sciendo

received: 7 September 2021
accepted: 28 February 2022

pages: 103-112

Blockchain technology applicability in New Zealand's prefabricated construction industry

Ehsan Bakhtiarizadeh Wajiha Mohsin Shahzad
Mani Poshdar James Olabode Bamidele Rotimi

ABSTRACT
Different industries are modernising their systems and introducing innovations to their management practices. However, the construction industry is recognised for its lack of technological systems on which the success of this sector is deemed to be heavily dependent. Previous studies have focused on enhancing the off-site construction supply chain. However, studies on the importance and utilisation of technology in this sub-sector are scarce, predominantly where the efficiency of off-site supply chain management is stalled as a consequence of the slow implementation of technology. Thus, this article employs an exploratory approach by providing insight into the applicability of blockchain technology in New Zealand's off-site construction and demonstrates the benefits associated with the adoption of this technology. A literature review was used to identify stakeholders' interrelationships in different stages of prefabrication projects. Then, a pilot interview from industry experts followed by a questionnaire survey was used to determine the involvement of stakeholders in different phases and the benefits that blockchain technology can bring to this industry. The results indicate that using blockchain as a secure information management system could improve the integration of prefabrication supply systems by producing a collaborative atmosphere amongst the organisations involved.

KEY WORDS
prefabrication, supply chain, blockchain, information integration, New Zealand

10.2478/emj-2022-0009

Ehsan Bakhtiarizadeh

Massey University, New Zealand
Corresponding author:
e-mail: e.bakhtiazadeh@massey.ac.nz

Wajiha Mohsin Shahzad

Massey University, New Zealand
ORCID 0000-0002-7683-287X

Mani Poshdar

Auckland University of Technology, New Zealand
ORCID 0000-0001-9132-2985

James Olabode Bamidele Rotimi

Massey University, New Zealand
ORCID 0000-0001-6744-4683

Introduction

The construction industry in New Zealand is overtaking other industries and has become one of the major contributors to the national GDP (Huang & Wilson, 2020). Supply chain management in this industry is considered a significant pivotal point of success for organisations performing roles in the highly competitive construction market (Samarasinghe, Tookey & Rotimi, 2013). However, fragmentation is an inherent attribute adhered to the

Bakhtiarizadeh, E., Shahzad, W. M., Poshdar, M., & Rotimi, J. O. B. (2022). Blockchain technology applicability in New Zealand's prefabricated construction industry. *Engineering Management in Production and Services, 14*(1), 103-112. doi: 10.2478/emj-2022-0009

construction sector, and it can deteriorate in off-site (prefabrication) construction where the concentration of work is scattered across "off" and "on" construction sites (Zhai, Zhong, Li & Huang, 2016). In New Zealand, prefabrication demands specific consideration around the barriers to its efficiency; supply chain integration is perceived as one of the main core subjects requiring enhancement (Darlow, Rotimi & Shahzad, 2021). Studies have shown that information exchanged across the entire supply system in a prefabricated project can substantially impact the outcome of the supply chain (Briscoe, Dainty & Millett, 2001). Numerous documents: design/construction drawings, RFIs, quality assurance documents, and statutory approvals are regarded as the types of information being exchanged daily within the supply system of prefabrication projects and managing the integration of this information results in a positive future collaboration amongst the supply chain partners (Bakhtiarizadeh, Shahzad & Rotimi, 2019).

Prefabrication is acknowledged as a solution to deficiencies in traditional construction methods. Reduced time and costs, enhanced quality of finished products, and increased sustainability factors are some examples of benefits associated with prefabrication (Shahzad, Mbachu, & Domingo, 2015). However, several impediments to the uptake of prefabrication disturb efficiency in its supply chain systems. Little transparency around the distribution of works at different sites, lack of the adoption of new advanced technologies, and ineffective information sharing systems are considered some of them (Jaillon & Poon, 2010). The root cause of the mentioned issues can be linked to inappropriate information integration techniques.

Integrated information ensures an integrated supply chain, and an integrated supply chain ensures the swift processes of preparation, design, manufacture, construction, and assembly (Čuš-Babič et al., 2014). It also provides trust amongst various stakeholders involved in a prefabricated construction project (Bankvall et al., 2010). Hence, using an effective information integration platform, such as blockchain, leads to improved trust and integration amongst participants involved in the supply chain of prefabrication projects (Casino, Dasaklis & Patsakis, 2018). The predominant benefit of blockchain technology compared to other technologies is the decentralisation and anonymity of the data stored in it (Li, Greemwood & Kassem, 2019). Contrary to other recent technologies, blockchain helps information to be processed and saved on multiple remote computers, providing organisations with an opportunity to store their information systematically in different locations (Li, Greemwood & Kassem, 2018; Hofbauer & Sangl, 2019; Florek-Paszkowska et al., 2021; Barczak et al., 2021).

This technology offers integration in the prefabrication and provides a secure decentralised database, helping prefabrication supply chain organisations to exchange and store their information effectively (Wang et al., 2017). Therefore, blockchain provides a transparent and secure information-sharing platform for the prefabrication supply chain (PrefabNZ, 2018).

Different studies have shown various process maps of the prefabrication supply chain. For instance, a study by Bakhtiarizadeh, Shahzad, and Rotimi (2019) explored prefabrication project phases and stakeholders involved in the supply chain. Also, other studies have demonstrated the value of information sharing across supply chain allies in the construction and design of projects (Samarasinghe et al., 2013; Čuš-Babič et al., 2014). However, little research has been conducted on New Zealand's prefabricated construction, and there is inadequate knowledge of the advantages of blockchain technology in this industry.

This study undertook a pilot interview with six prefabricated construction professionals to ascertain the interaction of stakeholders in different phases of prefabrication projects. Also, a questionnaire survey was used to identify the core impediment to the integration of prefabrication and to ascertain the applicability of blockchain technology with its related potential advantages. The following section of this article presents a review of previous studies. The second section discusses the research methodology and data collection and analysis tools. The third part describes the analysis and discussion around the results. The article is concluded with remarks.

1. Literature review

Prefabrication is considered an innovative method of construction that facilitates the construction of a portion of a building remotely or far from the final location (Shahzad, 2016). The major benefit of prefabrication over the traditional construction methods is the low level of inefficiencies in the productivity measures like time, cost, and quality (Darlow et al., 2021). In New Zealand, prefabrication is increasingly contributing to the delivery of construction projects (Darlow et al., 2021; PrefabNZ, 2018). The rising demand for new-built houses and the shortage of affordable dwellings is growing the need for a more effective and innovative project delivery system (Shahzad & Mbachu, 2013).

Despite the benefits of prefabrication, the industry struggles with several issues, such as a low level of integration and coordination amongst its supply chain organisations (PrefabNZ, 2015). Integration in supply systems refers to the consistency of delivery systems and uniformity of information sharing amongst stakeholders (Dainty, Millett & Briscoe, 2001). The complexity of integration in supply chains depends on the project size. Typically, the number of actors exchanging information in large projects can exceed hundreds, giving rise to the need to adopt innovative technologies in the supply chain integration techniques (Briscoe, Dainty & Millett, 2001).

Adopting technology in the construction supply chain has become critical for enhancing supply chain integration (Wang et al., 2020). Some examples of technological systems being used in supply chains are Enterprise Resource Planning (ERP), Electronic Data Interchange (EDI), Customer Relationship Management (CRM), Drones, Internet of Things (IoT), RFID, and GPS receivers (Wang et al., 2017). These systems have helped the uniformity and integration of information and, consequently, the integration of supply chains. Using these technologies, supply chain partners can exchange real-time information efficiently and effectively. Also, with the help of these technologies, unsafe human interference in information repositories can be minimised (Ngai, Cheng & Ho, 2004).

Information integration is considered collaborative, uniform, and controlled information sharing, and lack of information sharing results in decreased traceability, transparency, and trust (Prajogo & Olhager, 2012; Mentzer et al., 2001). Integration and efficient exchange of information in supply systems require coordination and trust (Cai, Jun & Yang, 2010). The low level of trust results in a low level of collaboration and reluctance to adopt technologies (Shahzad, 2016). Therefore, providing a secure technological source/storage for storing organisational information can lead to a more collaborative and efficient supply system with a higher level of trust (Korpela, Hallikas & Dahlberg, 2017).

One advanced technological system recently introduced globally is Distributed Ledger Technology (DLT) or blockchain technology. Blockchain is a secure consensus-based ledger that simplifies connections amongst its operators (Penzes, 2018). Blockchain was originally developed for crypto-currency transactions and designed based on a network of public and private decentralised nodes (Saberi et al., 2018). This technology enables immutable peer-to-peer (P2P) communication through a secure transaction database (Turk & Klinc, 2017).

New Zealand is showing resilience in adopting innovations and technologies (PrefabNZ, 2013), and blockchain can positively impact the enhancement of supply chains, especially in the prefabrication industry. Blockchain's traceability function is important for supply chain partners since prefabricated construction struggles with multiple stakeholders and suppliers from local or international companies (Bell, 2009). This function also helps clients/customers with the ability to track the provenance of the materials used in their final products, improving their trust and perspective on the genuineness of resources (Casino et al., 2018).

Similarly, blockchain technology helps facilitate interactions and information exchange amongst supply chain organisations in an organised manner (Prajogo & Olhager, 2012). This, in turn, results in the transparency of information and improved accountability of each partner regarding their contribution to the project delivery in New Zealand (Chowdhury et al., 2018). Providing transparency in the stakeholders' interactions can reduce the quality problems and improve organisational trust and confidence (Yang et al., 2020).

Moreover, as opposed to other pre-mentioned technological systems, blockchain provides more data/information security to its users, helping supply chain organisations benefit from a safe information repository that its stored information can be withdrawn and used for future projects (Li et al., 2019). Security in the information exchange is understood as legitimate or trusted information transmission across the communicators and safekeeping the data-generating processes (Tse et al., 2017). Security and trust are interlinked in the prefabrication supply chain. As prefabrication processes encompass a variety of information and sources, information security guarantees trustworthy digital commination and reliability of shared information (Lemieux, 2016).

In summary, blockchain can be the potential remedy for the shortcomings in the prefabrication supply chain integration in New Zealand. This technology can be used for information integration and, consequently, supply chain integration (Wang et al., 2020). Blockchain has the potential to resolve the problems stemming from the traceability of the origin of the products, transparency of exchanged information and security of systems used for prefabrication stakeholders' information sharing.

Previous studies have investigated the integration of prefabrication supply chain stakeholders and the potential benefits of using information technology. However, few studies have been conducted in New Zealand, and there is little knowledge about the applicability and benefits of using blockchain technology in the prefabrication supply chain. This study addresses the investigation gap in this area and provides insights into utilising blockchain technology in the prefabrication industry of New Zealand.

2. Research methodology

This study adopts mixed research to data collection and analysis as a complementary approach (Johnson, Onwuegbuzie & Turner, 2007). A literature review was carried out to identify and categorise stakeholders' interconnectivity in different stages of prefabrication projects. Then, a pilot study was conducted to ascertain the validity of identified stakeholders and the complexity of their relationships in certain project phases in New Zealand. Then, a questionnaire survey was developed. Firstly, it aimed to measure the significance of information integration amongst different organisations. Secondly, it sought to find the attributes of information essential for the success of the prefabrication supply chain, and finally, to ascertain the advantages of using blockchain technology in this industry.

2.1. Identification of stakeholders and phases of prefabrication

In order to identify the project development phases and stakeholders involved in prefabrication projects in New Zealand, two methods were used: literature review and interview. A total of 12 different phases of projects and a list of nine groups of stakeholders were primarily identified through a literature review. To ascertain the reliability and validity of the identified phases and stakeholders, a pilot study was undertaken. A participation invite was sent to 12 prefabrication construction experts, and six of them showed their inclination to participate. All experts had more than ten years of experience in New Zealand's construction industry. A process map of the 12 project phases and nine stakeholders was shown to them in separate interviews, and they were asked to check the correctness of the identified phases and stakeholders concerning their interrelationships in New Zealand.

2.2. Data collection

A questionnaire survey was developed for exploring the significance of information integration and the attributes of information contributing to the growth and success of the prefabrication construction supply chain (CSC) in New Zealand. Numerous current studies have employed the questionnaire survey as an efficient tool for collecting stakeholders' viewpoints and opinions pertinent to the CSC (Black, Akintoye & Fitzgerald, 2000). In this study, the questionnaire contained three relatively similar sections. A short overview of definitions was provided at the opening of the questionnaire, followed by a segment for collecting the basic information of participants. The respondents were from a broad spectrum of organisations, including, but not limited to, clients, contractors, designers, consultants, and suppliers. They were asked to answer the questions from clients' or contractors' perspectives. In the final section, respondents were required to answer multiple questions about utilising technology in their organisations, the disadvantages of non-integrated information exchange, necessary quality of information for the success of prefabrication, and advantages linked to the use of blockchain technology.

The questionnaire survey was sent to the PrefabNZ, an umbrella organisation for prefabrication in New Zealand, with around 350 members (including individuals and prefabrication firms). The minimum sample size calculated was 132 (at 95 % confidence interval; $p<0.05$). The study participants were initial randomly sampled from PrefabNZ members, and thereafter a snowball technique was used, so the study could develop an in-depth exploration of the applicability of blockchain in prefabrication (Creswell, 2005) and increase the diversity of the sample through a range of viewpoints (Kirchherr & Charles, 2018). To meet the snowball sampling technique requirements, the participants were encouraged to share the online questionnaire with their co-workers and other people they perceived to be qualified in the prefabrication industry of New Zealand. At the end of the data collection, 27 valid responses were collated, forming the basis for the data analysis. This represents a response rate of 20.4 %. Normally, studies related to construction have a rate of 20 to 30 % (Hwang, Shan & Looi, 2018). With direct reference to the questionnaire survey, nine respondents had over 15 years of related experience, seven between 10 and 15 years, eight between 5 and 10 years, and three less than 5 years. Also, 12 participants answered from clients' and 15 from contractors' standpoint.

3. Results and discussion

Prefabricated construction is better for geographically dispersed construction sites (PrefabNZ, 2018). However, this approach involves a more complex supply chain than traditional construction methods (Shahzad et al., 2013). Keeping an effective way of information exchange throughout prefabricated projects can considerably decrease this complexity (Wang et al., 2020). Integration of information among stakeholders in the prefabrication supply chain is complex, giving rise to myriad challenges on obtaining effective supply chain integration (Jaillon & Poon, 2010). Adopting information technology is necessary to streamline the complex information exchange processes and facilitate the prefabricated construction supply chain. In this study, the analysis of the questionnaire survey has been carried out in three steps: 1) utilisation of technology, 2) drawbacks associated with lack of information integration, and 3) advantages of blockchain technology in the prefabrication supply chain.

3.1. Prefabrication phases and stakeholders

A literature review and pilot interviews were used to identify the connection of prefabrication stakeholders with the phases of prefabrication projects in New Zealand. The nine groups of stakeholders comprise statutory bodies, clients, consultants or designers, developers, subcontractors, manufacturers, indirect and direct suppliers, and distributors or logistics enterprises with reference to (Gan, Chang & Wen, 2018) and (Bakhtiarizadeh et al., 2019). This study did not examine other stakeholders previously identified by other researchers. For example, Zhai, Reed, and Mills (2013) categorised the stakeholders into six groups, excluding the government in China. However, in New Zealand, the role of government or statutory bodies is also relevant to the prefabrication projects.

Moreover, according to the Royal Institute of British Architects (RIBA) plan of work 2013, the lifecycle of a construction project undergoes eight different phases from the initiation to the delivery. Also, Gibb (1999) classifies a modular construction project into 12 phases and compares them to the traditional construction approach. Using the mentioned research and with reference to the previous study by Bakhtiarizadeh et al. (2019), twelve prefabrication phases were tailored and tested for this study. The phases are Strategic Definition or Initialisation, Preparation and Briefing, Concept Design, Developed Design, Production Planning, Technical or Detailed Design, Construction (on-site preparation, off-site manufacturing, and transportation for assembly), Handover, Maintenance, Demolition (according to the sustainability criteria for future project use).

Interviewees also acknowledged that three phases: Detailed Design, Construction, and Handover are the main phases, intricately engaging most of the stakeholders. Also, they highlighted the essential roles of clients and contractors who are consistently involved from the inception until the end of projects and whose responsibilities are not limited to certain project phases.

3.2. Utilisation of technology

Adopting information technology in the supply chain has brought many benefits to different industries. Firstly, it has helped reduce products' development timeframes by enabling easier collaboration amongst the production crew. Secondly, it has reduced production costs. And lastly, it has enhanced the quality of products to match customers' requirements (Chou, 2004). Advanced systems, e.g. Electronic Data Interchange (EDI), Customer Relationship Management (CRM), and Enterprise Resource Planning (ERP), are some examples of information technology systems being used for Supply Chain Management (SCM).

However, these are being superseded by web-/cloud-based technologies such as the Internet of Things (IoT) and drones, enabling the swift and effective flow of real-time information across supply chain stakeholders (Ngai et al., 2004; Xing, Qian & Zaman, 2016).

Despite the added value of cloud-based technologies to SCM, there are still a few problems related to them. For instance, information security can be deemed an issue since there is always a risk of malicious attacks by hackers (Finch, 2004). Also, accessibility to information repositories for every supply chain member can be considered another issue

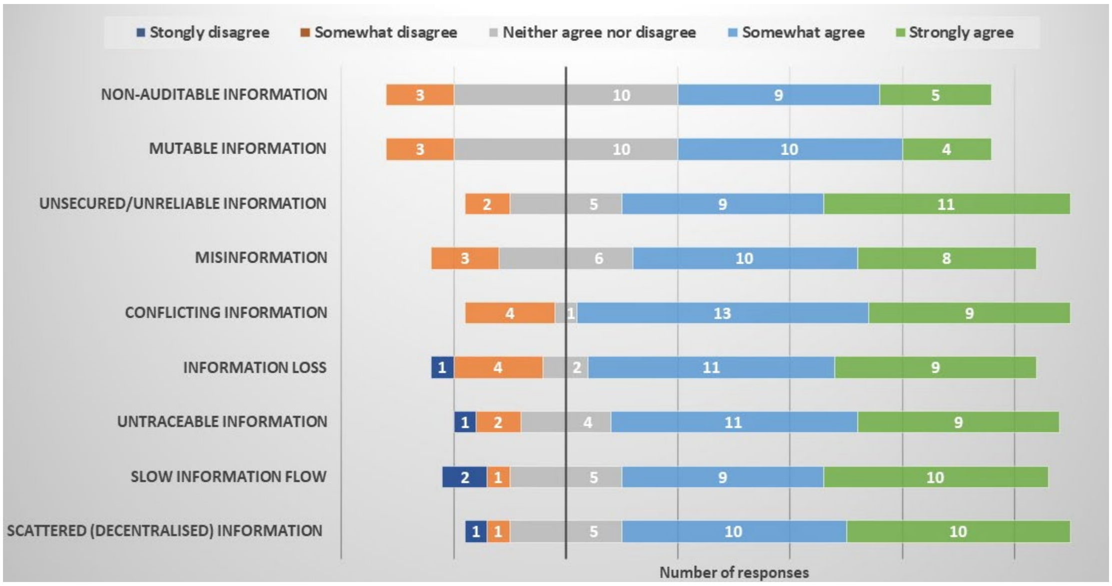

Fig. 1. Importance of information integration

(Chou, 2004). In the construction industry, the issues mentioned above can jeopardise organisations' critical information and trust amongst supply chain partners since all information is prone to change by any user either randomly or deliberately (Tse et al., 2017). With reference to the questionnaire in this study, 19 (out of 27) respondents demonstrated that information technology (in general) is used in their organisations, and 17 of them agreed that technology would be useful as a facilitator for information integration.

3.3. Significance of information integration

Information integration in the supply chain contributes to collaboration, trust and logistics integration (Gielingh & Tolman, 1991). However, uncertainties in supply chains appear when information exchange is not quite streamlined. Literature has proved numerous drawbacks associated with lack of information integration, e.g. scepticism, distrust, and fragmentation amongst the partner organisations.

In this study, an excerpt of previously studied drawbacks associated with lack of information integration was collected and incorporated in the survey. The respondents were asked to use a 5-point Likert scale and confirm the effect of those drawbacks on the outcome of their projects (Fig. 1).

Consequently, they also provided the attributes of information critical for the success of their supply chain (Fig. 2). The identified drawbacks associated with lack of information integration revolve around three main categories: transparency, traceability, and security. Information transparency is regarded as a decline in the uncertainty amongst the information exchangers (Angeletos & Pavan, 2004). Transparent information in the prefabrication supply chain improves trust and collaboration amongst stakeholders (Wang et al., 2020).

Traceability is the second critical attribute of information that helps the development of an efficient prefabrication supply chain. In the prefabricated supply chain, various types of materials are used, and the ability to trace the origin of these materials is highly crucial for prefabrication supply chain organisations and end-users (Saberi et al., 2018).

Information security is interpreted as the integrity of records and legitimacy of data (Lemieux, 2016). Information exchanged within an organisation varies from drawings and reports to legal documents (Sahin & Robinson, 2002). These types of information require an information-exchange platform that is capable of storing the information securely for future use. Therefore, a suitable information security engine is needed to warrant the secure transition of knowledge and learnings of a given project to the next. This attribute is critical for the integration of prefabrication supply chains.

3.4. Benefit of using blockchain technology in the prefabrication CSC

There is a close-knit relationship between information integration and blockchain technology as an enabler of a secure information sharing database. To

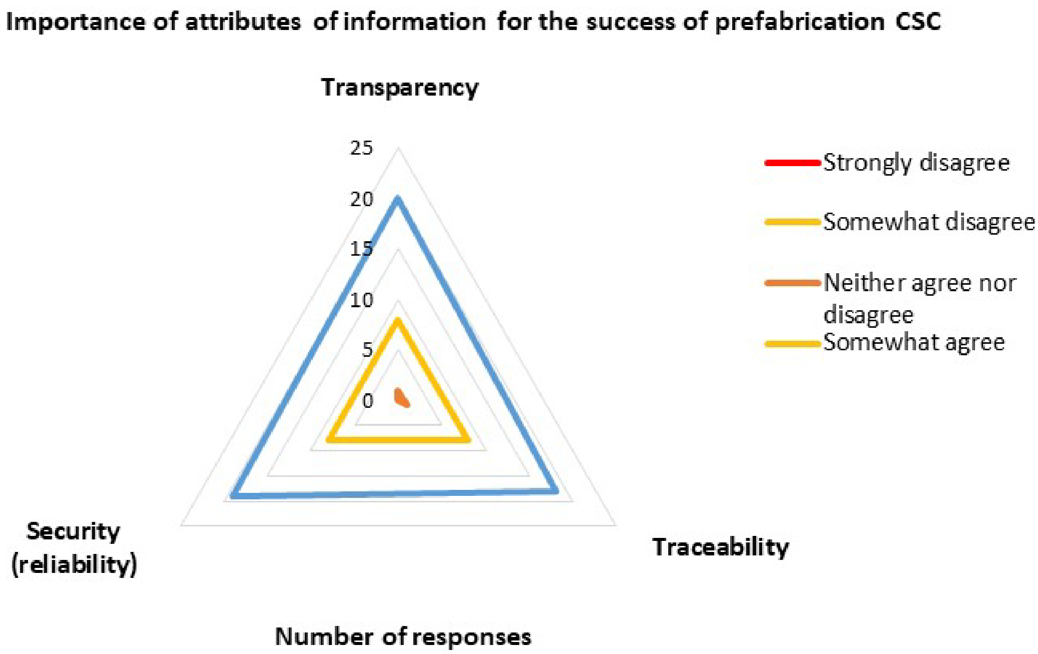

Fig. 2. Important attributes of information

diminish the disruptions to the prefabrication supply chain, information integration should be maintained and controlled constantly (Doran & Giannakis, 2011). Thus, blockchain technology would be a solution for creating integration in the prefabrication supply chain.

In New Zealand, the construction industry has long been intertwined with traditional construction approaches. However, with the rise of newer methods (e.g., prefabrication), industry experts are better discovering the benefits of using technologies. For this study, participants were asked to indicate their level of agreement with the benefits of information integration and blockchain technology. As indicated in Fig. 3, the results show that the breakeven point of the benefits of information integration commensurate with the benefits associated with blockchain technology meets at the level of 31 %.

Many studies have shown the ability of blockchain technology to store a range of information in different formats, such as models, sketches, images, drawings and recordings (Devine, 2015; Chen, Wang & Zhang, 2018). Once these types of information are recorded on the blockchain, information integration is formed, and the prefabrication sector will benefit by reducing fragmentation and improving transparency, traceability and information security.

4. Conclusions

Construction Supply Chain Management is regarded as a network of tasks providing services and values to clients (Mentzer et al., 2001). Most of the social, environmental, and economic shortcomings of traditional construction appear to have been resolved using newer practices, such as prefabrication. However, in this subsector of the construction industry, information integration, which is a major driver of supply chain integration, has not been paid attention to, resulting in a low level of trust amongst stakeholders (Shahzad et al., 2015). Information is transmitted securely amongst the stakeholders within an integrated supply system without any unwanted alterations. Also, It helps the prefabrication supply chain to benefit from the visibility and transparency attached to information integration platforms.

Blockchain technology, being an advanced information integration tool, represents a potential solution for dispelling inherent issues of supply chain systems by ensuring security, transparency, and traceability. Adopting this technology in the prefabrication industry of New Zealand can help obtain a more streamlined and efficient supply chain integration.

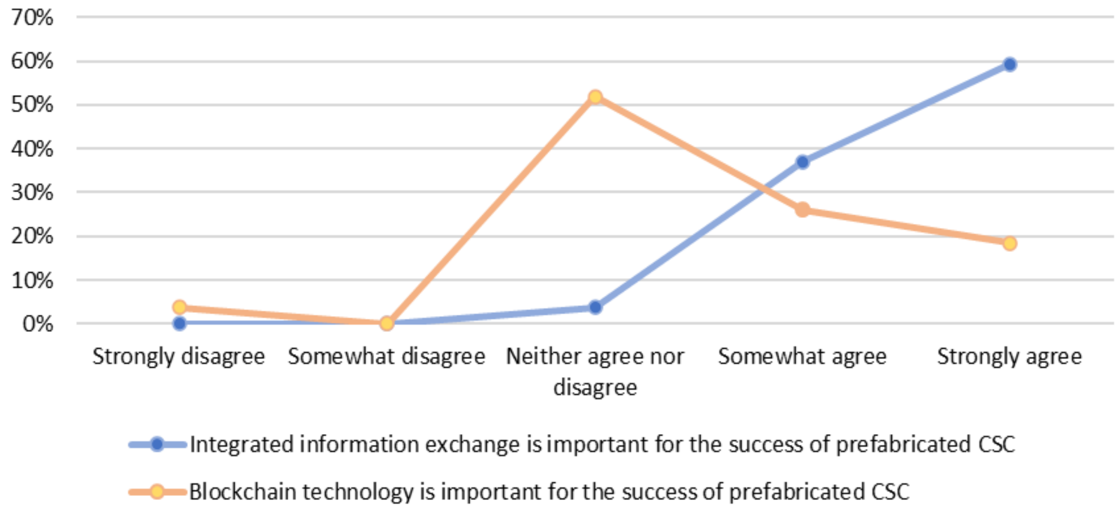

Fig. 3. Significance of using blockchain technology

This study explores the stakeholders' engagement in different stages of prefabrication projects and ascertains the benefits of using blockchain technology in New Zealand's prefabrication supply chain. Firstly, 12 construction phases and nine groups of stakeholders were identified through a pilot interviewing of industry professionals. Then, the disadvantages associated with lack of information integration and the importance of using blockchain technology as an information integration mechanism were explored by adopting a questionnaire survey for collecting a wider industry experts' opinion. Amongst the total of stakeholders and 12 project phases, two stakeholders and three phases were recognised as focal points in the supply chain network. The results show that using blockchain technology can enhance the integration of prefabrication projects by creating trust amongst the organisations working directly or indirectly in their supply systems. This technology also helps stakeholders with their business interactions and generates a transparent collaboration amongst prefabrication projects partners.

One limitation of this study is that the data was collected from the experts within a certain period. Also, all participants had not practically utilised blockchain technology as a tool in their professional experiences. In all cases, the technical definitions used in this study should have been explained to them clearly and upfront. The results of this study could be discussed by other studies which have provided frameworks for the uptake of the prefabrication supply chain. Blockchain technology will gradually become more accepted and more mature, which will enhance stakeholders' viewpoints on blockchain and other advanced IT systems.

Acknowledgements

The publication of the article for 11th International Conference on Engineering, Project, and Production Management - EPPM2021 was financed in the framework of the contract no. DNK/SN/465770/2020 by the Ministry of Science and Higher Education within the "Excellent Science" programme.

Ministry of Science and Higher Education
Republic of Poland

Literature

Angeletos, G.-M., & Pavan, A. (2004). Transparency of information and coordination in economies with investment complementarities. *Journal of American Economic Review*, *94*, 91-98. doi: 10.1257/0002828041301641

Bakhtiarizadeh, E., Shahzad, W., & Rotimi, J. O. B. (2019). A process map for supply chain relationships in prefabricated construction, 43rd AUBEA Conference, Australia, 112-123.

Bankvall, L., Bygballe, L. E., Dubois, A., & Jahre, M. (2010). Interdependence in supply chains and projects in construction. *Supply Chain Management, 15*(5), 385-393. doi: 10.1108/13598541011068314

Barczak, T., Kafel, T., & Magliocca, P. (2021). Network approaches and strategic management: Exploration opportunities and new trends. *Journal of Entrepreneurship, Management and Innovation*, *17*(3), 7-35. doi: 10.7341/20211731

Behera, P., Mohanty, R. P., & Prakash, A. (2015). Understanding Construction Supply Chain Management. *Production Planning & Control, 26*(16), 1332-1350. doi: 10.1080/09537287.2015.1045953

Bell, P. (2009). Kiwi prefab: Prefabricated housing in New Zealand: An historical and contemporary overview with recommendations for the future. Master's Thesis, Victoria University of Wellington. Retrieved from http://researcharchive.vuw.ac.nz/handle/10063/1111

Black, C., Akintoye, A., & Fitzgerald, E. (2000). An analysis of success factors and benefits of partnering in construction. *International Journal of Project Management, 18*(6), 423-434. doi: 10.1016/S0263-7863(99)00046-0

Briscoe, G., Dainty, A. R. J., & Millett, S. (2001). Construction supply chain partnerships: skills, knowledge and attitudinal requirements. *European Journal of Purchasing & Supply Management, 7*(4), 243-255. doi: 10.1016/S0969-7012(01)00005-3

Cai, S., Jun, M., & Yang, Z. (2010). Implementing supply chain information integration in China: The role of institutional forces and trust. *Jornal of Operations Management, 28*(3), 257-268. doi: 10.1016/j.jom.2009.11.005

Casino, F., Dasaklis, T. K., & Patsakis, C. (2018). A systematic literature review of blockchain-based applications: current status, classification and open issues. *Telematics and Informatics, 36*, 55-81. doi: 10.1016/j.tele.2018.11.006

Chen, S., Wang, H., & Zhang, L.-J. (2018). Blockchain-ICBC 2018. Proceedings of the First International Conference on the Services Conference Federation, Seattle, WA, USA, 25-30 June.

Chou D. C. (2004). Web technology and supply chain management. *Information Management & Computer Security, 12*(4), 338-349. 10.1108/09685220410553550

Chowdhury, M. J. M., Colman, A., Kabir, M. A., Han, J., & Sarda, P. (2018). *Blockchain Versus Database: A Critical Analysis.* 17th IEEE International Conference On Trust, Security And Privacy In Computing And Communications/ 12th IEEE International Conference On Big Data Science And Engineering (TrustCom/BigDataSE). doi: 10.1109/TrustCom/BigDataSE.2018.00186

Creswell, J.W. (2005). *Educational Research. Planning, Conducting, and Evaluating Quantitative and Qualitative Research*. Upper Sadle River, United States: Pearson Education.

Dainty, A. R., Millett, S. J., & Briscoe, G. H. (2001). New perspectives on construction supply chain integration. *Supply Chain Management, 6*(4), 163-173. doi: 10.1108/13598540110402700

Darlow, G., Rotimi, J. O. B., & Shahzad, W. M. (2021). Automation in New Zealand's offsite construction (OSC): a status update. *Built Environment Project and Asset Management*, in print. doi: 10.1108/BEPAM-11-2020-0174

Devine, P. (2015). Blockchain learning: Can crypto-currency methods be appropriated to enhance online learning? Proceedings of the ALT Online Winter Conference, Online, 7-10 December, 1-7.

Doran, D., & Giannakis, M. (2011). An examination of a modular supply chain: a construction sector perspective. *Journal of Supply Chain Management, 16*(4), 260-270. doi: 10.1108/13598541111139071

Finch, P. (2004). Supply chain risk management. *Journal of Supply Chain Management, 9*(2), 183-196. doi: 10.1108/13598540410527079

Florek-Paszkowska, A., Ujwary-Gil, A., & Godlewska-Dzioboń, B. (2021). Business innovation and critical success factors in the era of digital transformation and turbulent times. *Journal of Entrepreneurship, Management, and Innovation*, *17*(4), 7-28. doi: 10.7341/20211741

Gan, X., Chang, R., & Wen, T. (2018). Overcoming barriers to off-site construction through engaging stakeholders: A two-mode social network analysis. *Journal of Cleaner Production, 201*, 735-747. doi: 10.1016/j.jclepro.2018.07.299

Gibb, A. G. (1999). *Off-site fabrication: prefabrication, preassembly and modularisation*. John Wiley & Sons.

Gielingh, W. F., & Tolman, F. P. (1991). Information Integration in the Building and Construction Industries. *Computer-Aided Civil and Infrastructure Engineering, 6*(4), 329-334. doi: 10.1111/j.1467-8667.1991.tb00263.x

Hofbauer, G., & Sangl, A. (2019). Blockchain Technology and Application Possibilities in the Digital Transformation of Transaction Processes. *Forum Scientiae Oeconomia*, *7*(4), 25-40. doi: 10.23762/FSO_VOL7_NO4_2

Huang, T., & Wilson, R. (2020). *Auckland's Construction Sector: Industry Snapshot and Trends to 2019* (TR2020/002). Auckland Council. Retrieved from https://knowledgeauckland.org.nz/media/1714/tr2020-002-aucklands-construction-sector-trends-to-2019.pdf

Hwang, B.-G., Shan, M., & Looi, K.-Y. (2018). Key constraints and mitigation strategies for prefabricated prefinished volumetric construction. *Journal of Cleaner Production, 183*, 183-193. doi: 10.1016/j.jclepro.2018.02.136

Jaillon, L., & Poon, C. S. (2010). Design issues of using prefabrication in Hong Kong building construction. *Construction Management and Economics, 28*(10), 1025-1042. doi: 10.1080/01446193.2010.498481

Johnson, R. B., Onwuegbuzie, A. J., & Turner, L. A. (2007). Toward a Definition of Mixed Methods Research. *Journal of Mixed Methods Research*, *1*(2), 112-133. doi: 10.1177/1558689806298224

Kirchherr, J.. & Charles, K. (2018). Enhancing the sample diversity of snowball samples: Recommendations from a research project on anti-dam movements in Southeast Asia. PLoS ONE *13*(8), e0201710. doi: 10.1371/journal.pone.0201710

Konukcu, S. (2011). A knowledge chain framework for construction supply chains. Doctoral Thesis, Loughborough Universisty. Retrieved from https://repository.lboro.ac.uk/articles/thesis/A_knowledge_chain_framework_for_construction_supply_chains/9455099

Korpela, K., Hallikas, J., & Dahlberg, T. (2017). Digital supply chain transformation toward blockchain integration. 50th Hawaii International Conference On Systems Science, United States. doi: 10.24251/HICSS.2017.506

Lemieux, V. L. (2016). Trusting records: Is Blockchain technology the answer? *Records Management Journal,* 26, 110-139, doi: 10.1108/RMJ-12-2015-0042

Li, J., Greenwood, D., & Kassem, M. (2018). Blockchain in the built environment: Analysing current applications and developing an emergent framework. Proceedings of the Creative Construction Conference, Ljubljana, Slovenia, 30 June – 3 July, 59-66.

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, doi: 10.1016/j.autcon.2019.02.005

Mentzer, J. T., DeWitt, W., Keebler, J. S., Min, S., Nix, N. W., Smith, C. D., & Zacharia, Z. G. (2001). Defining Supply Chain Management. *Journal of Business Logistics, 22*(2), 1-25. doi: 10.1002/j.2158-1592.2001.tb00001.x

Ngai, E. W. T., Cheng, T. C. E., & Ho, S. S. M. (2004). Critical success factors of web-based supply-chain management systems: An exploratory study. *Production Planning & Control, 15*(6), 622-630. doi: 10.1080/09537280412331283928

Penzes, B. (2018). *Blockchain Technology in the Construction Industry*. Institution of Civil Engineers. doi: 10.13140/RG.2.2.14164.45443

Prajogo, D., & Olhager, J. (2012). Supply chain integration and performance: The effects of long-term relationships, information technology and sharing, and logistics integration. *International Journal of Production Economics, 135*(1), 514-522. doi: 10.1016/j.ijpe.2011.09.001

PrefabNZ. (2013). *Roadmap for Prefab in New Zealand*. Retrieved from http://www.prefabnz.com/Downloads/Assets/7641/1/PrefabNZ%20Roadmap%20for%20Prefab%20in%20New%20Zealand%20(2013).pdf

PrefabNZ. (2015). *Levers for prefabNZ*. Retrieved from http://www.prefabnz.com/Downloads/Assets/7645/1/PrefabNZ%20Levers%20for%20Prefab%20(2015).pdf

PrefabNZ. (2018). *Good Offsite Guide: A compilation of regulatory perspectives to assist in getting your great offsite projects off the ground*. Retrieved from http://www.prefabnz.com/Downloads/Assets/9743/1/PrefabNZ%20Good%20Offsite%20Guide%20FINAL%20(1).pdf

Rebs, T., Brandenburg, M., & Seuring, S. (2019). System dynamics modeling for sustainable supply chain management: A literature review and systems thinking approach. *Journal of Cleaner Production, 208*, 1265-1280. doi: 10.1016/j.jclepro.2018.10.100

Saberi, S., Kouhizadeh, M., Sarkis, J., & Shen, L. (2018). Blockchain technology and its relationships to sustainable supply chain management. *International Journal of Production Research, 57*(7), 2117-2135. doi: 10.1080/00207543.2018.1533261

Sahin, F., & Robinson, E. P. (2002). Flow coordination and information sharing in supply chains: Review, implications, and directions for future research. *Decision Sciences*, *33*, 505-536. doi: 10.1111/j.1540-5915.2002.tb01654.x

Samarasinghe, A., Tookey, J., & Rotimi, J. (2013). Supply chain collaboration in New Zealand house construction. 3-8th AUBEA Conference, New Zealand, 11-22.

Shahzad, W. M. (2016). Comparative analysis of the productivity levels achieved through the use of panelised prefabrication technology with those of traditional building system. Doctoral Thesis, Massey University. Retrieved from http://hdl.handle.net/10179/11207

Shahzad, W. M., & Mbachu, J. (2013). Prefabrication as an onsite productivity enhancer: Analysis of impact levels of the underlying constraints and improvement measures in New Zealand construction industry. *International Journal of Project Organisation and Management, 5*(4), 334-354.

Shahzad, W., Mbachu, J., & Domingo, N. (2015). Marginal Productivity Gained Through Prefabrication: Case Studies of Building Projects in Auckland. *Buildings, 5*(1), 196-208.

Stock, G. N., Greis, N. P., & Kasarda, J. D. (2000). Enterprise logistics and supply chain structure: the role of fit. *Journal of Operations Management, 18*(5), 531-547. doi: 10.1016/S0272-6963(00)00035-8

Tse, D., Zhang, B., Yang, Y., Cheng, C., & Mu, H. (2017). Blockchain application in food supply information security. 2017 IEEE International Conference on Industrial Engineering and Engineering Management (IEEM). doi: 10.1109/IEEM.2017.8290114

Turk, Ž., & Klinc, R. (2017). Potentials of Blockchain Technology for Construction Management. *Procedia Engineering, 196*, 638-645. doi: 10.1016/j.proeng.2017.08.052

Wang, J., Wu, P., Wang, X., & Shou, W. (2017). The outlook of blockchain technology for construction engineering management. *Frontiers of Engineering Management, 4*(1), 67-75. doi: 10.15302/J-FEM-2017006

Wang, Z., Wang, T., Hu, H., Gong, J., Ren, X., & Xiao, Q. (2020). Blockchain-based framework for improving supply chain traceability and information sharing in precast construction. *Automation in Construction, 111*, 103063. doi: 10.1016/j.autcon.2019.103063

Xing, K., Qian, W., & Zaman, A. U. (2016). Development of a cloud-based platform for footprint assessment in green supply chain management. *Journal of Cleaner Production, 139*, 191-203. doi: 10.1016/j.jclepro.2016.08.042

Yeo, K. J. (1993). Systems thinking and project management – time to reunite. *International Journal of Project Management*, *11*(2), 111-117. doi: 10.1016/0263-7863(93)90019-J

Zhai, X., Reed, R., & Mills, A. (2013). Factors impeding the offsite production of housing construction in China: an investigation of current practice. *Construction Management and Economics, 32*(1-2), 40-52. doi: 10.1080/01446193.2013.787491

Zhai, Y., Zhong, R. Y., Li, Z., & Huang, G. (2016). Production lead-time hedging and coordination in prefabricated construction supply chain management. *International Journal of Production Research, 55*(14), 3984-4002. doi: 10.1080/00207543.2016.1231432