The Influence of the Blockchain Technology on Trust in construction Supply Chain Management

Xiaoning Qian,
The Bartlett School of Construction and Project Management, UCL
(xiaoning.qian.17@ucl.ac.uk)
Eleni Papadonikolaki,
The Bartlett School of Construction and Project Management, UCL
(e.papadonikolaki@ucl.ac.uk)

Abstract

Blockchain technology is booming in many industries. Its application in supply chain management is also gradually increasing. Supply chain management has long been committed to reducing costs and increasing efficiency and is trying to optimise resources and reduce the sector's fragmentation. Trust has always been an important factor in managing supply chain relationships, and it also affects the efficiency of supply chain operations. Blockchain technology provides solutions for data tracking, data sharing, and smart contracts for supply chain management. These applications help to enhance the sources of trust in supply chain management and provide contractors with protection mechanisms to avoid the risks and costs of opportunistic behaviour in collaboration. This study is based on semi-structured interviews and publicly-available information from experts in blockchain and construction supply chain management. By content analysis, this paper discovers features and applications of the blockchain technology, explores sources of trust in supply chain management and explains and demonstrates the impact of blockchain technology on trust in construction supply chain management.

Keywords: blockchain technology, supply chain management, application, trust, experience

1. Introduction

A supply chain (SC) is defined as a network of suppliers, factories, warehouses, distribution centres, and retailers. Supply chain management (SCM) is committed to improving the performance of individuals across the entire supply chain (Hofmann, 2016). According to Pryke (2009), supply chain tendencies in the construction industry become loose and lead to an increase in transactions and a decrease in the average value. For a long time, the problem of poor trust in supply chain management in the construction industry has been magnified because of fragmented cooperation (Pryke, 2009). The key to excessive waste and looseness is trust among parties (Sterman, 2000). Blockchain technology is a possible way to provide a smoother information sharing mechanism and preserve security or transactions (Nakamoto, 2008). Blockchain technology works as a distributed database that maintains a continually growing list of data records to prevent tampering and modification (Morris, 2016; Nakamoto, 2008; Popper, 2016).

The research aim is to find out what blockchain technology can bring to trust in construction SCM. The research question is: *how does the blockchain technology change trust in SCM in construction industry and in which dimension or aspect*? This research will start with a literature review, looking for the characteristics of blockchain technology and existing applications, and analyse the trust of SCM and the construction industry. Then the methodology will be elaborated, with specific methods and implementation content. Next, the study will present and analyse the collected data, try to establish the mechanism and relationship, and compare the analysis concludes with the existing theories. The limitation will also be reflected. Finally, the study will conclude the thesis and give recommendations to participants and further research.

2. Sources of Trust in SCM

Studies have shown that corporate activity and interaction are influenced by previous levels of trust (Gulati & Nickerson, 2008). A better level of trust will increase the efficiency of the later cooperation. Good interaction and joint work in SCM always require trust (Morgan & Hunt, 1994). In supply chain management, trust is also considered to be a willingness to agree with partners and confidence in them (Moorman et al., 1992). There are two traditional theories of trust establishment. One is based on economics. Scholars in transaction cost economics see trust as a substitute tool for cost-effective coordination and risk management (Bromiley & Cummings, 1995). The second theory reflects the views of psychology and sociology, which is the view that this study adopts.

Psychologists divide the impact of trust into micro-level and macro-organisational aspects. Manu (2014) summarises trust in supply chain management as inter-organisational trust, agency trust and inter-entity trust. The more micro-trusted the subject, the higher the influence of the individual's psychological factors. In a macro and more rational perspective, trust can be built on potential benefits or losses. Wong and his colleagues (2008) describe the sources of trust in the following dimensions.

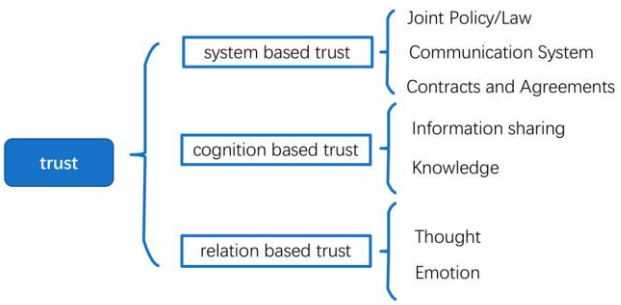

Figure 2.1: Sources of trust (Wong et al, 2008)

Rational trust is seen as believing that the other party will take opportunistic actions to ensure the company's interests (Tejpal et al 2013). Manu (2014) divides the foundation of trust in supply chain management in the construction industry into three categories below.

Relationship
Relationship-based trust comes from resource swaps and opportunity sharing in past collaborations. This kind of trust exists before the establishment of the project cooperation relationship, free from the limitations of personal experience, and is a more objective relationship at the organisational level. Akkermans et al. (1999) confirmed that the closer the cooperation among supply chain partners, the more data they share. This will increase the profitability and performance of all parties.

Competence
In construction projects, trust also comes from the company's reputation and resources, such as technological advantages, capital or market share (Das & Teng, 2001). At the same time, corporate performance and corporate risk also affect the company's capabilities, because it affects the difficulty of successful completion of the project.

System
At the rational and inter-organisational or macro level, trust can come from human and non-humans, such as computers and automated systems. Contract execution environments and sociocultural identity can form system-based trust. Such mechanisms provide an objective communication and monitoring channel to promote the development of trust in Parties.

Latham's (1994) construction industry report pointed out that construction is heavily dependent on competitive bidding and confrontation, which reduces the quality of trust and increase costs. The fragmentation of construction projects challenges the adjustment of risk management, integration of resources and management of performance in supply chains. Long-term supply chain relationships are compromised when short-term returns are treated as a top priority (Smyth, 2010, 2011). Specific issues include, for example, arrears, credit difficulties, bidding/contract drafting fees, and information asymmetry (Paunov, 2011; Manu, 2014).

3. Applications of the Blockchain Technology in SCM

Scholars state that blockchain technology offers solutions and may disrupt many industries (Kshetri, 2017). In the construction supply chain, some primary solutions of blockchain technology have been applied. Till now, blockchain technology has been applied to smart contracts, banks, and supply chains (Gatteschi et al., 2018). Each block in the network contains data and timestamp of the previous block of transaction creating thus a distributed ledger of information in the network (Nakamoto, 2008). Recognised blockchain networks can be divided into three categories: public blockchains without any access properties; semi-distributed consortium blockchains authorised by federation administrators (Zhu et al., 2018).

The main characteristics of blockchain are described as decentralization and transparency (Raval, 2016). Transparency is defined as the level of how outsiders can detect into the working system (Awaysheh & Klassen,2010). Blockchain technology is suitable for transparency improvement due to its unchangeable ledgers and distributed natures. With real-time data sharing distributedly, stakeholders can identify whether the quality, location, treatment, or any other details and procedures are qualified. Digital ledgers provide a proven, reliable solution with distributed data, which establishes a trusted relationship network within blockchain technology (Gartner, 2016). The main features of blockchain technology are tracking, recording and provenance and can be illustrated through the following examples

Maersk, the world’s largest container carrier company, used the blockchain technology into the logistics in cooperation with IBM (Popper & Lohr, 2017). It tracks the shipping containers with the location, time, temperature or other condition information by GPS or sensors. The tracking function brings

another function: recording. The cross-border shipment used to take several days before the application in the case. With blockchain technology, it takes minutes to be accomplished. With the implementation of blockchain technology, it can cut the enormous cost on record work and labour source.

Blockchain technology also provides provenance. A smart contract is a unique feature that runs in a digital environment is the ability to create algorithms and programs that can be partially or wholly executed or executed when certain conditions occur. It is a kind of technology to replace the complicated and troublesome interpersonal interaction (Crosby et al, 2016). The stakeholders in different levels would have more flexibility to act their best and create more value for the whole ecosystem (Koetsier, 2017).

The fragmentation of construction requires higher integration in supply chains (Smyth, 2010). Trust is an important factor in improving the efficiency of supply chain management (Morgan & Hunt, 1994). Manu (2014) divides the foundations of trust relationships among supply chain organisations in the construction industry into systems, relationships, and competence. However, it does not explain the specific relationship between the partners to promote trust. This study provides a lens for how blockchain technology affects supply chain management, especially in the construction industry. It can bring inspiration to future business development ideas which supply chain companies in construction can use to provide solutions for inter-firm trust relationships. Blockchain technology initiatives will also gain a better understanding of the needs of SCM in construction industry.

4. Methodology and Methods

This research used semi-structured interviews and an interpretivist lens to collect data and use thematic analysis to analyse and reach a qualitative conclusion (Bryman, 2012). This study is based on a mixture of narrative research and grounded theory research and a mixed data collection strategy. The data from this study was derived from 10 interviews and two public lectures from experts on blockchain applications.

The interviewees are mainly selected from industries of blockchain technology, supply chain management, and construction project. Their selection was crucial for research validity and relevance. The three themes and interviewees profiles are listed in Table 4.1The semi-structured interviews lasted around half an hour per interview. The first two introductory questions are used to provide an industry orientation for the interviewee and provide a basic understanding of the blockchain or supply chain concepts. Then the following three questions were about each topic they belong to. Finally, one or two discussion items were asked based on the previous problems discussed before, or to determine the individual subjective tendency of the interviewee about the application of the blockchain technology in SCM.

Table 4.1: Profiles of interviewees and data sources

Theme		Sources of data (interview or public lecture)
Blockchain	Interviewee 1A	Research fellow in blockchain solutions
	Interviewee 1B	Professor on computer security
	Public lecture 1C	6 Blockchain experts in technology
	Public lecture 1D	8 Blockchain experts in applications
Applications of Blockchain in SC	Interviewee 2A	Professional in operating electronic payment
	Interviewee 2B	Business developer of Internet of Things (IoT)
	Interviewee 2C	Economics expert researching smart contracts
Construction SCM	Interviewee 3A	Construction procurement manager
	Interviewee 3B	Director of a logistics firm on construction materials
	Interviewee 3C	Operation officer of logistics firm for construction materials
	Interviewee 3D	Professional in port warehouse (logistics recorder)
	Interviewee 3E	Project manager of a construction firm

Some research limitations of the research design are as follows. As the interviewees' responses do not guarantee research validity, the interview time was adjusted to positively and succinctly answer research questions without reduction in data quality. Trust is divided into interpersonal and inter-organisational levels and this study only focused on relational instead of micro or interpersonal factors of the trust developed, so as to be consistent to the main research question about SCM. Also, the interviewees' knowledge and cognition are subjective, so this study cannot promise an entirely objective conclusion but instead the interpretation and construction of a reality drawn upon their data. Through interviews and data analysis, this study can only qualitatively give specific explanations of the problem, but it cannot provide more precise quantitative judgments.

5. Applications of Blockchain Technology in Construction

The interviews with practitioners considered the two characteristics of the blockchain, decentralisation and transparency, have their unique applications, advantages and disadvantages. By interviewing people in the e-tracking, Smart Contract, and Finance industries who are doing blockchain-related research, it was extracted that blockchain has the following applications in the supply chain.

1) Tracking

The function of tracking was initially derived from the Internet of Things (IoT). Long before the blockchain technology emerged, the IoT has begun to focus on instant peer-to-peer dissemination of information. Interviewee 2B tells us: *"The most significant advantage is the increased efficiency of the distribution of information and knowledge. The information dissemination mechanism provided by the blockchain will significantly enhance the maintenance and after-sales." "The instant tracking method can save 70% of the after-sales cost.",* according to interviewee 1A.

At the same time, the labour costs required to record progress will be significantly reduced. Interviewee 3D stated: "*Once information is passed to the next level of contractors faster than ever before, we can reduce the dates of inventory turnover and improve other indexes related to the efficiency of supply chain management."*

2) Contracting

Interviewee 2C, who has done research on smart contract states that individual industry contracts given through electronic technology can help people avoid trivial contract drafting and inspections. Interviewee 2C stated: "*Once a party has more critical information that is not publicly available, it is very likely that it will avoid the contractual restrictions and draw benefits that are not beneficial to the other party. Smart contracts are committed to providing the most detailed and dependable terms of the agreement within the legal scope of the most regulated and widely used."*. The goal of blockchain technology is to automate the contract, making it infinitely perfect, and making people's distrust of the other party signing the agreement to a minimum, thereby improving the efficiency and legal protection of the participants in signing the contract.

3) Money transfer/Payment

Many banks have applied blockchain technology to their financial systems. The main reason is that its peer-to-peer transaction recording method can save workload for centralised processing in traditional banking systems. According to interviewee 3E, the project manager, and interviewee 3B, the director, one of the significant problems in supply chain management is the management of money flow. In interviewee 3B's words: *"The biggest problem is the payment problem. Few people will complete the transfer on the date of payment."*. Interviewee 3E explains: *"Arrears are not the deliberate act of most people. Their capital chains are also affected by other arrears, especially small companies. This is an industry-wide problem, and it will only be better if everyone improves."*

In larger projects, many small and medium-sized enterprises will face the threat of direct bankruptcy once the upstream or downstream contractors' default. On the one hand, the financial transfer system

of the blockchain plus the detailed design of the smart contract can guarantee the proper execution of the transfer. They can significantly reduce the ambiguity of the contractual transaction date and other default issues faced by the companies.

6. Changes of Trust Mechanisms in Supply Chain Management

As mentioned in the literature review above, the experience of collaboration or the reputation that companies have built on cost is a source of confidence across the supply chain industry. From the interviews, interviewees 3B, 3C, and 3E concurred that trust came from three aspects. The relationship is illustrated in Figure 4.1. As is shown in the figure, the trust between suppliers comes from the cost reduction, which depends mainly on the level of the risk. They believe that a company's existing reputation, cooperation history and industry norms can help reduce the risk of cooperation, thereby enhancing trust.

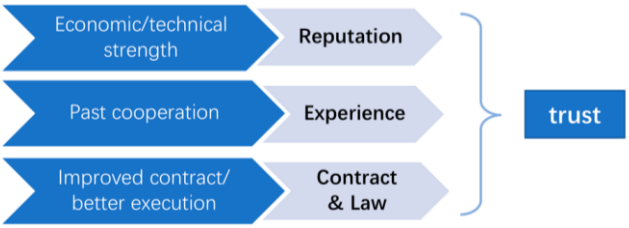

Figure 6.1: Sources of trust in construction SCM

1) Reputation

Interviewee 3B stated: *"Reputation is usually recognised in the industry, for example, a list of companies that are identified by an official or authority is considered to be more trustworthy."* In the interview, interviewee 3B clarified by saying: *"When working with state-owned or partially state-owned enterprises, we would simplify the review or inspection process to reduce pre-contact costs. Because state-owned companies have national credibility support, we will trust such companies more."* Interviewee 3B mentioned that this is also because state-owned enterprises are often able to obtain bank loans and trust in all aspects in the first place, making them less prone to economic crises. *"There is less condition of default.",* interviewee 3A explains the reason why reputation is a source of trust. At the same time, interviewee 3C emphasizes: *"In the supply chain of the industry, technical or management advantages are also considered part of the reputation. These advantages mean that companies with advantages have scarce resources in the industry."* Although there may be cases where the bid price is too high, people usually choose to be willing to work with them and trust them.

2) Experience

According to interviewee 3B, past cooperation experience is considered to be the most common source of trust in supply chain cooperation: "*During the first cooperation between contractors, both parties spend a lot of time and energy to test each other. So, we would spend more time on information transfer and coordination. Once the results of initial cooperation or multiple cooperation are satisfactory to both parties, and there are no other conflicts of interest, we will choose to continue to cooperate and strengthen trust, reducing efforts to guard against and suspect*." For interviewee 3E, although this is a source of trust for most vendors in the industry, *"it takes much energy from the first collaboration to the next mutual trust. Not all partners can turn out to be long-term partners. This conversion rate from 'strangers' to 'trusted partners' is not very high."*

3) Contracts and laws

Another primary source of trust is contracts and legal norms. In the absence of cooperation experience or a massive corporate aura, the agreement is considered to be a kind of enforcement guarantee. The more detailed the contract, the stronger the security that the signing party brings. Also, the degree of perfection of contracts and laws and their enforcement are the most fundamental guarantees for

corporate cooperation. Interviewee 3B stated: *"As this safeguard mechanism is strengthened, the difficulty of cooperation between enterprises will be reduced because they can build enough trust. This kind of trust does not require past cognitive help, because the law and the contract can guarantee that the losses and costs brought by the other party's uncertain behaviour in the cooperation are adequately compensated".*

The interview data shows that trust comes from reputation, past cooperation experience and mandatory execution such as contracts, laws and regulations. Based on the data above, the functions of trust of blockchain applications could be illustrated as shown in Figure 4.2.

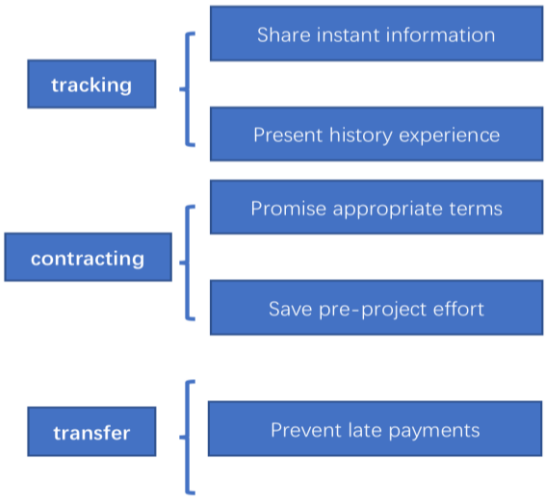

Figure 6.2: Functions of trust of blockchain applications

In this way, the source of information, the way it flows, and the enforcement of specifications will affect trust and ultimately affect the effectiveness of supply chain management. The blockchain technology can be seen as a third party that provides transparency and reliability. *"Once certified by an authority or industry, it will have the ability to bring credibility proofs that increase trust between companies.",* indicates the expert in the public lecture 1C. When applied, this technology will improve the flow of information and knowledge, helping members of the network optimise resource allocation and reduce costs. So, the technology can increase trust while reducing the need for trust in collaboration. Better contract integration and transfer methods enhance the supervision and execution of external management (legal and financial); transparent real-time tracking and decentralised data sharing bring more reasonable rights and openness to all parties.

From the interview data, three applications of blockchain: tracking, contracting, and transfer have the functions of sharing instant information, presenting history data, promising terms, saving pre-project effort, and preventing deferred payments. The direct sources of trust in supply chain management in the construction project industry are reputation, experience and contacts. Data tracking can display historical data, which can replace the actual past cooperation to some extent. Contracting can provide detailed terms and enhance the contract and execution together with the prevention of deferred payments. In this way, blockchain applications enhance trust in SCM. The relationships among these concepts are illustrated below in Figure 6.3. Through the analysis, the process of how blockchain technology affects supply chain management parameters by influencing and altering the trust dimension is explained in Figure 6.4.

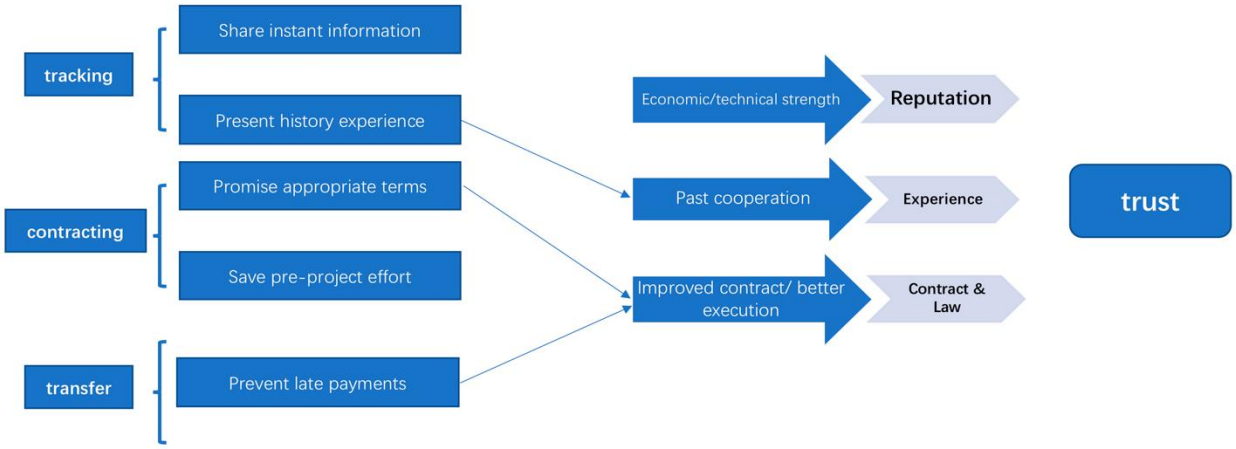

Figure 6.3: Influence of blockchain applications on sources of construction SCM trust

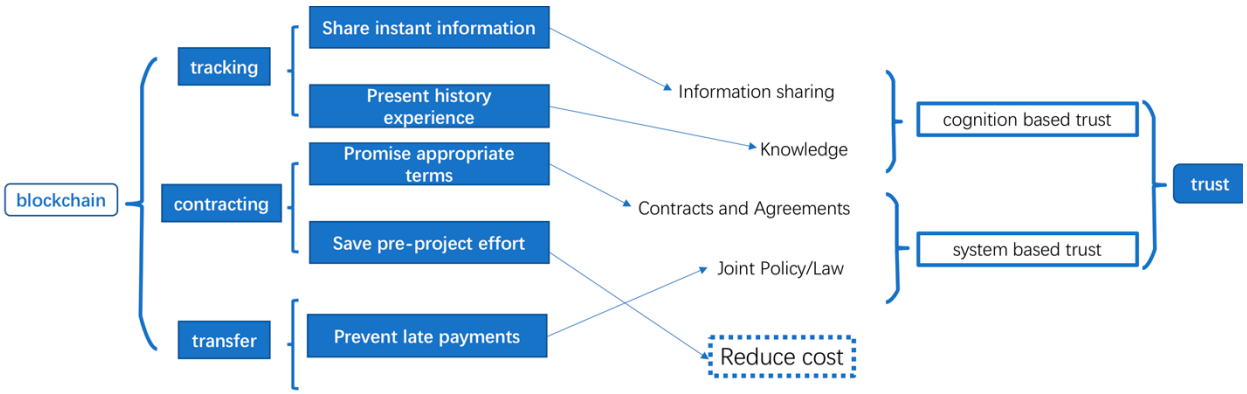

Figure 6.4: Influence of Blockchain Applications on SCM Trust Dimensions

Information sharing and historical display are ways to enhance cognition-based trust. Optimized contractual treaties and effective payment mechanisms increase the credibility and feasibility of the system. Besides, quality smart contracts reduce many of the upfront efforts for the project, which directly reduces costs. With the application of blockchain technology, members of the supply chain industry do not need to spend a lot of money and efforts to establish peer-to-peer repeated cooperation to gain trust. They only need to trust a blockchain trading system that has been designed well. This kind of management tool is somewhat similar to the alliance, but it has a more transparent sharing mechanism, less centralised tendency and more comprehensive and reasonable institutional treaty than the ordinary business alliance. Information sharing, knowledge, contracts and agreements and policy contribute to the cognition based and system-based trust according the classification of Wong et al. (2008), as shown previously in Figure 2.1.

7. Discussion and Conclusion

From the empirical fieldwork, this study identified and analysed how the characteristics of the blockchain, transparency and decentralisation, and its applications influence the way people trust among partners in supply chains. With the three existing applications of blockchain technology in the supply chain, the blockchain technology can increase the source of trust among contractors. Answering the main research question, it can be said that regarding the dimension of the trust sources, the blockchain applications mainly enhance trust by affecting the cognition-based trust and the system-based trust. At the same time, for construction supply chain management, the function of contracting is expected to reduce the cost of contract signing or bidding and solve the capital flow issues in projects.

Through semi-structured interviews, this paper identifies the characteristics of the blockchain technology, discusses the applications of blockchain in SCM, and points out how they affect trust in

construction SCM. This study goes a step further by explaining the reason that clear rules or sufficient tracking information brought by the blockchain technology can improve the "trust relationship" through the system-based and cognition-based trust. It can directly reduce the cost and need of building trust in the early stages of cooperation.

This conclusion is in part in line with the idea that more historical data and collaborative experience will reduce opportunistic behaviour and increase trust. The improvement of smart contracts and the strengthening of enforcement will help reduce the need for trust. The improvement of the mandatory external mechanism will reduce the uncertainty in the cooperation process. Also, the conclusion resonates with the classification of sources of trust: relationship, competence and system. Interview data extends this view, further explaining that technical strength or reputation can lead to trust because companies with good representations can have more credit lines, thereby reducing risk in cooperation. Interview data indicates that construction industry practitioners have shown proper expectations for blockchain technology to solve trust problems, especially concerning delayed project payments and credit issues (Paunov, 2011).

When selecting the type of the blockchain network, this paper mainly focused on the open blockchain network, ignoring the private blockchain network. In private or semi-federal blockchain networks, the degree of transparency and decentralisation will diminish as licenses are not fully issued. The analysis also did not consider the cost of developing blockchain technology solutions.

For supply chain managers, increasing efficiency and reducing total cost has always been an important goal. Based on the findings above, the practical implications of this study and recommendations for leveraging the potential of digitalisation to manage trust are: 1) improving the contract details, 2) improving the level of information sharing and 3) being sensible to new technologies like the blockchain. Improving the blockchain technology itself is very important. Whether the current market and social development conditions allow decentralised business models remains to be studied. Among the publicly decentralised information, some are not wholly decentralised in the current application scenario. For example, registration of private information. The extent to which blockchain technology can develop depends on the degree of social acceptance of decentralisation, which requires more research on social ethics. There are other parts of trust in supply chain management, such as object trust and mechanism trust (Tejpal et al, 2013). More research can be done on different types of trust in construction supply chain management. With the wave of the powerful blockchain technology, the way of how different types of enterprises could rely on blockchain technology to obtain tangible benefits will be the focus of future research.

References

Akkermans, H., Bogerd, P., & Vos, B. (1999). International Journal of Operations & Production Management, 19(5/6), 565-582.

Awaysheh, A., & Klassen, R. (2010). International Journal of Operations & Production Management, 30(12), 1246-1268.

Bromiley, P., & Cummings, L.L. (1995). Transaction costs in organizations with trust. In: Bies, R., Sheppard, B., Lewicki, R. (Eds.), Research on Negotiation in Organizations (pp. 219–247). Greenwich: JAI Press .

Hofmann, E. (2013). Supply Chain Management: Strategy, Planning and Operation, S. Chopra, P. Meindl, 5th ed, ISBN:978-0273765226. Journal of Purchasing and Supply Management, 19(3), 212-213.

Crosby, M.; Pattanayak, P.; Verma, S., & Kalyanaraman, V. (2016). Blockchain technology: Beyond bitcoin. Appl. Innov. 2, 6–10.

Das, T., & Teng, B. (2001). Trust, Control, and Risk in Strategic Alliances: An Integrated Framework. Organization Studies, 22(2), 251-283.

Gartner. (2016). The Bitcoin Blockchain: The Magic and the Myths.

Gulati, R. & J. A. Nickerson. (2008). Interorganizational trust, governance choice, and exchange performance. Organization Science, 19(5), 688-708.

Koetsier, J. (2017). Blockchain Beyond Bitcoin: How Blockchain Will Transform Business in 3–5 Years.

Manu, E. (2014). Supply Chain Management Practices in Construction and Inter-organisational Trust Dynamics, PQDT - UK & Ireland.

Morgan, R., & Hunt, S. (1994). The commitment-trust theory of relationship marketing. Journal of Marketing, 58(3), 20.

Morris, D.Z. (2016). "Leaderless, Blockchain-Based Venture Capital Fund Raises $100 Million, And Counting," Fortune.

Nakamoto, S. (2008). "Bitcoin: A Peer-to-Peer Electronic Cash System," Bitcoin.org.

Paunov, C. (2011). The global crisis and firms' investments in innovation. Research Policy, 41(1), 24-35.

Popper, N. (2016). "A Venture Fund with Plenty of Virtual Capital, but No Capitalist," New York Times

Popper, N., & Lohr, S. (2017). Blockchain: A better way to track pork chops, bonds, bad peanut butter? https://www.nytimes.com/2017/03/04/business/dealbook/ blockchain-ibm-bitcoin.html.

Pryke, S. (2009). Innovation in the Built Environment. Oxford, UK: Wiley-Blackwell.

Raval, S. (2016). Decentralised applications: harnessing Bitcoin's Blockchain technology First

Sterman, J. (2000). Business dynamics: Systems thinking and modeling for a complex world / John D. Sterman. Boston: Irwin/McGraw-Hill.

Tejpal, G., Garg, R., & Sachdeva, A. (2013). Measuring Business Excellence, 17(1), 51-71.

Gatteschi, V., Lamberti, F., Demartini, C., Pranteda, C., & Santamaría, V. (2018). Blockchain and Smart Contracts for Insurance: Is the Technology Mature Enough? Future Internet, 10(2), .

Wong, Cheung, Yiu, & Pang. (2008). A framework for trust in construction contracting. International Journal of Project Management, 26(8), 821-829.

Zhu, Y., Riad, K., & Guo, R. (2018). New instant confirmation mechanism based on interactive incontestable signature in consortium blockchain. Frontiers of Computer Science, pp.1–16.