Blockchain Capabilities in Supply Chain Management: A Literature Review

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Due to the unique characteristics of blockchain, such as transparency, tractability, decentralization, immutability, blockchain has been widely employed in multiple industries that request higher level of trust and security. Supply chain has a perfect match with blockchain, as both chains involve multi-party collaboration and coordination. The global Covid-19 pandemic in the past four years has accelerated the use of blockchain in supply chain. Prior researchers indicated that blockchain capability is increasingly becoming one of the important organizational IT capabilities, however, a thorough study or literature review on blockchain capability is rare in the literature. For the literature review purpose, this study uses Scopus as an academic searching engine to explore the past papers on blockchain capability in supply chain management, and summarizes the most influential 28 articles published in recent years. Based on resource-based view and appearance frequency in the literature, we develop a conceptual framework to investigate the internal and external capability dimensions of blockchain. The literature review results of this paper help researchers in the same research domain understand the components and measures of blockchain capabilities, and thus offer significant value in directing blockchain theory and practice in efficient supply chain.

CCS CONCEPTS • Information systems→Record storage systems • Applied computing→Enterprise interoperability • Applied computing→Enterprise information systems • General and reference→General literature

Additional Keywords and Phrases: Blockchain capabilities, supply chain, literature review

INTRODUCTION

The global blockchain technology market size is expected to grow at a compound annual growth rate (CAGR) of 87.7% from 2023 to 2030 [1]. Two of the major reasons supporting the vigorous growth of blockchain are:

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the increased understanding of blockchain as a new organizational capacity, and the destructive effect of Covid-19 in recent years. Blockchain technology has played a vital role in developing a digital platform for managing the COVID-19 pandemic in many sectors. This includes its applications in finance, manufacturing, medical science, healthcare, public sectors, supply chain and more [2,3]. Blockchain technology itself also gained sufficient improvement in recent years. For example, researchers have discussed about the identity management system in Bitcoin [4], the way to store blockchain data in a digital evidence inventory [5], a new algorithm to support anonymity and accountability of blockchain access control [6], the post-quantum cryptography to ensure quantum-resistance in blockchain [7], the improvement of blockchain scalability by enhancing Transactions Per Second (TPS) and Time To Finality (TTF) [8], etc. Owning to its unique technological features, such as transparency, traceability, decentralization, immutability, and suitability for unknown actors [9], blockchain possesses a special complex and significant practical value in many industries.

The above advanced blockchain technologies offer many potential benefits to businesses, and many business sectors see a bright future in the use of blockchain [10]. Examples include the construction industry [11] and the financial sector [2]. In the case of the construction and financial industries, blockchain technology can help create mechanisms for smart contracts. The contract-related transaction processes involved in both industries, i.e. the selection of material suppliers and lending policies, can be automated and made intelligent through the smart contract mechanism. This will not only reduce the loss of profit due to human error and incomplete consideration, but will also increase the efficiency of cooperation [10]. Regarding to the application of blockchain in supply chain, the idea of blockchain has excited the IT and supply-chain worlds. It has also prompted established IT companies and start-ups to initiate promising pilot projects. This include: Walmart tested an application that traces pork in China and produce in the US. Amazon provided Amazon managed blockchain solutions to Nestle to trace the originality of coffee beans. Provenance, a UK start-up, after a piloted tracing of tuna in the Southeast Asian supply chain, raised $800,000 to adapt blockchain technology to trace food [12]. As to March 2023, there are 23 startups in China that are able to provide blockchain services to various industries. For example, Harvest supply chain uses blockchain, AI, and big data technologies to create supply chain financial information solutions. ScanTrust creates copy-proof QR codes for retailers. The solution can be placed on product packages and verified using a smartphone and helps manufacturers protect against counterfeit goods as well as aids consumers to determine whether a potential purchase is real or fake [13].

Supply chain management has a perfect match with blockchain. Supply chain management is the process of transferring a product or service from raw material suppliers to the end consumers, operated by one or more companies [10]. The various participants in the supply chain work together and bonded with consistent business objectives. The smooth functioning of the entire supply chain depends on the alignment of participants from upstream to downstream, where the exchange of information between partners facilitates the efficiency of supply chain operations and builds the ability to quickly react to changes in the market [14]. There are basically two types of Blockchain networks: permissonless and permissioned. When the network is open for anyone to participate, and there are no restrictions, and the participation is not controlled by an administrator, then it is a permissionless blockchain. When the network is limited only to designate participants, and participation needs to be proved by an administrator, then it is a permissioned blockchain [15]. Bitcoin, Ethereum, and BNB Chain are all examples of permissionless blockchains, and permissioned blockchains, are typically used in private business settings and tailored for certain use cases [16]. In that sense, Supply chains which usually involve invited participants in the chain are typically permissioned blockchains [17]. Blockchain network may document

updates to a single shared ledger, providing total data visibility and a single source of truth. Companies in the chain can query a product's status and location anywhere at any time because transactions are constantly time-stamped and the latest. This helps to tackle challenges such as counterfeit goods, compliance violations, delays, and waste. To this end, an in-depth discussion of the application of blockchain in supply chain operation has an important and practical value [18].

Recently, blockchain capabilities as one of the important IT capabilities drew a larger amount of researcher's attention. Blockchain capabilities in this research is defined as an organizational IT capability to facilitate blockchain operations and with a goal to enhance overall organizational performance. The concept is about how to reasonably use and manage blockchain resources and convert them into improved organizational performance [18]. In general, developing blockchain as a capability may offer several advantages to an organization: (1) improve efficiency, (2) allow faster transactions, (3) save transaction time and operational cost, (4) quick settlements and payment, (5) enhance third party trust with the use of cryptography, and (6) real time information leads to transparency at both sides [19]. In the field of supply chain, prior researchers, such as [9] conducted a systematic literature review on the integration of blockchain and supply chain, and proposed blockchain capabilities in supply chain as one of the important opportunities for future research. Based on resource-based view and sociomaterialism theory, [18] also proved a significant effect of blockchain operation capabilities on competitive performance in supply chain management. Though blockchain capabilities are becoming a critical organizational performance indicator, a thorough study on blockchain capabilities itself, especially the specific components of blockchain capabilities in supply chain are rare. This paper intends to fill in this gap. It follows [18]'s general framework and examines the internal and external components of blockchain capabilities.

The remainder of this paper is as follows. In the second section, we conducted a literature review to understand the factors/components of blockchain capabilities in the supply chain industry. After the literature review, we summarized the most important factors in the literature, and build a conceptual framework to present the internal and external aspects of blockchain capabilities. A discussion of potential contributions and future research will be conducted in the last section of the paper.

LITERATURE REVIEW AND RESEARCH FRAMEWORK

A systematic review of the extant literature on blockchain and supply chain is rare. Among the few studies, [9] is the pioneer study to analyze and organize the literature on blockchain in supply chain management. It shed light on the current applications, disruptions and challenges of blockchain between the years of 2008 to 2018. Similarly, [20] summarized 178 articles to examine all the relevant research done in the supply chain field, and identify opportunities, social impacts and current technology trends across multiple industries. Meanwhile, [21] reviewed 106 articles to provide an overview of the use of blockchain in supply chain management. Last, [22] presented the blockchain adoption factors, enablers and barriers in supply chain. Despite blockchain and supply chain as a combined concept has been studied in the past literature related research, few of them focused on the literature of blockchain capabilities, and explore the key components of it. In the following, we explained our data collection and framework development processes.

All articles for our analysis were collected through Scopus. We used "blockchain capability" as the keyword, and add "supply chain management" as the restricted field. The result showed 162 articles, out of which 93% of the paper were published between 2019 and 2023. There are totally 58 conference papers and 69 peer-

reviewed journal articles. After checking and filtering, we finalized 28 most relevant articles that described blockchain capabilities in supply chain, and summarized them in Table 1. This searching result reflects the recent trends of blockchain research.

Table 1: Literature on Blockchain Capabilities

No.	Articles	Main Ideas	Key Components of Blockchain Capabilities
1	[23]	Barriers of blockchain adoption in supply chain are multi-faceted, with technological barriers and immaturity.	Capital/Knowledge and skills/ Organizational culture/Leadership/ Technology resources on BC/Technology readiness/ Coordination/Trust/ Legal support/ Infrastructure support
2	[24]	The relationship between trust/trust theory and blockchain in supply chain management.	Trust
3	[25]	Blockchain adoption in the pharmaceutical supply chain is driven by transparency, efficiency, traceability, data security, external pressure.	Capital/Organizational culture/ Technology resources on blockchain
4	[26]	Blockchain used to increase transparency and efficiency. Barriers include privacy, high cost, supply chain readiness, and scalability.	Capital/ Technology readiness/ Knowledge and skills/ Technology resources on blockchain
5	[27]	Blockchain evaluation methodologies have varied approaches and objectives, applicable for different technology adoption stages.	Capital/ Technology readiness/ Technology resources on blockchain / Organizational culture/ Leadership/ collaboration
6	[28]	Ecosystem readiness is the most important factor for blockchain adoption.	Capital/ Organizational culture/ leadership/ compatibility/ Legal support
7	[29]	Evaluation of enterprise blockchain consortia include 5 five different dimensions.	Capital/ Leadership/ Collaboration/ Compatibility/ Legal support
8	[30]	Blockchain adoption is hindered by technological, organizational, and environmental barriers.	Capital/ Technology readiness/ Technology resources on blockchain/ Organizational culture/ Leadership/ Knowledge and skills/ Coordination/ compatibility/Trust/ Legal support/ Infrastructure support
9	[31]	Poor regulatory provisions, technology immaturity, scalability, bandwidth issues, smart contract issues have higher driving power.	Technology readiness/ Technology resources on blockchain/Legal support
10	[32]	Blockchain adoption in Indian agriculture supply chain is hindered by lack of regulation and trust.	Legal support/ Trust
11	[33]	Adoption of blockchain technology in supply chains is determined by economic, organizational, and environmental factors.	Capital/ Technology readiness/trust/ Organizational culture/ collaboration/Infrastructure support
12	[34]	Blockchain adoption is hindered by lack of business awareness and familiarity, while other barriers are secondary and linked.	Technology readiness/ Organizational culture/ leadership/ knowledge and skills/ legal support
13	[22]	Blockchain adoption factors include organizational readiness, security, complexity,	Capital/Technology resources on blockchain, Planning, Technology readiness,

		partnerships, competition, governmental influence, and transparency.	leadership/Business Knowledge/Compatibility/Legal Infrastructure
14	[35]	High understanding and communication are needed for successful integration of blockchain into supply chains.	Technology resources on blockchain, technology readiness/Organizational culture/Leadership/Compatibility/Legal support
15	[36]	Investment costs, data security, and utility are important for implementation.	Capital/Technology readiness/Knowledge and skills/Infrastructure support
16	[37]	Trust is driving blockchain adoption in supply chains.	Trust/Technology readiness
17	[38]	Constructs of the Technological Readiness Index (TRI)- Insecurity and discomfort have no effect on perceived ease of use and usefulness.	Technology readiness
18	[21]	A systematic review of SCM from a blockchain and smart contract perspective.	Capital/Technology resource on blockchain/Collaboration
19	[20]	Blockchain has the potential to revolutionize the supply chain.	Capital/Organizational culture/Knowledge and skills/Legal support/Infrastructure support
20	[18]	Blockchain operation capabilities have a positive impact on supply chain integration and competitive performance.	Capital/Organizational culture/Leadership/Knowledge and skills/Collaboration/Compatibility
21	[39]	Blockchain technology can be used to improve supply chain integration and reduce carbon emissions.	Collaboration
22	[40]	The framework identifies foundational conditions, capabilities, and outcomes for successful blockchain projects.	Leadership/Collaboration
23	[14]	The growth of business asset size is a major motivator for utilizing blockchain technology.	Capital
24	[10]	Blockchain is essential for industrial applications.	Technology resources on blockchain /Technology readiness/Knowledge and skills/Compatibility/Legal support /Infrastructure support
25	[41]	Critical success factors for implementation are companies' capabilities; collaboration; technology maturity; supply chain practices; leadership; and governance of the traceability efforts.	Organizational culture/Leadership/Knowledge and skills/Compatibility/Legal support/Infrastructure support
26	[42]	Blockchain applications are essential for trade and supply chain financing.	Collaboration/Compatibility/Legal support
27	[43]	Factors encouraging and discouraging the implementation of blockchain technology in Bulgarian supply chain organizations.	Technology resource on blockchain /Leadership/Collaboration
28	[44]	Network collaboration was the best criterion for implementing blockchain technology into the circular supply chain.	Infrastructure support

Based on the above 28 selected articles, we calculated and coded the frequency of each dimension of blockchain capabilities, and presented the results in Table 2.

Table 2. Frequency of Blockchain Capability Key Components

Key Components	Frequency	Key Components	Frequency
Capital	14	Knowledge and Skills	9
Technology readiness	13	Compatibility	9
Legal support	13	Infrastructure support	9
Leadership	12	Trust	6
Technology resources on Blockchain	11	Planning	4
Organizational culture	11	Business knowledge	4
Coordination/collaboration	11	Technical management knowledge	3

Resource based view proposed that the competitive advantage is a function of the resources and capabilities of the firm [45]. It can assist in the understanding of organizational IT capabilities, which set a link between IT capabilities and organizational performance/competitive advantage [46]. Resource based view prioritizes organizational internal factors while distinguishing the differences between internal factors and external factors in term of their influence on organizational performance. Therefore, in this study, we also follow prior study's approach (e.g., [18]), and summarize the key components of blockchain capabilities from both internal aspects and external aspects. Based on Table 2, we eliminate the factors that are below 5 in frequency to demonstrate sufficient level of significance. Figure 1. shows our conceptual framework of blockchain capability components. The internal factors are divided into organizational aspect, management aspect, and technology aspect, and external factors include relationship aspect and government aspect. The 11 selected factors are: capital, organizational culture, leadership, knowledge and skills, technology resources on blockchain, technology readiness/maturity, collaboration/coordination, compatibility, trust, legal support, and infrastructure support. In the following, details of the 11 dimensions were introduced.

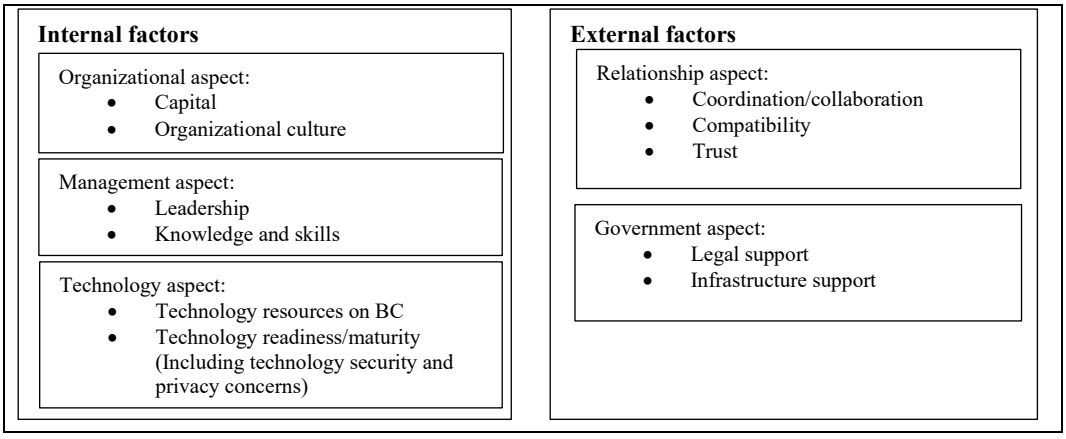

Figure 1: Research Framework on Blockchain Capability Key Components

3. EXPLANATION OF THE RESEARCH FRAMEWORK

3.1 Internal factors

3.1.1 Capital

Blockchain technology is scalable, involves multiple users, and requires a high level of investment. The cost of investing in blockchain technology consists of three main components: funding research, purchasing hardware and software facilities, and using energy and infrastructure [33,18]. Additionally, capital is required for upgrading and maintaining the system for sustainability. [46] illustrate the uncertainty of the total amount of investment as an important factor that prevents weak funded management teams from making decisions to adopt blockchain. Thus, the capital advantage is an important component in determining a firm's blockchain capabilities.

3.1.2 Organizational Culture

Organizational culture is an influential factor in the perception of decision-makers toward innovative technologies. Senior leaders must recognize the importance of using technology and focus on the value of change before adopting blockchain technology [46]. [34] pointed out that replacing a new IT system will lead to a shift in the working patterns of all departments and participants within the supply chain business, and it is the long-term commitment and risk management of top managers that would keep the organization from scaring change.

3.1.3 Leadership

[41] stated that leading companies have a strong role in driving industry trends. Under conditions of capital and resource consolidation, the priority of leading companies to invest in and use blockchain technology is seen as a trendsetter for the industry, testing the viability and potential risks of blockchain. Leadership within the industry is the soft power factor that determines the willingness of supply chain companies to invest in blockchain capabilities.

3.1.4 Knowledge and Skills

The application of blockchain technology is a complex process that requires experts and employees technical skills to ensure a smooth application process [48]. Experts have the relevant expertise to understand the application of the technology and to sensitively realize the issues related to the supply chain management field [9]. Employees need to be adequately trained to use the technology correctly in daily operations [36]. Therefore, human resources with necessary blockchain knowledge and skills are a fundamental part of blockchain capabilities.

3.1.5 Technology Resources on Blockchain

Technology resources on blockchain usually mean the blockchain technological platform, which include distributed ledger technology, and securities. [10] demonstrated the importance of implementing and deploying blockchain applications for a specific business or industry using a good blockchain platform that can provide

the required services. It is proposed that the choice of blockchain platform depends on the needs of the industry and industry collaboration chain.

3.1.6 Technology Readiness/Maturity

[41] divide technology readiness/maturity into three subtopics, namely technical feasibility, maturity, and data security. The study by [46] found that technical complexity, maturity, and data security have a positive impact on organizational resistance to blockchain. At the same time, [10] also believed that blockchain applications must include security and privacy policies and procedures as an integral part of design and implementation. All in all, technology maturity is a key success factor for enterprises to avoid the limitations of blockchain technology [47]. Such a blockchain capability helps address the slow adoption and implementation of blockchain technology in supply chain despite of its attractiveness.

3.2 External factors

3.2.1 Collaboration/Coordination

Collaboration among enterprises is required to achieve consensus. [18] pointed out that through good collaboration among enterprises, blockchain technology logistics can be rapidly popularized in supply chain. [47] argue that collaboration among supply chain partners can incentivize achievement of goals, partner trust, and be able to coordinate rights, responsibilities, and actions of different stakeholders [40]. Collaboration can not only help with the smooth adoption of blockchain technology, but also contribute to the overall objectives of survival and development.

3.2.2 Compatibility

[10] showed the importance of compatibility in enabling information exchange and processing within an enterprise and between organizations. In addition, [18] found that the lack of common standards will prevent various blockchains from working together. Therefore, [46] argue that enterprises must either procure or develop blockchain-based solutions that are compatible with their legacy systems or retrofit their existing systems to be blockchain-compatible.

3.2.3 Trust

Trust among supply chain partners is an important prerequisite for information exchange and sharing. For example, [24] found that building trust is key to the successful use of blockchain technology for supply chain information sharing. [18] proposed that a good trust atmosphere can help organizations avoid the loss of economic benefits brought about by knowledge sharing. Trust between blockchain collaborators, as one of the blockchain capabilities, promotes the operation of blockchain in the supply chain [37], and thus helps improve the overall organizational performance.

3.2.4 Legal Support

Experts agree that a robust legal framework is needed when conducting blockchain activities in the supply chain. Governments must formulate policies and regulations to protect blockchain infrastructure from illegal access and malicious attacks [10], as well as intellectual property and data security [49]. Experts explained that lack of government and industrial policies are barriers to blockchain adoption [46], hindering stakeholder

engagement. In addition, the government also needs to adjust and formulate new regulations to accelerate the adoption of blockchain to promote the widespread application of blockchain technology in business activities [10]. Therefore, Government guidance is needed to protect sensitive and private information, regulate encryption activities, and create new regulations to support blockchain transactions.

3.2.5 Infrastructure Support

[10] and [46] believe that the government needs to provide the necessary infrastructure and functions to create, manage and control basic blockchain functions to help establish trust transactions and carry out normal business activities, and accelerate the participation of external stakeholders. The government should support supply chain and blockchain-related education and training programs, support research and development work, and promote the rapid development of blockchain technology and its application in the supply chain field [10]. Government support and leadership in terms of infrastructure can help businesses use blockchain technology efficiently and securely for long-term growth.

4. RESEARCH METHOD

Based on the current framework, a series of qualitative interviews will be arranged to test the face and content validities of the focal construct – blockchain capabilities. After confirmation of the validities, the confirmed sub-dimensions of blockchain capabilities will be investigated in a large scale survey with supply chain practitioners from multiple industries. As part of the future research, in the cross-sectional survey, a dependent variable – organizational performance will be added as the consequence of blockchain capabilities. Blockchain capabilities will be treated as a higher-order construct consistent of two sub-dimensions that involve 11 constructs.

5. DISCUSSION OF POTENTIAL CONTRIBUTIONS AND FUTURE RESEARCH

Blockchain, as an innovative, decentralized and distributive technology, has increasingly attracted the attention of researchers and practitioners from multiple fields. So far, a number of pioneer studies focused specifically on the integration between blockchain and supply chain. Most of the research in this stream described the applications, challenges, and future trends in this area, however, the discussions of blockchain capabilities as one of the strategic IT capabilities have been largely ignored. The potential contributions of the current research are listed below: First, it is among the pioneer studies to have a systematic literature review on blockchain capabilities, especially blockchain capabilities' applications in supply chain management. Second, it also contributes to integrating the internal and external factors of blockchain capabilities in one conceptual framework to have an overarching understanding of blockchain capabilities. Third, our work builds up a solid foundation for blockchain researchers in the future to develop measures of blockchain capabilities, as well as test the causal relationships between antecedents/consequences of blockchain capabilities and blockchain capabilities itself. Fourth, our study also contributes to the practice of blockchain operations and applications by emphasizing the importance of blockchain capabilities as an important performance indicator. It further provides actionable roadmap to leverage organizational resources and to organize, evaluate, develop and enhance blockchain capabilities in effective supply chain management. In the future, efforts should be paid to develop blockchain capability measures, and empirically investigate the relationship between capability antecedents (influencing factors) and consequences (organizational performance).

6. CONCLUSION

Through a systematic review and analysis of the past papers on blockchain and supply chain, this study provided a conceptual framework to comprehend the key components of blockchain capabilities. Based on the resource based view and past research on block-supply chain [18], we divided our research framework into two categories, and matched the most mentioned factors of blockchain capabilities into each category. Our research is believed to provide solid foundation for future research on exploring blockchain capabilities, as well as to offer a blueprint for blockchain practitioners in multiple supply chain practices.

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