objective of organizations changed to competitive advantage, creating value-added, and reducing costs through global sourcing
Specialization Era – Phase One	In the 1990s, the focus became more on core competencies and adopted a specialization model. Firms outsourced non-core operations to the other companies and abandoned vertical integration.
Specialization Era – Phase Two	New aspects of supply planning, collaboration, execution, and performance management were adapted to the supply chain.
Supply Chain Management	The use of the World Wide Web (Web 2.0) led to more creativity, information sharing, and collaboration among users.

Harland (1996) described *supply network* as a dynamic, interconnected, complex, interdependent network of suppliers, manufacturing facilities, and linking multiple organizations (Bales et al., 2004). The structure of the supply network includes the member companies and the links between them. Lambert and Cooper (2000) suggest that three primary aspects of the company network structure include:

1. Members of the supply chain
2. Structural dimensions of the network
3. Different types of process links across the supply chain

Based on the characteristics of a supply network and the challenges that might arise managing such supply chains, this study applies blockchain technology to provide a decision-making framework that can capture the emerging phenomena of complex supply network challenges.

Blockchain Technology

Blockchain technology created by Nakamoto (2008) is an emerging information technology that provides new opportunities for decentralized market design with transparent and user-friendly applications that allow consumers to participate in the decision-making (Mengelkamp et al., 2018). Based on the World Economic Forum report in 2015, blockchain has been considered as one of the megatrends that are going to change the world in the next decade (Kshetri, 2018).

Blockchain consists of nodes within a communication network that contain a common communication protocol. Each node stores a copy of the blockchain on the network, and a consensus function verifies transactions to preserve the immutability of the chain (Wang et al., 2019). Each block is identified through its cryptographic hash, and each block is referred to as the hash of the previous block, which creates a link between blocks to form a blockchain. The transactions of each block are hashed in a Merkle tree. The root hash and the hash of the previous block are recorded in the block header. Blockchain provides interaction between users by a pair of public and private keys (Casado-Vara et al., 2018). The hashing process transforms assets into a digitally encoded token that can be registered, tracked, and traded with a private key on the blockchain (Ivanov et al., 2019).

Supply Chain Challenges and Adaptation With Blockchain Technology

In a supply network, flows of data have different forms and satisfy different needs. This leads to a complex course of controlling, ensuring immutability, and security transparency.

Therefore, an efficient mechanism is required that enhances immutability and ensures confidentiality of transactions in the supply network.

This study aims to explore the feasibility of using blockchain technology to address current limitations, efficiently manage the process, and enhance the resiliency of supply chain systems. We grouped the current supply network systems limitations (Apte & Petrovsky, 2016; Fawcett & Magnan, 2002; Kleindorfer & Saad, 2005; Kshetri, 2018; Wilding et al., 2012) to be addressed under four main categories per the blockchain features:

- *Network Communication and Information Flow:* (1) Analog gaps between customer and supplier, (2) lack of information sharing among all involved stakeholders, (3) lack of an integrated global view concerning increasingly dynamic supply chains
- *Transparency:* (1) Lack of traceability of failures in the flow of the process, (2) limited visibility concerning how and where products are sourced, made, and stored
- *Data and Information Management:* (1) Disparate record keeping, (2) lack of accurate and reliable data for analytics, (3) excessive redundancy and crosschecking, (4) long and costly audit processes
- *Performance measurement:* (1) high cost of managing the network, (2) decreased speed due to network arrangement and communication, (3) lack of flexibility due to various policies and structure in the network

Categories of Supply Network Challenges and Blockchain-Related Solutions

The supply network's complexity consists of multiple elements, including raw material suppliers, distributors, manufacturers, retailers, and end consumers (Francisco & Swanson, 2018). The major complexity of supply chain processes has led to challenges in the supply network and conflicts that are raised from local objective versus network strategies (Terzi & Cavalieri, 2004). Defining boundaries among the multiple interconnections of a network is one of the methodological challenges in studying the supply network (Park et al., 2013). One of the other challenges is the coordination of complex influx and outflow of materials (Park et al., 2013).

This study identifies the main challenges and limitations of supply networks through the literature and aims to provide related blockchain empowered solutions to improve the current challenges. Table 4 describes the taxonomy of challenges in supply chain networks and the related blockchain features identified as a solution in the literature. The blockchain features that can improve those challenges are linked to each category of supply network challenges as the recommended solution to tackle those challenges.

Table 4. Taxonomy of Challenges in the Supply Networks and Adaptation With Blockchain Technology

Category	**Supply Chain Network Challenges**	**Blockchain Empowered Solution**
Network Communication and Information Flow	Miscommunication between suppliers and retailer (Ludema, 2002)	Value chain visibility for all parties (Kshetri, 2018)
	Inappropriate use of power and opportunistic behavior (Dani et al., 2003)	Seamless networks, visibility, and symmetric information to all actors (Wang et al., 2019)

	Lack of effective collaboration, communication, and partnership (Fawcett & Magnan, 2002; Saberi et al., 2019; Terzi & Cavalieri, 2004; Wang et al., 2019) Conflicts in local versus global interests Strong reluctance of sharing common information (Fawcett & Magnan, 2002; Terzi & Cavalieri, 2004)	
	Risks and disruptions from natural disasters or conflicts (Ivanov et al., 2019; Park et al., 2013) Defining boundaries among the interconnections of a network (Park et al., 2013) Coordination of complex influx and outflow of materials (Park et al., 2013)	
	Contradictory operational objectives and priorities; Different culture and geographical disperse of the partners (Saberi et al., 2019; Wang et al., 2019)	
	Complicated distribution structure and lack of information about the margins of products for the customers (Yoo & Won, 2018)	

Category	**Supply Chain Network Challenges**	**Blockchain Empowered Solution**
Transparency	Lack of common purpose; power imbalances; culture and procedures; autonomy (Fawcett & Magnan, 2002)	Immutable Ledger (Abdirad & Krishnan, 2020; Chen et al., 2017; Francisco & Swanson, 2018; Kshetri, 2017, 2018; Queiroz et al., 2019)
	Lack of accountability (Fawcett & Magnan, 2002; Kshetri, 2017)	Decentralized platform (Kshetri, 2017, 2018) Real-time basis data and tracking (Kshetri, 2018; Wang et al., 2019)
	Traceability disruptions (Queiroz et al., 2019)	Smart contracts improve responsiveness; reduce lead time; decrease transaction and monitoring cost; enhance visibility, trust, security, and transparency (Queiroz et al., 2019); smart contracts ensure the participation of the consumers (Kshetri, 2017)

	Information privacy of customers; lack of audit trails (Kshetri, 2017; Tatar et al., n.d.)	Encrypted data with hash functions; no single point of failure; secure messaging between devices; audit trail to ensure accountability (Kshetri, 2017, 2018)
	Lack of transparency (Francisco & Swanson, 2018; Yoo & Won, 2018)	Data is controlled with private & public keys (Kshetri, 2017) Owner choose the information that is released (Kshetri, 2017)
	Lack of trust in information legitimacy (Chen et al., 2017; Wang et al., 2019); Fraud, corruption, tampering, and falsifying the information as trust problems (Tian, 2017)	Transparency (Francisco & Swanson, 2018; Saberi et al., 2019); Traceability (Chen et al., 2017; Francisco & Swanson, 2018; Ivanov, Dolgui, & Sokolov, 2019; Mengelkamp et al., 2018; Saberi et al., 2019)
	Unstable distribution prices (Yoo & Won, 2018)	Authenticity and legitimacy (Wang et al., 2019) Accountability (Fosso Wamba et al., 2018)
		Openness, neutrality, reliability, and security for all members of the supply chain (Tian, 2017)
		Trust (Folkinshteyn & Lennon, 2016; Kiviat, 2015)
		Transactions are viewable by the whole network that protects against double-spending (Yoo & Won, 2018)

Category	**Supply Chain Network Challenges**	**Blockchain Empowered Solution**
Data and Information Management	Inefficient transactions, fraud, pilferage, centralized and stand-alone information management system (Saberi et al., 2019)	Disintermediation (Saberi et al., 2019) Transparency (Francisco & Swanson, 2018; Saberi et al., 2019; Tian, 2017) Traceability (Chen et al., 2017; Francisco & Swanson, 2018; Ivanov, Dolgui, & Sokolov, 2019; Saberi et al., 2019)
	Lack of information about the origin of the product (Casado-Vara et al., 2018)	Authentication & privacy (Abdirad & Krishnan, 2020; Kshetri, 2017)

Category	**Supply Chain Network Challenges**	**Blockchain Empowered Solution**

Performance	Cost	Paper records elimination Reduce regulatory compliance costs Tracking processes with IoT Identify the defective products easily from the source Track the quality and counterfeit of the ingredients from the partners; Provide meaningful data to assess the quality No costly regulation and overhead (Yoo & Won, 2018) Cost reduction due to disintermediaries (Folkinshteyn & Lennon, 2016; Tapscott & Tapscott, 2017)
	Speed	Digitalizing physical process and reduce interactions and communications time (Kiviat, 2015; Kshetri, 2018)
	Delays and defaults in the delivery of goods (Casado-Vara et al., 2018)	
	Dependency	Partners should be more responsible and accountable for their actions Digital certification Audit trail (Kshetri, 2018)
	Risk Reduction	Address the holistic source of risk by verifying provenance Network only permits mutually accepted parties to engage in transactions (Kshetri, 2018)
	Sustainability	Validation of participants' identity (Kshetri, 2018)
	Flexibility	Address consumer's concern about the products Higher level of impact with IoT integration (Kshetri, 2018)

Blockchain in Supply Chain

Blockchain has the potential for supply chain improvements. Based on the features of blockchain technology, Kshetri (2018) claims that blockchain has the potential to help achieve supply chain critical objectives. There are some pilot practices of blockchain technology in a supply chain with no evidence of large-scale adoption (Wang et al., 2019). The supply chain has been expected to be one of the most promising non-finance application domains of blockchain (Kshetri, 2018). There is limited empirical evidence of the advantages of blockchain on the existing supply chain. Supply chain as a complex workflow has been identified as one of the main potential areas of blockchain application to deliver a real rate of interest (Kshetri, 2017).

Wang et al. (2019) categorize the current literature of blockchain in the supply chain into four types: descriptive, conceptual, predictive, and prescriptive. The sources of insecurity can be tracked within a supply network. Blockchain can facilitate managing crisis situations regarding security vulnerabilities. Blockchain can be applied to register time, location, price, involved parties, and the related information while the ownership of an item is changing (Kshetri, 2017). Trust enhancement, accurate information sharing, and verifiability are crucial because of current challenges such as inefficient transactions, fraud, pilferage, and poor performance in the supply network (Saberi et al., 2019). The technological developments and applications of blockchain technology can improve supply chain transparency, security, durability, and process integrity, which results in more organizational, technological, and economic feasibility (Saberi et al., 2019). As the supply networks contain large numbers of stakeholders, process tracking would be more difficult.

Smart contracts can automate the processes. The agreed contracts can be delivered to the specified parties for digital execution. Programs can be updated based on agreed verifications, and copyright documents can be released to the relevant parties. Smart contract adoption can fundamentally change the supply chain structures and governance (Wang et al., 2019). The governance and process rules of smart contract in a blockchain-based supply chain provides actor certification and approval and the processes that are permitted to be accessed for execution (Saberi et al., 2019; Sabz Ali Pour et al., 2018).

A blockchain-based supply chain management system can improve the system in several ways. First, it provides the ability to record, provide, and share prices. Second, companies can deliver honest information to consumers. Third, the purchase intentions of buyer information can be obtained. Fourth, marketing operations for exploiting customers' propensity with no personal information can be included. Fifth, the trading contracts process can be automated using smart contracts (Yoo & Won, 2018). The supply chain management processes can be improved by blockchain monitoring, which provides efficient customer service management and convenient demand management (Yoo & Won, 2018).

The literature on blockchain technology in the supply chain is still in its early stages. The literature mostly describes blockchain as a distributed ledger technology because it is data-management technology that consists of a chain of decentralized computer terminals and a network software protocol on the base of a peer-to-peer node's network (Fosso Wamba et al., 2018). Several systematic literature reviews studied the blockchain applications in supply chain management (Denyer & Transfield, 2009; Transfield et al., 2003) and offered a more in-depth understanding of the technology (Queiroz et al., 2019). A list of literature review articles in the field of supply chain and blockchain is presented in Table 5.

Table 5. Supply Chain and Blockchain Literature Review Studies

Author(s)	Objective(s)	Outcome(s)
Fosso Wamba et al. (2018)	A systematic review of supply chain cases over the knowledge gap in bitcoin, blockchain, and financial technology	Illustrates technology evolvement and adaptation of organizations to apply the advantages of blockchain technology.
Wang et al. (2019)	Systematic academic and practitioner literature review on understanding blockchain technology for future supply chain	Retained 24 articles out of 227 papers in 2017 and categorizes the blockchain applicability in the supply chain into four areas: visibility and traceability, supply chain digitalization and disintermediation, improved data security, and smart contracts. The study identified the main drivers of blockchain development within supply chains as trust, product safety, authenticity and legitimacy, public safety and anti-corruption, and supply chain disconnections and complexities.
Queiroz et al. (2019)	Systematic literature review on blockchain supply chain management integration	Twenty-seven papers were identified in the past decade that address it, with the main theoretical approach of conceptual and framework. It shows essential implications for managers, practitioners, consultants, and decision-makers in the field (tracking enhancement, real-time visibility, decentralized operation, smart contracts, improving securities, reduced transaction costs). Also, the study identified a vital gap in the literature relate to blockchain–supply chain management integration in emerging economies and developed empirical studies.
Saberi et al. (2019)	Literature review on the application of blockchain and smart contract to overcome the potential barriers in supply chain	Introduced four categories of barriers for blockchain technology adaptation, including inter-organizational (new rules, responsibilities, policies, and expertise), intra-organizational (relationships among parties and their privacy policies related to information and data usage), technical (technology access limitation to get real-time information, data manipulation, and information immutability) and external barriers (pressures, lack of proper governmental and industry policy).
Ivanov et al. (2019)	Conceptual model	Adoption and application of blockchain technologies applied to supply chain traceability and introduced the behavioral theory as the lens for this framework on theoretical guidance of Unified Theory of Acceptance and Use of Technology (UTAUT).
Kim & Laskowski (2018)	Platform development	Smart contracts on the Ethereum blockchain platform that execute a provenance trace and enforce traceability limitations.
Chen et al. (2017)	Conceptual model	Adoption of blockchain technology to improve supply chain quality management and develop a blockchain-based supply chain quality management framework.
Gausdal et al. (2018)	Theoretical framework	Identify the key elements and barriers to digital innovation. The main identified barriers include high cost of implementation, technology-oriented culture, lack of investment initiatives, low level of blockchain diffusion through the supply chain, and risk aversion.
Yoo & Won (2018)	Platform Development	Applied blockchain and smart contracts for price-tracking that improve the transparency of the product distribution structure.

Case Studies

In this section, three blockchain-based supply chain use cases are analyzed to explore how the main features of blockchain are suited best for supply network management.

Walmart

Partners: Walmart, the largest grocery retailer in the United States, has partnered with IBM, JD.com, and Tsinghua University to conduct studies on the adoption of blockchain technology in the food supply chain (JD, 2017).

Purpose of Blockchain: Walmart's ultimate goal of using blockchain in their supply chain is to enhance transparency (IBM Blockchain, 2017). The partners established the Blockchain Food Safety Alliance to design blockchain solutions for food tracking, traceability, and safety (JD, 2017).

Benefits of Blockchain: Traceability includes tracking and tracing the products throughout both directions of product flow within the supply chain. Products can be tracked from their origins to the stores, and they can be traced back from the shelves to the farms. With blockchain, identifying the sources of foodborne illnesses and tracing back to the farms/origins can be reduced from days to seconds (JD, 2017). Such abilities not only provide benefits for public health but also reduce the economic impact for Walmart since only the contaminated products would be discarded, rather than all similar products (Tan et al., 2018).

Other benefits of blockchain for Walmart are improved security and trust. Customers can learn more about the products they consume, which results in higher confidence. In the food supply chain, most of the data is still processed on paper or in systems that cannot talk to each other (IBM Blockchain, 2017). Blockchain adoption provides immutability that avoids any alteration and transparency that provides everyone to access the ledger. This can effectively reduce the chance of food fraud and human errors (Tan et al., 2018).

Another benefit of the adoption of blockchain technology is to reduce waste by providing faster routes for perishable items, eventually leading to more sustainable operations. Still, a large portion of food is spoiled before arriving at the stores. Decreased delivery times can reduce waste by applying blockchain technology (Tan et al., 2018).

Method: Walmart conducted two pilot projects to test the effectiveness of the developed blockchain application. A pilot study was conducted in China on the pork supply chain, and the other pilot study was conducted in the United States on the mango supply chain (Tan et al., 2018). Both studies were successful in improving food safety, increasing recall speed, building higher trust for customers, and decreasing costs (Tan et al., 2018).

Challenges: The adoption pilot studies showed that adoption of blockchain technology is achievable; however, the mass adoption would introduce more challenges. Walmart has hundreds of thousands of suppliers worldwide, more than 4,000 retail stores in the United States, and more than 6,000 stores in 23 other countries (Walmart, 2021). Within its huge supply chain, most small- and medium-size enterprises do not have the technological infrastructure or training to adopt blockchain. Moreover, broad adoption of blockchain requires a high cost of implementation.

Maersk

Partners: Maersk, the world's largest integrated shipping company, has partnered with IBM to develop the TradeLens platform utilizing blockchain technology in the global supply chain in 2018 (Gausdal et al., 2018). TradeLens brings a diverse set of stakeholders together in a platform, including shippers/cargo owners, freight forwarders, intermodal operators, ocean carriers, ports, terminal operators, customs authorities, and financial service providers

(TradeLens, 2018). Similar supply chain companies, including Hapag-Lloyd, Ocean Network Express (ONE), CMA CGM, and Mediterranean Shipping Company (MSC), joined TradeLens, extending the scope of the consortium to include more than half of the global ocean container carrier industry (Maersk, 2019).

Purpose of Blockchain: Maersk's ultimate goal of using blockchain technology is to improve collaboration and trust across the partners of the global supply chain (Maersk, 2019). It is expected to increase the efficiency of the supply chain that mostly depends on manual processes in current technology (Kralingen, 2018).

Benefits of Blockchain: Senior Vice President of IBM states that "blockchain for the enterprise is solving previously unsolvable problems" (Maersk, 2019). TradeLens provided supply chain visibility, ease of documentation, and the ability to add new features on top of the platform (Kralingen, 2018). The built-in security feature of blockchain that makes it immutable prevents any alteration in the history of the transactions or smart contracts. This enables trust among the partners and keeps the records so that partners can keep track of the documentation digitally rather than undertaking all the processes manually on paper.

Method: Maersk and IBM utilized the open-source Hyperledger technology program by the Linux Foundation, contributed by a couple of hundred developer enterprises to develop TradeLens (Kralingen, 2018; TradeLens, 2018). The platform is governed transparently by the partners, enabling the trust that brings the partners together. The platform supports innovation with its structure that eases adding new features and applications to serve the diverse needs of different types of stakeholders of the supply chain (TradeLens, 2018). All communication among the blockchain nodes is end-to-end encrypted, increasing its security (Kralingen, 2018). Only the partners of the permissioned blockchain platform can access the data. The partners participate in consensus for transaction validation and data hosting.

Initial Phases: A pilot project involved shipment with Saudi Customs demonstrated immutability, auditability, and transparency features of the platform, in addition to reducing costs and processing time (Madsen, 2019).

The initial phase of the developed platform implemented the processing of Bill of Lading among the supply chain partners. It resulted in a significant decrease in the administrative costs—up to 15% of the cargo value based on the initial tests. Considering the industry covers almost 60% of the world's GDP, the efficiency increase is considered astounding (Gausdal et al., 2018).

As of September 2019, the utilization of TradeLens included more than 100 organizations, five out of the world's six largest shipping companies, 55 ports, and almost a dozen customs authorities, with more than 10 million weekly shipping events (Madsen, 2019).

DHL and Accenture for Pharmaceutical Industry

Partners: DHL, an international courier, package delivery, and express mail service, and Accenture, a multinational company selling consulting and processing services, cooperated to develop a blockchain application for the healthcare and life sciences industry (Accenture, 2018). The blockchain application is suitable to establish communication among various stakeholders, including manufacturers, storage facilities, distributors, hospitals, pharmacies, and healthcare providers (Accenture, 2018).

Purpose of Blockchain: DHL and Accenture's ultimate goal of using blockchain technology is to fight against counterfeit medications. They aim to reach this goal by implementing serialization, tracking, and tracing features in a blockchain platform (Heutger et al., 2018).

Benefits of Blockchain: The pharmaceutical industry is under the threat of counterfeit drugs. According to Interpol, more than one million deaths are related to counterfeit drugs every year (Aces & Kleeberger, 2018). The developed blockchain platform can provide the ability to verify the point of origin of the drug and whether it is genuine or counterfeit, helping to save lives.

It helps pharmaceutical supply chain companies to maintain their reputation by giving them the ability to track every step of drugs in all parts of their life cycle. It enables better management of drug inventory at any part of the supply chain by determining faster delivery routes, handling and storage conditions, and tracking expiration dates (Heutger et al., 2018).

Another benefit of the blockchain platform is to keep drug quality high. When a drug is detected as non-compliant, it can immediately be traced back to the origin. All drugs manufactured under the same conditions can seamlessly be located and recalled. This process can take weeks with a paper-based supply chain. However, it can be completed in seconds using blockchain technology.

Method: The partners developed a working prototype of the blockchain platform. After working on the proof of concept, they developed the blockchain-based serialization prototype with supply chain partners in six locations to track the life cycle of drugs. Simulations demonstrated that the blockchain platform for genuine medicine could process 7 billion new serial numbers and 1,500 new transactions per second (Accenture, 2018).

The events related to the drugs in each step of the supply chain are recorded in the blockchain, and since it is immutable, they cannot be changed. A serial number is given to each sealed unit of drugs. Information including manufacturer, plant ID, and the expiration date is associated with the serial number and stored in the blockchain. While each unit is aggregated into cases and pallets, shipped to distributors, and eventually placed on the shelves, blockchain can track the exact location of each drug unit. Pharmacies, healthcare providers, and patients can trace back the drugs to see the origin of the drugs and whether it is counterfeit (Accenture, 2018; Aces & Kleeberger, 2018; Alla et al., 2018).

Conclusion

This research reviewed current blockchain technology adoptions aiming to enhance the resiliency of the supply network. Most of the blockchain adoption efforts facilitate collaboration and communication among suppliers to support the decision-making process. The limitations and challenges of the supply chain system were addressed by integrating various applications of blockchain technology.

In this study, we analyzed three blockchain-based supply chain use cases to identify how the main features of blockchain are suited best for supply network management. Immutability, traceability, tracking, and security by encryption are the features of blockchain technology utilized by most of the applications. Transforming from traditional paper-based manual supply chain management procedures to digital, immutable, and rapidly processing characteristics of blockchain technology helps enterprises provide solutions to improve public health, prevent fraud, significantly reduce costs and processing times, and ensure trust among partners.

Blockchain brings some benefits for the supply chain; however, it also presents some challenges to implement. In particular, some of the case studies we explored showed that the supply chain architecture and characteristics, stakeholder relations, and technological infrastructure of the organization and its stakeholders are important parameters for blockchain adoption. Qualitative studies have been conducted in the literature so far; however, there are still benefits of developing quantitative studies that enable researchers to test various scenarios on a well-informed blockchain adoption decision support system that uses modeling and simulations techniques.

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