Shifting trust in construction supply chains through blockchain technology

Qian, Xiaoning (Alice); Papadonikolaki, Eleni

Abstract

Purpose – Blockchain technology is booming in many industries. Its application in supply chain management is also gradually increasing. Supply chain management (SCM) 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. To this end, this study aims to examine how trust is affected by the introduction of blockchain technology in construction supply chain management.

Design/methodology/approach – This study is based on semi-structured interviews and publicly-available information from experts in blockchain and construction supply chain management. Through content analysis, the data is analysed thematically to explore how various types of trust, such as system-based, cognition-based and relation-based, are affected by blockchain technology.

Findings – Blockchain technology provides solutions for data tracking, contracting and transferring resources in supply chain management. These applications help enhance the various sources of trust in SCM and provide supply chain partners with protection mechanisms to avoid the risks and costs of opportunistic behaviour in collaboration, shifting trust from relational to system-based and cognition-based.

Research limitations/implications – This study focuses only on inter-organisational rather than interpersonal trust and empirical data from experts whose knowledge and cognition could be subjective.

Practical implications – Leveraging the potential of digitalisation to manage trust requires that leaders and managers actively try to improve contractual arrangements, information sharing and being open to new innovative technologies like blockchain.

Social implications – From a relational view of supply chain management, the extent to which blockchain technology can develop and spread depends on the readiness of the social capital to accept decentralised governance structures.

Originality/value – This study builds upon an original dataset and discusses features and applications of blockchain technology, explores the sources and dimensions of trust in supply chain management and explains the impact of blockchain technology on trust.

Keywords (maximum 12): blockchain technology, supply chain management, trust, experience

Introduction

Advancements in digital technologies, through better computer infrastructure, associated with increasing computing power, mobile devices, for example hand-held devices or headsets, and various pervasive technologies, have taken the world closer to 'Industry 4.0'. This deep technological shift brings a paradigmatic change to the world, comparative to other historical changes over the last three hundred years (Schwab, 2016). The fourth industrial revolution or industry 4.0 is an industry supported by digital technologies and automation that leverages the power of cyber-physical systems, the internet of things (IoT), blockchain technology, cloud and cognitive computing (Lasi et al., 2014). Especially in construction, according to the Institute of Civil Engineers (ICE, 2017) the industry 4.0 brings a digital transformation that is: *"the application of digital technologies to all aspects of human life. [In this report] it applies to the wholesale changes in how our industry designs, builds, operates, maintains and decommissions assets. It also refers to the transformation of how we value data, and the impacts upon processes and systems, and ultimately decision making."*

Against this backdrop, the traditional character of construction, which is a highly project-based sector (Morris, 2004), is challenged by the pervasive digital technologies. The construction sector is very diverse consisting of numerous multi-disciplinary firms and professional service providers that are rarely integrated with each other (Vrijhoef, 2011). Typically, construction firms working together in projects are geographically dispersed and construction supply chain partners are based in numerous different locations, working together to achieve common goals but predominantly with a project focus (Winch, 2002). Hence, the supply chain view of construction is very useful for understanding it. A supply chain (SC) is defined as a network of suppliers, factories, warehouses, distribution centers, and retailers (Christopher, 2011). Supply chain management (SCM) is committed to improving the performance of individuals across the entire supply chain (Chopra and Meindl, 2007). 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 construction has been magnified because of fragmented cooperation (Pryke, 2009). The key to addressing excessive waste and looseness of relations in supply chains is trust among parties

(Sterman, 2002).

Among the proliferation of various digital technologies in Construction 4.0 – a construction-centered view of industry 4.0, where a confluence of technological trends interact (Sawhney et al., 2020), blockchain technology promises a revolution in the structure and development of supply chain relations in construction. Indeed, due to its transactional nature, 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 (Nakamoto, 2008, Morris, 2016, Popper, 2016). Research on blockchain applications in construction is a novel field, and has various applications, as to rationalising energy distribution (Hu et al., 2019), linking with Building Information Modelling (BIM) and common data environments (Nawari and Ravindran, 2019b, Parn and Edwards, 2019) and ensuring cyber-security (Nawari and Ravindran, 2019a). Li et al. (2019) and Turk and Klinc (2017) have outlined other potential applications of blockchain technology in construction such as smart cities, sharing economy, intelligent transport, construction management and business models.

Following on from these seminal studies, the boundaries of this study are blockchain applications for construction management and in particular, the research aim of this study 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 construction SCM and in which dimension or aspect*? This study starts with a literature review of the relevant concepts, looking for the characteristics of blockchain technology and its existing applications, and analyse trust in construction SCM. The ensuing section presents the methodology and elaborates with specific methods of data collection and analysis. Next, the study presents and analyses the collected data, trying to establish the mechanism and relations of key concepts, such as trust, blockchain and supply chains. The penultimate section discusses the findings and compares the analysed data with existing theories and knowledge in the area. This includes a reflection on the research and practical limitations. Finally, the study concludes and gives recommendations to practitioners and researchers.

Theoretical background and knowledge gap

Sources of Trust in SCM

Trust conceptualisations in business

Trust is a key concept in psychology, sociology, philosophy and business. Studies have shown that corporate activity and interaction are influenced by previous levels of trust (Gulati and Nickerson, 2008). The most prominent definitions of trust include its description as “willingness to be vulnerable” (Mayer et al., 1995), "willingness to rely" (McAllister, 1995) or "confident, positive expectations" (Lewicki et al., 1998). It is expected that higher level of trust increases the efficiency of the cooperation. Good interaction and joint work in SCM always require trust (Morgan and Hunt, 1994). However, there are trust definitions with darker connotations, for instance rational trust that is seen as believing that the other party will take opportunistic actions to ensure their company's interests (Tejpal et al., 2013). In supply chain management, trust is also considered to be a willingness to agree with partners and have confidence in them (Moorman et al., 1992). There are two traditional theories of trust establishment (Laan et al., 2011).

The first is based on economics. In the field of social capital, trust helps to improve relationships because it brings mutual benefits, opportunities, risks and knowledge sharing (Inkpen, 2005, Nahapiet and Ghoshal, 1998). Scholars in transaction cost economics see trust as a substitute tool for cost-effective coordination and risk management (Bromiley and Cummings, 1995). Young-Ybarra and Wiersema (1999) argue that collaborative experience can reduce the risk of opportunistic behaviour and thus increase trust. The second theory reflects the views of psychology and sociology, which is the view that this study adopts. Rotter (1980) argues that trust-based decision-making depends on the personal characteristics of the decision maker. However, Bhattacharya et al. (1998) believe that most of the disciplines such as sociology ignore the differences in individual trust tendencies. Figure 1 presents the spectrum of various conceptualisations of trust.

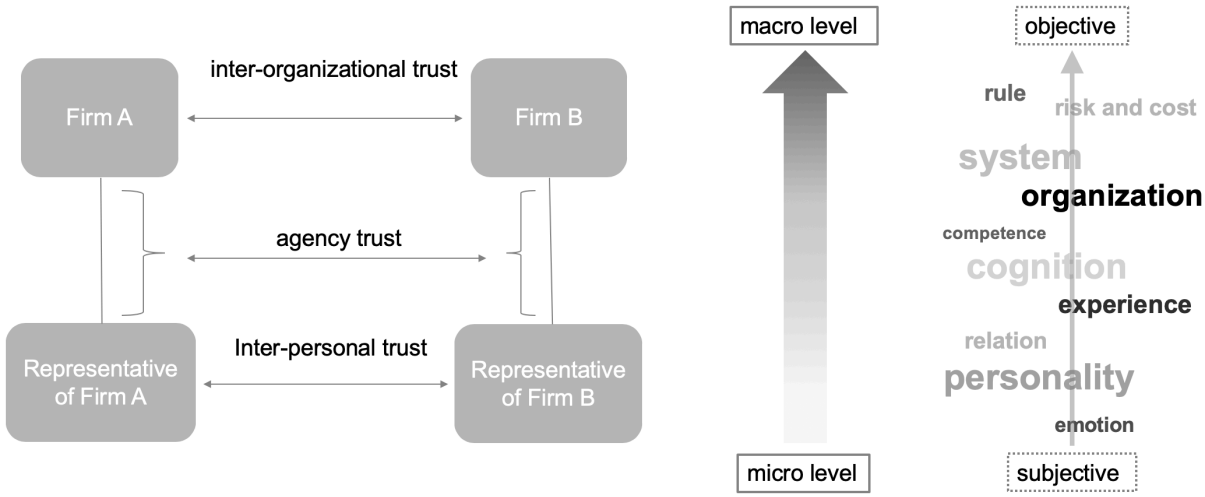

Figure 1: Conceptualisations of trust. This study focuses on the top part of the spectra.

Trust in construction supply chains

Psychologists and social scientists divide the impact of trust into micro- and macro-level. Manu (2014) in his thesis, summarised the trust in supply chain management as inter-organisational trust, agency trust and inter-entity trust. The higher micro-trusted is a subject, the higher the influence of an individual's psychological factors. Bachmann (2011) argued that the existing research is too focused on the micro-level, and the macro-interaction interaction impact lacks sufficient research. Due to the overemphasis on interaction and micro-level approach, the role of organisations in trust development has not been thoroughly studied to date and is a promising future direction of research. Wong et al. (2008) described the sources of trust as system-based trust (from communication systems and processes), cognition-based trust (from information sharing and knowledge) and affect-based trust (based on sentiment and hence relational). Figure 2 presents an analysis of Wong et al. (2008) conceptualisation of trust.

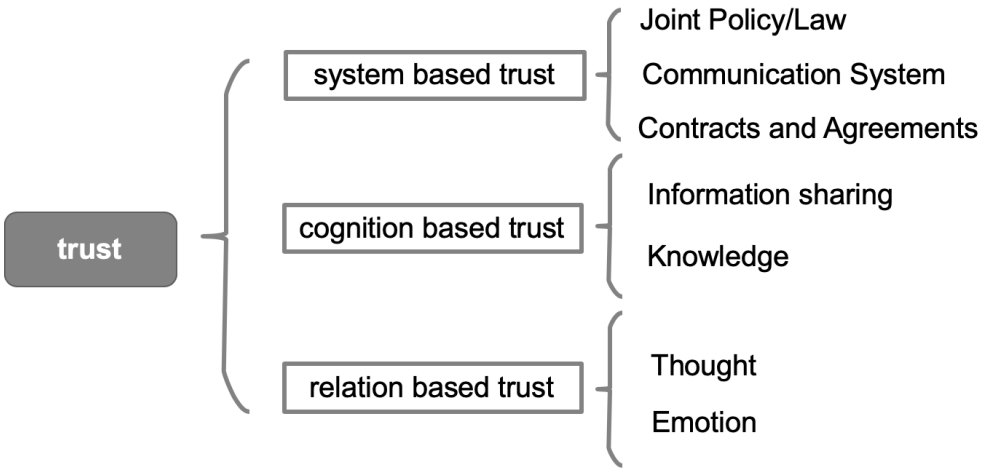

Figure 2: Sources of trust, adapted by Wong et al.,(2008).

Manu (2014) divided the foundations of trust in supply chain management in construction into three categories: (1) relationship, (2) competence and (3) system. First, relationship-based trust comes from resource swaps and opportunity sharing from previous collaborations or interactions. This kind of trust exists prior to establishing 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 information they share. This in turn increases the profitability and performance of all parties. Second, in construction projects, trust also comes from the company's reputation and resources, such as technological advantages, capital or market share (Das and Teng, 2001). At the same time, corporate performance and corporate risk also affect the company's capabilities, because it affects the success of completing the project. Third, as explained by Wong et al. (2008), communication systems, contracts and agreements are sources of system-based trust in the front-end of construction project set-up. At an inter-organisational or macro level, trust may come from both human and non-human agencies, such as information systems and automated systems. Contracts, drawings, digital representations, such as from Building Information Modelling (BIM) are all boundary objects (Papadonikolaki et al., 2019) that affect inter-organisational systems and can form and contribute to system-based trust.

Latham (1994) construction industry report pointed out that the industry 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 (Pryke and Pearson, 2006). Long-term supply chain relationships are compromised when short-term returns are treated as a top priority (Pryke, 2009). Specific issues include, for example, arrears, credit difficulties, bidding/contract drafting fees, and information asymmetry (Paunov, 2012, Manu, 2014).

Applications of Blockchain Technology in SCM

Blockchain technology features and applications

Blockchain technology offers solutions that may disrupt many industries (Kshetri, 2017). The first use of the concept of blockchain dates back in 2008, introduced in a white paper on Bitcoin, the world's first cryptocurrency by Satoshi Nakamoto, pseudonym used for a person and a community (Nakamoto, 2008). A blockchain is an encrypted digital ledger that is stored in a public or private network on numerous nodes (computers). These nodes use a common communication (governance) protocol across the network and a consensus mechanism is used to validate transactions to ensure the immutability of the chain (Bashir, 2017). These nodes contain a copy of encrypted data blocks (records) chained by hash codes to each other (Swan, 2015).

The main characteristics of blockchain are described as decentralisation and transparency (Raval, 2016). 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). Details of any transaction are transmitted to the network for validation and verification when a new transaction is created and only if all nodes agree that the transactions in the data block (record) are valid in accordance with a common communication (governance) protocol, the block is attached to the blockchain and the copy of each node of the blockchain is updated accordingly (Karafiloski and Mishev, 2017). These transactions once in a block cannot be changed or deleted by a single actor when this block is attached to a chain (tamperproof ledgers). This is decentralisation. Blockchain networks can be divided into three categories: public blockchains without any access properties (e.g. are Bitcoin and Ethereum); semi-distributed consortium blockchains authorised by federation administrators (Zhu et al.,

2019) and private blockchains strictly controlled by the administrator (Guegan, 2017).

Transparency is defined as the level of how outsiders can detect into the working system (Awaysheh and Klassen, 2010). Blockchain technology is suitable for improving transparency due to its tamperproof ledgers and distributed nature. 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 (Valdes et al., 2016).

The main applications of blockchain technology are tracking, recording and provenance and can be illustrated through a few examples. Maersk, the world's largest container carrier company, used blockchain technology into the logistics in cooperation with IBM (Popper and Lohr, 2017). The blockchain-enabled logistics process tracked 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 took minutes to be accomplished. With the implementation of blockchain technology, it reduced enormous cost on record work and labor source (Popper and Lohr, 2017). Especially in supply chains, blockchain solutions have been applied to improve cost, quality, speed, dependability, risk reduction, sustainability and flexibility with the incorporation of the Internet of Things (IoT) (Kshetri, 2018). The blockchain-IoT combination can facilitate sharing of services and resources leading to the creation of marketplaces and allowing the automation in a cryptographically verifiable manner of time-consuming workflows (Christidis and Devetsikiotis, 2016).

Another application of blockchain technology is on providing 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). Without human interruption, an automated system will activate the "smart contract", trigger the pre-set conditions or conditions agreed by the parties and notify (or update) all participants by contract. An example is automatic system notification and payment. Apart from these taylorist views of how

blockchain technology can improve SCM, supply chains as inter-organisational constellations can leverage the technology to improve their relations.

Relational view of construction supply chains

Historically, a supply chain was conceptualised as a set of flows: a downstream flow of material, an upstream flow of transactions and a bidirectional flow of information (Christopher, 1992). Supply chain management (SCM) emerged as a philosophy that theorises and suggests activities for the regulation of these flows. Later, a supply chain was considered actually to be a network and not a – linear – chain per se (Pryke, 2009), given that the multiple organisations that form this network, generate different and multiple information streams simultaneously (Christopher, 2005). Thus, a supply chain could be considered as a "supply-demand network", or a complex and distributed network of organisations (Christopher, 2011).

This chapter is aligned with Pryke's (2009) intention to demonstrate that SCM in construction is much more than a trend and could potentially contribute to added value for the client and the other stakeholders in the built environment, beyond mere financial gains. In construction, SCM was seen as the management of the information, material, and cash flows (Arbulu, 2009, Vaidyanathan, 2009). Other scholars further simplified these flows to material and information flows (Cutting-Decelle et al., 2009), as cash flow could be potentially seen as part of the information flow (Papadonikolaki, 2020). Others extended the set of flows to include material, labour, and equipment (Cox and Ireland, 2002). A more relational view of SCM focuses on the actors and their interrelations to improve trust and information flows across the supply chain (Pryke, 2009, Papadonikolaki, 2016, Dulaimi et al., 2007).

The fragmentation of construction requires higher integration in supply chains (Vrijhoef, 2011). Trust is an important factor in improving the efficiency of supply chain management (Miles and Huberman, 1994). Manu (2014) divided the foundations of trust relationships among supply chain partners in construction into systems, relationships, and competence. Xu (2020) established that self-reinforcing cycles of trust and collaboration in supply chains create 'bounded solidarity'. Although there are reports of contractors using collaborative technologies (Manu and Knight, 2020), little is known about how trust in relationships among supply chain partners are affected by digital technology.

Blockchain technology has shown the potential to support trust in construction SCM through open and transparent transactions, revolutionising the sector, leading to delivery of higher quality projects (Maciel, 2020). At the same time, blockchain technology can offer a framework to future software applications in construction securing the transfer of sensitive project data over common data environments (Pärn and Edwards, 2019). This paper examines through what trust mechanisms blockchain technology affects supply chain management to improve inter-organisational relations. This study provides a lens for how blockchain technology affects SCM, especially in construction. It can inspire future business development ideas to provide solutions for inter-firm trust relationships in construction supply chains. Blockchain technology development initiatives will also gain a better understanding of the needs of SCM in construction industry.

Methodology and Methods

Methodological rationale

Research methodology typically stems from researchers' worldviews on ontology, cognition, and interpretation of phenomena (Ponterotto, 2005). To this end, according to idealism ontology, reality can only be understood via the human mind and then interpreted. Such interpretation through mainly socially constructed meanings (Robson and McCartan, 2016), particular through the use of language, is social constructivism. This work follows the view of Crotty (1998) that all knowledge and meaningful reality are “contingent upon human practices, being constructed in and out of interaction between human beings and their world, and developed and transmitted within an essentially social context”.

Drawing upon this interpretivist lens, the qualitative data collected was mainly analysed and summarised through textual interpretation by constructing meaning through language. In terms of methods, this study deployed semi-structured interviews to collect data and used thematic analysis to analyse it and reach a qualitative conclusion (Bryman, 2016). This study is based on a mixture of grounded theory research and narrative research following a mixed data collection strategy, all of which are qualitative research methods as defined by Creswell (1994). The data from this study was derived from 10 interviews, following a narrative approach (as researchers identified the background of

interviewees and retold their stories) and two public lectures, following ground theory approach (as data was given by participants rather than based on a priori theory) from experts on blockchain applications.

Data collection process

The interviewees were selected from industries of blockchain technology, supply chain management and construction project, to support the research aim and scope. Their selection was crucial for research validity and relevance. The criteria for interviewee section were industry or research experience in blockchain solutions and understanding of SCM concepts. The research design included three main themes: blockchain technology, SC applications of blockchain and construction SCs. These topics acted as a priori codes (Saldanā, 2009) of the research and provided structure. For each of the three themes, one or two people were chosen initially. Subsequently, they recommended the rest of the interviewees following a snowballing technique, until reaching the 'saturation point', where according to Atkinson and Flint (2001) where no new data would be received. The three themes and interviewees profiles are listed in Table 1. These three themes related to the study were defined so as to ensure that experts will have specialised knowledge at least in one for the themes, as blockchain in construction supply chain is a nascent area and the interfaces among those areas are not well-developed.

Table 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 & developing 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

The semi-structured interviews lasted around half an hour per interview. According to the interview protocol of the study, interviewers were notified in advance of the interview about its purpose and method before being interviewed. To protect their privacy, no names that could be identified people

or companies appeared. The research team received ethics clearance in accordance to university rules before conducting data collection. The interviews or seminars were recorded and later transcribed to ensure the authenticity and accuracy of the information.

The first two introductory questions are used to provide an industry orientation for the interviewee and provide a basic understanding of trust, blockchain and supply chain concepts. Then the following three questions were about each topic the specific interviewee belonged 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.

Data analysis and limitations

The interviews after being transcribed they were analysed systematically. The transcripts were analysed or 'coded' (Miles and Huberman, 1994) using both deductive and inductive coding, consistent with qualitative content analysis process (Cho and Lee, 2014). As there is not a definitive manner to rigorously analyse qualitative data (Robson and McCartan, 2016) the theoretical framework was used as an indication of sensitising concepts (Blumer, 1954) for data analysis. Subsequently, concepts of the theoretical framework were first used as deductive (theory-based) codes that directed the analysis of the empirical fieldwork, in first order coding. The deductive codes were terms such as 'trust', 'blockchain', 'supply chains' and so forth. Another set of codes was inductive (data-based), from the data, as repetitive concepts emerged from the semi-structured interviews. The inductive codes were derived by summarising the data during analysis (Saldanā, 2009). These were later used as second order coding to cross-compare the previous codes and create clusters of meaning and help organise the data by identifying common patterns and themes in the third order coding. Table 2 provides examples of quotations and how these were coded. Accordingly, the coding was done as follows:

- 1st layer: the main theme related to the quotation: either source of trust or applications of the blockchain technology,
- 2nd layer: the most important keywords used in the quotation and

- 3rd layer: output or conclusion of the quotation.

Table 2: Examples of implementation of the coding process.

Quotations	**Theme: 1st layer code**	**Keywords: 2nd layer code**	**Output: 3rd layer code**
The most significant advantage is the increased efficiency of the distribution of information and knowledge.	Application of blockchain	efficiency	tracking
The information dissemination mechanism provided by the blockchain will significantly enhance the maintenance and after-sales.	Application of blockchain	dissemination	tracking
If you have real time data, such processing and distribution can effectively reduce your logistics costs	Application of blockchain	Real-time data	tracking
Let's say, if we know each other for 10 years. I believe in you, so I don't need a promise from you. This is actually because we have known each other for a long time, and there could be no contract.	Source of trust	believe	experience
The financial problem matters a lot	Source of trust	financial	irrelevant data
At the beginning, we definitely didn't trust each other. But if they are large companies, listed companies, state-owned enterprises, central enterprises, etc. We also cooperate with them, their size and fame are some invisible source of the trust. They won't default easily due to their goodwill.	Source of trust	size	reputation company size

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 (Buskens, 2002), 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, consistent with the researchers' constructivist ontology (Robson and McCartan, 2016). Through interviews and data analysis, this study can only qualitatively give specific explanations of the problem, but it cannot provide more precise quantitative judgments.

Data presentation and analysis

Applications of Blockchain in Construction

The interviews with practitioners considered the two characteristics of the blockchain, decentralisation and transparency, have their unique applications, advantages and disadvantages. From a quantitative analysis of the third order codes on applications of blockchain technology, the concepts of tracking, contracting and transferring were the most prevalent in the data. Table 3 tabulates this data and the counts of third order codes. After deductive coding and thematic clustering of the data from the interviewees in the e-tracking, smart contract, and finance industries, who are doing blockchain-related research and development, it was extracted that blockchain has three main applications in the supply chain: tracking, contracting and transferring, as seen in Figure 3 below.

Table 3: Quantitative analysis of 3rd layer codes about applications of blockchain technology in construction.

Codes	**Count of 3rd layer code**
contracting	29
tracking (including Internet of Things (IoT)	58
transfer (including currency)	23
irrelevant quotations	5967
Total	6077

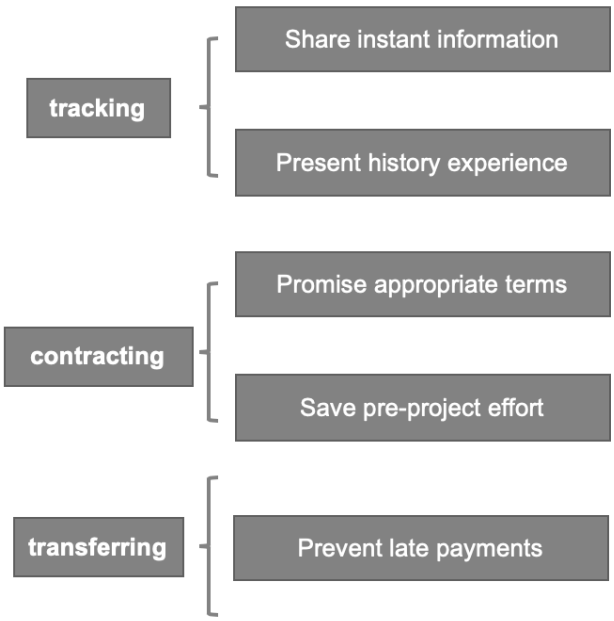

Figure 3: Functions of trust of blockchain applications in supply chain management.

Tracking

First, the data confirmed that function of tracking in blockchain applications relates the Internet of Things (IoT) (Kshetri, 2018). Long before the emergence of blockchain, the IoT had begun to focus

on instant peer-to-peer dissemination of information. Interviewee 2B stated: *"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."* Interviewee 1A added that *"The instant tracking method can save 70% of the after-sales cost."*. Simultaneously, they expected that the labor costs required to record progress will be significantly reduced: *"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"* (Interviewee 3D). The interviewees challenged the prevalent view that blockchain can increase transparency and Interviewee 1A mentioned: *"With open permissions, the allowed user accounts can directly access the information in the system. When these instructions are adjusted according to industry standardisation, the network may allow specific users only to obtain accurate information. Therefore, the blockchain network cannot be considered to be completely transparent."*. Interviewee 2A stated: "Although we believe that it does have transparency, it is not possible to open all viewing rights to each user."

Contracting

Second, data revealed that industry contracts through digital technology can help people avoid trivial contract drafting and inspections. Experts in the public lecture 2C concurred that they are working to optimise algorithms and frameworks so that smart contracts can cover a broader range of more specific terms, as imperfect or incomplete contracts have led to conflicts between parties. 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.

Transferring

Third, transferring cash flows are popular applications of blockchain. Many financial institutions

apply blockchain to their financial systems because its peer-to-peer transaction recording method can simplify the administration of centralised processing in traditional banking systems. Interviewees 3E and 3B, concurred that managing cash flow is the most significant problem in SCM. Interviewee 3B described: *"The biggest problem is the payment problem. Few people will complete the transfer on the date of payment."*. Interviewee 3E explained: *"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."* Blockchain applications such as smart contract can guarantee proper execution of transfers. They can significantly reduce ambiguity in contractual transaction date and other default issues faced by suppliers.

Sources of trust in SCM

After inductive coding of the data, repetitive concepts emerged from the semi-structured interviews and revealed the interviewees' perceptions on trust sources in SCM. From a quantitative analysis of the third order codes on sources of trust in construction SCM, the concepts of reputation, experience and contracts (including legal aspects and certifications) were the most prevalent among the data. At a lesser extent, the code of company size was apparent in the data. Table 4 presents this data and the counts of third order codes. These codes are also summarised in Figure 4. As shown in the figure, the trust among suppliers comes from cost reduction, which depends mainly on the level of the risk. The interviewees stated that a company's existing reputation, cooperation history and industry norms can help reduce the risk of cooperation, thereby enhancing trust. These findings are analysed in detail next.

Table 4: Quantitative analysis of 3rd layer codes about sources of trust in construction SCM.

Codes	**Count of 3rd layer code**
reputation	20
experience	23
contract/law (including certifications)	18
company size	4
irrelevant quotations	6458
Total	6523

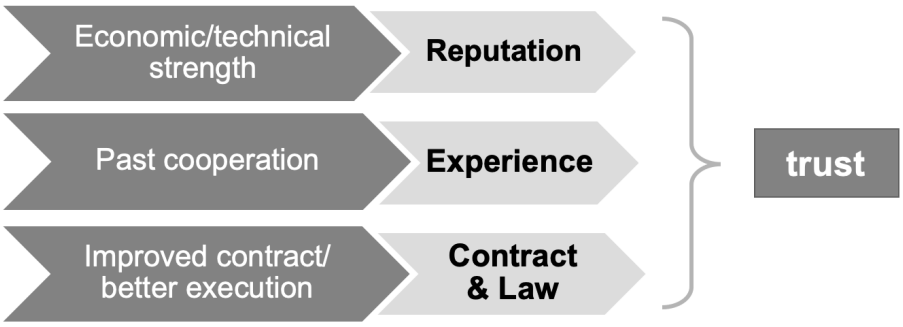

Figure 4: Sources of trust in construction supply chain management.

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 emphasised: *"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.

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."

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".* Interviewee 1B added that: *"The speed and efficiency of sharing information and knowledge have always been a key in supply chain management, so blockchain can indeed improve it".*

Data interpretation: Changes of Trust Mechanisms in SCM

After exploring potential applications of blockchain in SCM and sources of trust in SCM, further analysis of the data through second order coding and cross-comparison, inter-relations on how blockchain applications affects trust in SCM were created. From the interview data, three applications of blockchain: tracking, contracting, and transferring have the functions of sharing instant information, presenting history data, promising terms, saving pre-project effort, and preventing deferred payments (see Figure 3). The direct sources of trust in supply chain management in the construction project industry were according to the analysis presented above, reputation, experience and contacts (see Figure 4). 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 findings and SCM blockchain applications and

sources of SCM trust are illustrated below in Figure 5. According to Figure 3 the prevalent blockchain in construction SCM, mostly support experience-related and contractual sources of trust in SCM.

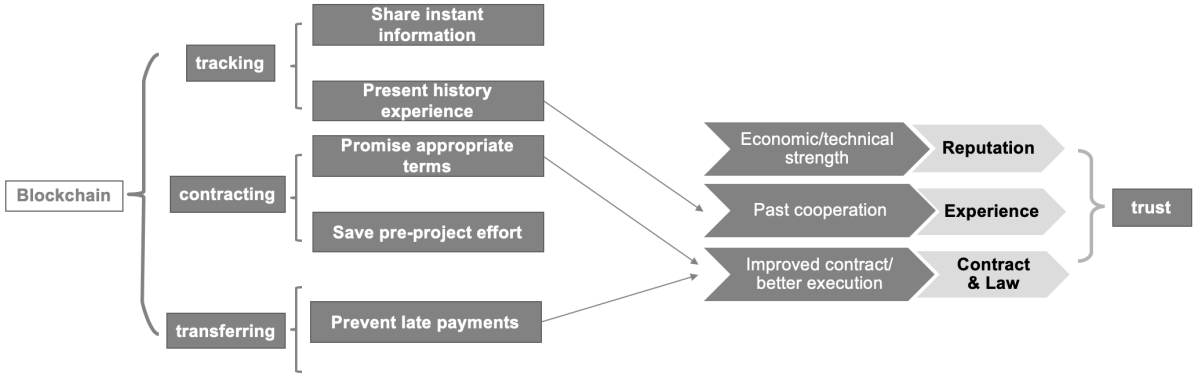

Figure 5: Influence of blockchain applications on the sources of construction supply chain management trust.

Information flows and the enforcement of specifications affect trust and ultimately the effectiveness of SCM. Blockchain technology can be seen as a third party, as Decentralised Autonomous Organisations (DAO) that provides transparency and reliability (Tezel et al., 2019). DAO, according to experts in the public lecture 1C: *"Once certified by an authority or industry, it will have the ability to bring credibility proofs that increase trust between companies."*. When applied, this technology will improve the flow of information and accumulated knowledge, helping members of the network optimise resource allocation and reduce costs. Therefore, blockchain can increase trust while reducing the need for various other sources of trust in collaboration. To this end, by comparing the data with the dimensions of trust framework by Wong et al. (2008), blockchain applications can support well system- and cognition-based trust. Better contract integration and payment transferring methods enhance the supervision and execution of external management of legal and financial aspects; transparent real-time tracking and decentralised data sharing bring more reasonable rights and openness to all parties. Figure 6 illustrates the process of how blockchain technology applications affects SCM by influencing and altering trust dimensions.

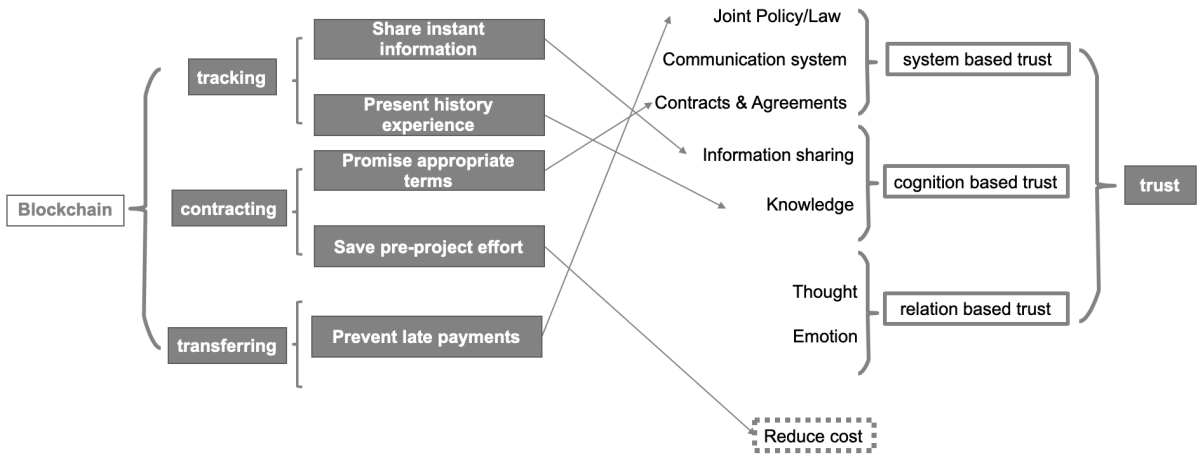

Figure 6: Influence of blockchain applications on supply chain management trust dimensions by Wong et al. (2008).

Information sharing and history of firms working together can enhance cognition-based trust. Optimised contractual treaties and effective payment mechanisms increase the credibility and feasibility of the system. Additionally, smart contracts may reduce upfront efforts for projects, which directly reduces costs. With the application of blockchain technology, supply chain partners spend less 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. As a management tool this DAO would entail a transparent sharing mechanism, less centralised tendency and more comprehensive and reasonable institutional treaty than the ordinary business alliance. However, Interviewee 1A noted: *"An important question is whether the current market is mature enough to withstand decentralised bookkeeping power".* Information sharing, knowledge, contracts and agreements and policy contribute to the cognition-based and system-based trust according to Wong et al. (2008) classification and can replace the need for relation-based trust dimension (see Figure 6).

Discussion

Reconceptualising trust in technology-laden solutions

The findings align with previous studies where contractors and supply chains combined relationship

management approaches with digital technologies that facilitated information management (Manu and Knight, 2020, Papadonikolaki, 2016). These systems are either Enterprise Resource Planning (ERP) systems or BIM and digital platforms (Mahamadu et al., 2014). However, apart from highlighting the value of digital technologies in databases and design information management, there has been a little emphasis on the value of digital technologies in building trust. Papadonikolaki (2018) studied innovation networks in the Netherlands and it was established that working with digital technologies such as BIM, contractors and supply chain partners still experienced lack of trust due to uncertainty about the accuracy of shared information.

This shows the contribution of this study, as blockchain technology has shown demonstrable benefits in various sectors as DTLs redefine trust among business parties through business process reengineering (Li et al., 2019). In the context of SCM, trust has been identified as both a prerequisite (Green et al., 2005), and a consequence of SC communications and relationship-building (Papadonikolaki and Wamelink, 2017). Responding to the research question of how blockchain technology changes trust in construction SCM, the study revealed that blockchain supports trust by affecting the cognition-based trust and the system-based trust, by complimenting a higher level of trust to existing systems and digital platforms such as BIM, by replacing relation-based trust dimension explained by Wong et al. (2008).

Contribution to theory and knowledge

From the empirical fieldwork, this study identified and analysed how the characteristics of the blockchain, transparency and decentralisation, and its applications influence the way trust flows among partners in supply chains and presented a wealth of empirical data to improve knowledge on the topic. Trust has been identified as both a drive and a hurdle to technology adoption in construction (Li et al., 2019), but there is little evidence of how blockchain technology can improve trust in SCM. SCM in construction remains an innovative ideas that requires organisational change and transformation (Fernie and Thorpe, 2007). Through three main applications of blockchain in construction SCM: tracking, contracting and transferring, blockchain technology can increase the source of trust among partners. Answering the main research question, it can be said that regarding the

dimension of the trust sources, blockchain mainly enhances trust by affecting the cognition-based trust and the system-based trust and essentially replaces relation-based trust dimension by Wong et al. (2008) classification. This aligns with the transformation of trust from relational to technological in SCM (De la Pena and Papadonikolaki, 2019). Simultaneously, for construction SCM, the function of contracting is expected to reduce the cost of contract signing or bidding and solve the capital flow issues in projects. The data analysis shows that blockchain technology in SCM can reduce the cost of building initial trust in subsequent collaborations.

This study partially supports the idea that more historical data and collaborative experience will reduce opportunistic behaviour and increase trust (Young-Ybarra and Wiersema, 1999) (see Figures 4 and 5). The improvement of smart contracts and the strengthening of enforcement through mandatory external mechanisms will help reduce the need for trust as supported by (Storey et al., 2006). Also, the data analysis resonates with the classification of sources of trust: relationship, competence and system by Manu (2014) to higher detail. For Brown et al. (2010) technology or other organisational strengths help with gaining trust. The empirical data extends this view, further explaining that technological strength and reputation can lead to trust because companies well-represented have more credibility, thereby reducing cooperation risk.

Practical implications and future directions

The study showed that construction practitioners have realistic expectations for blockchain technology to solve trust problems, especially concerning delayed project payments and credit issues (Paunov, 2012). Also, the experts untangled some blockchain misconceptions regarding transparency (see 'tracking' sub-section) and discussed its conditions, needs and limitations. For supply chain managers, increasing efficiency and reducing total cost has always been an important goal. Based on the research findings, the practical implications and recommendations for leveraging the potential of industry 4.0 to manage trust are:

- improving contractual arrangements,
- improving information sharing to reduce interaction cost,,

- being open to innovative technologies like blockchain.

Spearheading the advancement of blockchain technology itself is crucial. Whether the current market and social development conditions allow decentralised business models such as DAO remains to be studied. The extent to which blockchain technology can develop depends on social acceptance of decentralisation, which requires more research on social ethics. When selecting the type of the blockchain network, this paper mainly focused on public rather than private blockchains. In private or semi-federal blockchain networks, the degree of transparency and decentralisation depend on permission. The analysis also did not consider the cost of developing blockchain technology solutions and this could be a future research direction. With the wave of the powerful blockchain technology, the way of how different types of construction firms, such as consultants, contractors, clients and supply could leverage blockchain to obtain tangible benefits will be focus of future research.

Conclusion

Construction 4.0 utilises digital technologies and automation to leverage the power of cyber-physical systems such as blockchain technology. This study followed a constructivist epistemology to understand how trust in construction SCM changes due to blockchain applications, by semi-structured interviews with industry experts. First, this paper untangled the characteristics of blockchain technology of decentralisation and transparency, challenging these concepts. It was established that transparency depends on the governance rules and the permissions in place, whereas decentralisation depends among other on who is setting those rules (an individual or an institution). Second, the study discussed the applications of blockchain in SCM, which can be described as tracking, contracting and transferring, connecting with other technologies of construction 4.0 and especially the IoT. All of these were equally discussed in the empirical dataset, but especially experience and contractual issues of trust had more to gain from these three blockchain applications. Third, the study pointed out how these blockchain applications affect trust in construction SCM and it was revealed that they contribute more to system- and cognition-based trust and essentially reduce the need for setting up relation-based trust. This responds to the research question of *how blockchain technology changes trust in*

construction SCM.

This study goes a step further by explaining the reason that clear rules or sufficient tracking information brought by blockchain technology can shift from relation-based trust towards system- and cognition-based trust. However, further investigations on the nature of decentralisation is needed to define the appropriate process to set up DAOs in a manner that all SC partners will trust. This will strengthen the cognition-based trust and create the system for setting the appropriate permissions for the update of DAOs in construction. The above steps can directly reduce the cost and need of building trust in the early stages of cooperation. To this end, blockchain technology is a key technology in construction 4.0 that can bring the cyber (digital technologies) physical (social capital) closer together by transforming trust to support various ecosystems of construction supply chains that shape and produce the built environment.

References

Akkermans, H., Bogerd, P. & Vos, B. 1999. Virtuous and vicious cycles on the road towards international supply chain management. *International Journal of Operations & Production Management,* 19**,** 565-582.

Arbulu, R. 2009. Application of integrated materials management strategies. *In:* O' Brien, W. J., Formoso, C. T., Vrijhoef, R. & London, K. A. (eds.) *Construction Supply Chain Management Handbook.* Boca Raton, FL: CRC Press.

Atkinson, R. & Flint, J. 2001. Accessing hidden and hard-to-reach populations: Snowball research strategies. *Social research update,* 33**,** 1-4.

Awaysheh, A. & Klassen, R. D. 2010. The impact of supply chain structure on the use of supplier socially responsible practices. *International Journal of Operations & Production Management,* 30**,** 1246-1268.

Bachmann, R. 2011. At the crossroads: Future directions in trust research. *Journal of Trust Research,* 1**,** 203-213.

Bashir, I. 2017. *Mastering blockchain*, Packt Publishing Ltd.

Bhattacharya, R., Devinney, T. M. & Pillutla, M. M. 1998. A formal model of trust based on outcomes. *Academy of management review,* 23**,** 459-472.

Blumer, H. 1954. What is wrong with social theory? *American sociological review,* 19**,** 3-10.

Bromiley, P. & Cummings, L. 1995. Transaction costs in organizations with trust. R. Bies, B. Sheppard, R. Lewicki, eds. Research on Negotiations in Organizations, Vol. 5. JAI Press, Greenwich, CT.

Brown, S. A., Dennis, A. R. & Venkatesh, V. 2010. Predicting collaboration technology use: Integrating technology adoption and collaboration research. *Journal of Management Information Systems,* 27**,** 9-54.

Bryman, A. 2016. *Social research methods*, Oxford university press.

Buskens, V. 2002. *Social networks and trust,* Amsterdam, Interuniversity Center for Social Science Theory and Methodology-Thela Thesis.

Cho, J. Y. & Lee, E.-H. 2014. Reducing confusion about grounded theory and qualitative content analysis: Similarities and differences. *The qualitative report,* 19**,** 1-20.

Chopra, S. & Meindl, P. 2007. Supply chain management. Strategy, planning & operation. *Das summa*

summarum des management. Springer.
Christidis, K. & Devetsikiotis, M. 2016. Blockchains and smart contracts for the internet of things. *Ieee Access,* 4**,** 2292-2303.
Christopher, M. 1992. *Logistics and supply chain management: Strategies for Reducing Cost and Improving Services,* London, UK, Financial Times Professional Ltd.
Christopher, M. 2005. *Logistics and supply chain management: Creating Value-Adding Networks,* New York, USA, Financial Times Prentice Hall.
Christopher, M. 2011. *Logistics and Supply Chain Management,* Dorset, UK, Financial Times Prentice Hall.
Cox, A. & Ireland, P. 2002. Managing construction supply chains: the common sense approach. *Engineering Construction and Architectural Management,* 9**,** 409-418.
Creswell, J. W. 1994. *Research design: Qualitative & quantitative approaches,* Thousand Oaks, California, USA, Sage Publications.
Crosby, M., Pattanayak, P., Verma, S. & Kalyanaraman, V. 2016. Blockchain technology: Beyond bitcoin. *Applied Innovation,* 2**,** 71.
Crotty, M. 1998. *The foundations of social research: Meaning and perspective in the research process,* London, Sage Publications Limited.
Cutting-Decelle, A. F., Young, R. I., Das, B. P., Anumba, C. J. & Stal-Le Cardinal, J. 2009. Standards-Based Approaches to Interoperability in Supply Chain Management: Overview and Case Study Using the ISO 18629 PSL Standard. *In:* O' Brien, W. J., Formoso, C. T., Vrijhoef, R. & London, K. A. (eds.) *Construction Supply Chain Management Handbook.* Boca Raton, Florida, USA: CRC Press.
Das, T. K. & Teng, B.-S. 2001. Trust, control, and risk in strategic alliances: An integrated framework. *Organization studies,* 22**,** 251-283.
De La Pena, J. & Papadonikolaki, E. From relational to technological trust: How do the IoT and Blockchain technology fit in? Proceedings of 2019 European Conference on Computing in Construction (EC3), 2019. European Council on Computing in Construction (EC3).
Dulaimi, M., Akintoye, A. & Main, J. 2007. Collaborative relationships in construction: the UK contractors' perception. *Engineering, Construction and Architectural Management,* 14**,** 597-617.
Fernie, S. & Thorpe, A. 2007. Exploring change in construction: supply chain management. *Engineering, Construction and Architectural Management,* 14**,** 319-333.
Green, S. D., Fernie, S. & Weller, S. 2005. Making sense of supply chain management: a comparative study of aerospace and construction. *Construction Management and Economics,* 23**,** 579-593.
Guegan, D. 2017. Public blockchain versus private blockhain.
Gulati, R. & Nickerson, J. A. 2008. Interorganizational trust, governance choice, and exchange performance. *Organization Science,* 19**,** 688-708.
Hu, W., Hu, Y. W., Yao, W. H., Lu, W. Q., Li, H. H. & Lv, Z. W. 2019. A blockchain-based smart contract trading mechanism for energy power supply and demand network. *Advances in Production Engineering And Management,* 14**,** 284-296.
Ice. 2017. *State Of The Nation 2017: Digital Transformation* [Online]. London, UK: Institution of Civil Engineers. Available: https://www.ice.org.uk/getattachment/news-and-insight/policy/state-of-the-nation-2017-digital-transformation/ICE-SoN-Report-Web-Updated.pdf.aspx [Accessed].
Inkpen, A. C. 2005. Strategic Alliances. *In:* Hitt, M. A., Freeman, R. E. & Harrison, J. S. (eds.) *The Blackwell Handbook of Strategic Management.* London: John Wiley & Sons.
Karafiloski, E. & Mishev, A. Blockchain solutions for big data challenges: A literature review. IEEE EUROCON 2017-17th International Conference on Smart Technologies, 2017. IEEE, 763-768.
Kshetri, N. 2017. Can blockchain strengthen the internet of things? *IT professional,* 19**,** 68-72.
Kshetri, N. 2018. 1 Blockchain's roles in meeting key supply chain management objectives. *International Journal of Information Management,* 39**,** 80-89.
Laan, A., Noorderhaven, N., Voordijk, H. & Dewulf, G. 2011. Building trust in construction partnering projects: An exploratory case-study. *Journal of Purchasing and Supply Management,* 17**,** 98-108.
Lasi, H., Fettke, P., Kemper, H.-G., Feld, T. & Hoffmann, M. 2014. Industry 4.0. *Business & Information Systems Engineering,* 6**,** 239-242.

Latham, S. M. 1994. *Constructing the team*, HM Stationery Office London.
Lewicki, R. J., Mcallister, D. J. & Bies, R. J. 1998. Trust and distrust: New relationships and realities. *Academy of management Review,* 23**,** 438-458.
Li, J., Greenwood, D. & Kassem, M. 2019. Blockchain in the built environment and construction industry: A systematic review, conceptual models and practical use cases. *Automation in Construction,* 102**,** 288-307.
Maciel, A. 2020. Use of blockchain for enabling Construction 4.0 *In:* Sawhney, A., Riley, M. & Irizarry, J. (eds.) *Construction 4.0: An Innovation Platform for the Built Environment.* London: Taylor & Francis, Routledge.
Mahamadu, A.-M., Mahdjoubi, L. & Booth, C. A. Determinants of Building Information Modelling (BIM) acceptance for supplier integration: A conceptual model. *In:* Raiden, A. & Aboagye-Nimo, E., eds. Proceedings 30th Annual ARCOM Conference, 2014 Portsmouth, UK. Association of Researchers in Construction Management: , 723-32.
Manu, E. 2014. *Supply chain management practices in construction and inter-organisational trust dynamics.* Doctor of Philosophy, University of Wolverhampton.
Manu, E. & Knight, A. 2020. Understanding Supply Chain Management from a Main Contractor's Perspective. *In:* Pryke, S. (ed.) *Successful Construction Supply Chain Management: Concepts and Case Studies.* 2nd edition ed. London, UK: Wiley.
Mayer, R. C., Davis, J. H. & Schoorman, F. D. 1995. An integrative model of organizational trust. *Academy of management review,* 20**,** 709-734.
Mcallister, D. J. 1995. Affect-and cognition-based trust as foundations for interpersonal cooperation in organizations. *Academy of management journal,* 38**,** 24-59.
Miles, M. B. & Huberman, A. M. 1994. *Qualitative data analysis: An expanded sourcebook,* Thousant Oaks, CA, Sage Publications Inc.
Moorman, C., Zaltman, G. & Deshpande, R. 1992. Relationships between providers and users of market research: the dynamics of trust within and between organizations. *Journal of marketing research,* 29**,** 314-328.
Morgan, R. M. & Hunt, S. D. 1994. The commitment-trust theory of relationship marketing. *Journal of marketing,* 58**,** 20-38.
Morris, D. Z. 2016. Leaderless, blockchain-based venture capital fund raises $100 million, and counting. *Fortune (magazine)***,** 05-23.
Morris, P. W. G. 2004. Project management in the construction industry. *In:* Morris, P. W. G. & Pinto, J. K. (eds.) *The Wiley guide to managing projects.* Hoboken, NJ: John Wiley & Sons.
Nahapiet, J. & Ghoshal, S. 1998. Social capital, intellectual capital, and the organizational advantage. *Academy of management review,* 23**,** 242-266.
Nakamoto, S. 2008. *Bitcoin: A peer-to-peer electronic cash system* [Online]. Available: http://bitcoin.org/bitcoin.pdf [Accessed].
Nawari, N. O. & Ravindran, S. 2019a. Blockchain and Building Information Modeling (BIM): Review and applications in post-disaster recovery. *Buildings,* 9.
Nawari, N. O. & Ravindran, S. 2019b. Blockchain technology and BIM process: Review and potentialapplications. *Journal of Information Technology in Construction,* 24**,** 209-238.
Papadonikolaki, E. 2016. *Alignment of Partnering with Construction IT: Exploration and Synthesis of network strategies to integrate BIM-enabled Supply Chains,* Delft, A+BE Series | Architecture and the Built Environment.
Papadonikolaki, E. 2018. Loosely coupled systems of innovation: Aligning BIM adoption with implementation in Dutch construction. *Journal of Management in Engineering,* 34**,** 05018009.
Papadonikolaki, E. 2020. The Digital Supply Chain: Mobilising Supply Chain Management Philosophy to Reconceptualise Digital Technologies and Building Information Modelling (BIM). *In:* Pryke, S. (ed.) *Successful Construction Supply Chain Management: Concepts and Case Studies.* 2nd edition ed. London, UK: Wiley.
Papadonikolaki, E., Van Oel, C. & Kagioglou, M. 2019. Organising and Managing boundaries: A structurational view of collaboration with Building Information Modelling (BIM). *International Journal of Project Management,* 37**,** 378-394.
Papadonikolaki, E. & Wamelink, H. 2017. Inter- and intra-organizational conditions for supply chain integration with BIM. *Building Research & Information***,** 1-16.

Pärn, E. & Edwards, D. 2019. Cyber threats confronting the digital built environment: Common data environment vulnerabilities and block chain deterrence. *Engineering, Construction and Architectural Management,* 26**,** 245-266.
Parn, E. A. & Edwards, D. 2019. Cyber threats confronting the digital built environment: Common data environment vulnerabilities and block chain deterrence. *Engineering, Construction and Architectural Management,* 26**,** 245-266.
Paunov, C. 2012. The global crisis and firms' investments in innovation. *Research Policy,* 41**,** 24-35.
Ponterotto, J. G. 2005. Qualitative research in counseling psychology: A primer on research paradigms and philosophy of science. *Journal of counseling psychology,* 52**,** 126.
Popper, N. 2016. A venture fund with plenty of virtual capital, but no capitalist. *New York Times,* 21.
Popper, N. & Lohr, S. 2017. Blockchain: A better way to track pork chops, bonds, bad peanut butter. *New York Times,* 4.
Pryke, S. 2009. *Construction Supply Chain Management (Innovation in the Built Environment),* West Sussex, UK, Wiley-Blackwell.
Pryke, S. & Pearson, S. 2006. Project governance: case studies on financial incentives. *Building Research & Information,* 34**,** 534-545.
Raval, S. 2016. *Decentralized applications: harnessing Bitcoin's blockchain technology*, " O'Reilly Media, Inc.".
Robson, C. & Mccartan, K. 2016. *Real world research,* London, John Wiley & Sons.
Rotter, J. B. 1980. Interpersonal trust, trustworthiness, and gullibility. *American psychologist,* 35**,** 1.
Saldanā, J. 2009. *The Coding Manual for Qualitative Researchers,* London, UK, SAGE Publications Ltd.
Sawhney, A., Riley, M. & Irizarry, J. 2020. *Construction 4.0: An Innovation Platform for the Built Environment,* London, Taylor & Francis (Routledge).
Schwab, K. 2016. *The fourth industrial revolution,* Geneva, Switzerland, World Economic Forum.
Sterman, J. 2002. System Dynamics: systems thinking and modeling for a complex world.
Storey, J., Emberson, C., Godsell, J. & Harrison, A. 2006. Supply chain management: theory, practice and future challenges. *International Journal of Operations & Production Management,* 26**,** 754-774.
Swan, M. 2015. *Blockchain: Blueprint for a new economy*, " O'Reilly Media, Inc.".
Tejpal, G., Garg, R. & Sachdeva, A. 2013. Trust among supply chain partners: a review. *Measuring Business Excellence,* 17**,** 51-71.
Tezel, A., Papadonikolaki, E., Yitmen, I. & Hilletofth, P. Preparing Construction Supply Chains for Blockchain: An Exploratory Analysis. CIB World Building Congress 2019 Constructing Smart Cities, Hong Kong SAR, China, 17–21 June 2019., 2019.
Turk, Ž. & Klinc, R. 2017. Potentials of blockchain technology for construction management. *Procedia engineering,* 196**,** 638-645.
Vaidyanathan, K. 2009. Overview of IT Applications in the Construction Supply Chain. *In:* O' Brien, W. J., Formoso, C. T., Vrijhoef, R. & London, K. A. (eds.) *Construction Supply Chain Management Handbook.* Boca Raton, Florida, USA: CRC Press.
Valdes, R., Furlonger, D. & Chesini, F. 2016. The Bitcoin Blockchain: The Magic and the Myth. *Gartner Research.* Gartner.
Vrijhoef, R. 2011. *Supply chain integration in the building industry: The emergence of integrated and repetitive strategies in a fragmented and project-driven industry,* Amsterdam, The Netherlands, IOS Press.
Winch, G. M. 2002. *Managing construction projects,* Oxford, UK, Blackwell Science.
Wong, W. K., Cheung, S. O., Yiu, T. W. & Pang, H. Y. 2008. A framework for trust in construction contracting. *International Journal of Project Management,* 26**,** 821-829.
Xu, J. 2020. Understanding Trust in Construction Supply Chain Relationships. *In:* Pryke, S. (ed.) *Successful Construction Supply Chain Management: Concepts and Case Studies.* 2nd edition ed. London, UK: Wiley.
Young-Ybarra, C. & Wiersema, M. 1999. Strategic flexibility in information technology alliances: The influence of transaction cost economics and social exchange theory. *Organization science,* 10**,** 439-459.
Zhu, Y., Riad, K., Guo, R., Gan, G. & Feng, R. 2019. New instant confirmation mechanism based on

interactive incontestable signature in consortium blockchain. *Frontiers of Computer Science,* 13**,** 1182-1197.