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Blockchain Technology in Construction Supply Chain Management: Enhance Transaction Speed, Cost Effectiveness And Security

Zhou Zilin[1], Khoo Terh Jing[1,*], Ha Chin Yee[1], Deng Zihao[1], Li Yao[1]

[1] Department of Construction Project Management, School of Housing, Building, and Planning, Universiti Sains Malaysia,11800 Minden, Penang, Malaysia

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ABSTRACT

The traditional construction sector encountered obstacles that prevented it from developing, including knowledge asymmetry, complicated intermediary relationships, and high transaction costs. Blockchain technology offered a more effective, secure, and convenient mode of transaction and management to the construction industry because it was a decentralized, safe, and reliable information transmission and management tool. Blockchain technology could be applied to the construction industry's supply chain to achieve traceability and supervision, enhancing the transparency and dependability of transactions. At the same time, blockchain technology could be applied to the management of the construction supply chain to achieve rapid information sharing and verification, lowering transaction costs, and increasing transaction efficiency. However, the previous study on the use of blockchain technology in the building sector was still in its infancy and required more investigation and study. This study aimed to investigate how blockchain technology could be used in supply chain management for the construction sector to address present issues. The study's goals were to examine how blockchain technology could speed up transactions and improve supply chain management for the construction industry, as well as to examine how it could lower transaction costs and increase data sharing and information transparency. This study used a semi-structured interviewing technique for the purpose of gathering and analysing data. The researcher learned more about professionals and industry experts' thoughts and experiences with blockchain technology in construction supply chain management through in-person or remote interviews with them. The advancement of the construction industry's digital transformation and information upgrading reflected the significance of this study. This study would help the supply chain management in the construction sector in enhancing the effectiveness of supply chain transactions in the construction industry and reducing the transaction cycle; lowering the price of supply chain transactions in the construction industry and boosting the industry's competitiveness; strengthening the security and reliability of supply chain transactions in the construction industry and reducing data compromise and transaction risks.

* *Corresponding author.*
E-mail address: terhjing@usm.my
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1. Introduction

The construction industry, as one of the traditional industries, has been plagued by many problems and challenges [1]. Among them, slow transaction speed, opaque information and high security risks have been plaguing the development of the construction industry (Wang *et al*., [42]). In recent years, with the rapid development of blockchain technology, people have started to try to apply it to the construction supply chain management to improve transaction speed, reduce costs and increase security [34] .

The characteristics of blockchain technology, such as decentralization, immutability, security, and reliability, provide a wide scope for its application in the management of the construction industry [2] . By using blockchain technology, the construction industry can establish a complete, transparent, and secure information flow, realize the whole process of monitoring and management from construction material procurement to construction acceptance, etc., significantly improve transaction speed and efficiency, reduce costs and risks, and ensure information security and privacy at the same time [1] .

Although blockchain technology has been widely used in the fields of finance and logistics, its application in the construction industry is still in the initial stage. Currently, there are problems such as slow transaction speed, opaque information, and high security risks in the construction industry, which not only affect the development of the construction industry, but also adversely affect the interests of consumers [43] . At the same time, the traditional management mode of the construction industry has been unable to meet the current needs of society, and digital transformation and information upgrading have become the inevitable choice for the transformation and upgrading of the construction industry [13] .

Despite the advancements made in the utilization of blockchain technology within the construction business, contemporary study reveals the existence of evident gaps in knowledge. The existing body of research pertaining to the actual implementation of blockchain technology in the domain of construction supply chain management is currently constrained and lacks comprehensive investigation. Most of the existing research primarily emphasizes the theoretical and conceptual aspects, while practical application situations are very limited in their support. Furthermore, most of the current research predominantly emphasizes transaction speed, cost reduction, and security enhancement, while neglecting comprehensive investigations into the practical implementation and promotion aspects. This includes specific operational strategies and practical measures that can be undertaken. Furthermore, despite certain advancements in the utilization of blockchain technology within the construction sector, there remains a dearth of empirical evidence to comprehensively substantiate its true impact and worth. Hence, it is imperative to address these research deficiencies by conducting thorough investigations to offer more comprehensive direction and assistance for actual implementations.

To research the use of blockchain technology in construction supply chain management, with the main objectives of improving transaction speed, reducing costs, and increasing security, and study how to use decentralized, non-tamper able, safe, and reliable features of blockchain to solve the problems existing in the construction industry, to realize the digital transformation and information upgrade of the construction industry.

2. Blockchain Technology Applications in The Construction Supply Chain Management

Together with the development of information technology and the expansion of the Internet, the construction industry is progressively ushering in an era of digital transformation and information

upgrading. The traditional construction supply chain management approach, however, has information asymmetry, time-consuming interactions, and expensive prices that limit the sector's expansion [22]. To solve these problems, a lot of companies and organizations are starting to investigate how supply chain management may be built using blockchain technology.

Due to its decentralized, trustworthy, and secure information management and transfer platform, blockchain technology is quickly evolving into an effective tool for the construction industry to replace the existing management approach. In the building supply chain management, blockchain technology has unique advantages and prospective uses. We will give a general overview of how blockchain technology is applied to supply chain management in the construction sector in this segment, as well as discuss how it improves transaction speed, reduces costs, and increases security.

2.1 The Impact of Blockchain on the Speed of Supply Chain Transactions in the Construction Industry

The utilization of blockchain technology has resulted in enhanced efficiency in supply chain transactions within the construction industry. The supply chain management commonly employed in the construction sector is characterized by a multitude of intricate processes and intermediary connections, resulting in a deceleration of transactional flow [41] . In contrast, blockchain technology has the potential to enhance transaction speed through the elimination of intermediary connections and the facilitation of prompt confirmation and settlement of transactions [22] . In traditional supply chains, the process of validating and verifying transactions involves multiple intermediaries and interconnected stages. The process at hand may need a substantial amount of time and effort, encompassing various forms of communication, audits, authorizations, and settlements. In contrast, the decentralized nature of blockchain technology facilitates direct communication between transaction parties, eliminating the need for intermediaries that often consume significant amounts of time. Transactions on the blockchain are documented within a decentralized ledger, which possesses an immutable nature, hence enabling users to engage in collaborative efforts and ascertain the veracity of these transactions. Once a transaction has received approval, it is appended to a block on the blockchain and then made accessible to the public. The expeditious confirmation and dissemination of transactions can enhance transactional efficiency and reduce processing duration. Moreover, the use of smart contracts through automation can significantly reduce the time needed for manual processes, resulting in further acceleration of transactions. Smart contracts are capable of automatically executing predetermined activities when specific criteria are satisfied. These contracts consist of pre-established rules that facilitate automated execution. Consequently, human interaction becomes unnecessary, thereby facilitating expedited transaction processing.

A typical example, the 2016-launched blockchain supply chain finance technology from Santander Bank serves as a concrete illustration. The platform makes use of blockchain technology to enhance the speed and security of supply chain financing through quick settlement and fund flow. To guarantee prompt delivery and precise money distribution, stakeholders in the supply chain can share and verify transaction information using smart contracts in real time. This enhances the effectiveness of the entire supply chain finance process by reducing pointless paper papers and time-consuming approval processes. In supply chain finance, blockchain technology can potentially address the issue of trust. Information about supply chain financing transactions is permanently recorded on the blockchain and cannot be altered by any participant due to the immutability and transparency of the blockchain. This lowers the danger of financial fraud while also giving financial institutions more trustworthy transaction data [3].

In summary, the elimination of intermediary connections, the expedited validation of transactions, and the automatic implementation of intelligent agreements collectively contribute to a significant acceleration in the speed of supply chain transactions within the construction industry.

2.2 The Cost-Effectiveness of Blockchain in Supply Chain Management in the Construction Industry

Supply chain management in the construction sector may be improved cost-effectively thanks to blockchain technology. Operational costs and transaction fees can be minimized by removing intermediary linkages, streamlining processes, and automating execution [15] . Additionally, the cost of processing paper documents and manual tasks can be decreased thanks to blockchain technology. By enhancing the supply chain's efficiency and dependability, extra expenditures brought on by delays and mistakes can be avoided [29] . Unlike the decentralized nature of blockchain technology, which enables supply chain participants to conduct transactions directly without the need for intermediaries, traditional supply chain management in the construction industry involves numerous intermediaries and links, each of which requires human resources and time costs. This cuts down on the time and expense of human operations and eliminates the need for middlemen. Blockchain technology also can automate business procedures and smart contract execution. The automatic execution of smart contracts eliminates the need for manual processes and minimizes the cost of employing people. Smart contracts can also automate settlements and payments based on pre-established rules, lowering transaction costs and delays. The cost of processing and storing paper documents can be decreased with the use of blockchain technology. To track and confirm transactions in traditional supply chain management, a significant amount of paperwork is required. The need for substantial paper documentation and manual records is removed in blockchain, on the other hand, and transactions are recorded in a tamper-evident distributed ledger, which lowers the cost of document processing and storage [43] .

Together, the elimination of intermediary connections, process simplification, automation of execution, and decreased processing of paper documents with blockchain technology can result in cost savings and advantages in the building supply chain management.

2.3 Blockchain's Security Assurance in Construction Supply Chain Management

In the construction business, supply chain management using blockchain technology can be secure. Data security and tamper resistance are achieved via distributed storage and cryptography in the blockchain technology [44]. Cryptographic algorithms check the authenticity and integrity of each transaction to ensure it. In the meantime, data on the blockchain is kept among numerous nodes and is resistant to manipulation and destruction. Due to decentralized information storage and flaws in the transmission method, data in traditional supply chain management is susceptible to risks like tampering, theft, and fraud. Contrarily, blockchain technology ensures data security by encrypting and cryptographically validating transaction data. Only when a transaction has been confirmed by a cryptographic method is it posted to the blockchain. As a result, the transaction data is less vulnerable to forging or tampering. Data security is also improved by blockchain technology's distributed storage and consensus mechanism [43]. The fact that data on the blockchain is stored across numerous nodes rather than in a single data central lower the possibility of data attack. The consensus technique also guards against manipulation and guarantees data consistency across all nodes [6].

In conclusion, by utilizing cryptography and distributed storage, blockchain technology ensures the security and tamper-proofing of data in supply chain management in the construction industry.

3. Methodology

3.1 Research Approach

Semi-structured interviews will be used to collect and analyze data for this research. Semi-structured interviews are a type of research technique that combine the traits of both organized and unstructured interviews [16]. A specified number of respondents with appropriate industry expertise and knowledge will be chosen for the study, including professionals, company leaders, and academic specialists in the construction and blockchain industries. The study will use remote interviews to ask respondents questions regarding the applicability, problems, and possibilities of blockchain technology in construction supply chain management. During the interviews, respondents' comments will be recorded, and differences in opinions and experiences amongst respondents will be noted.

3.2 Sampling Method

Snowball sampling is a non-probability sampling approach that is widely employed in research when a comprehensive sampling frame, such as hidden populations, populations with unique features, or specific social networks, is difficult to collect [12], as shown in Figure 1.

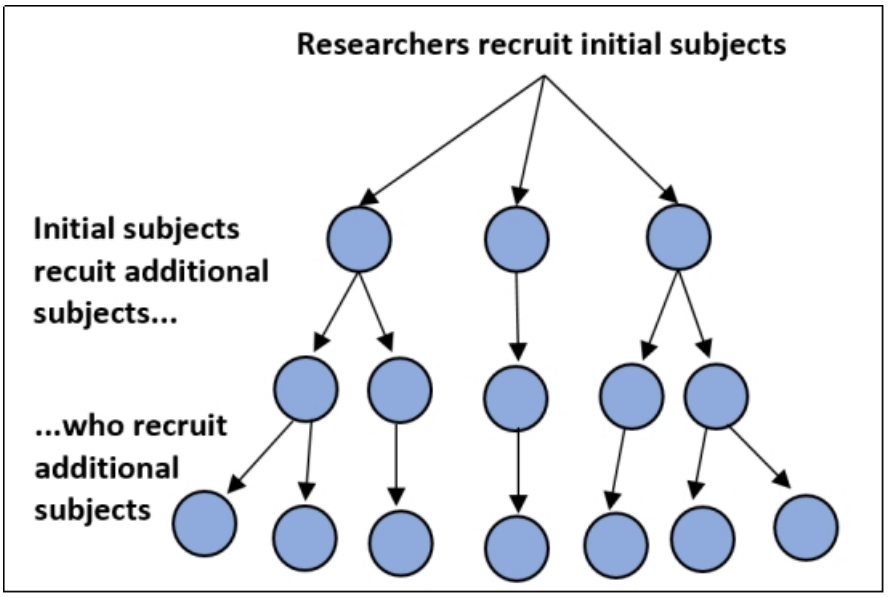

Fig. 1. Snowball sampling process

In this study, the researcher will initially identify a group of respondents who possess industry expertise and experience that is deemed relevant. These individuals will serve as the initial nodes in the snowball sampling method. The researcher will engage in dialogue with the initial respondents, inquiring about the use of blockchain technology in the management of supply chains within the construction industry, as well as exploring associated concerns and considerations. Throughout the duration of the interview, the researcher will inquire with the respondents regarding their ability to provide recommendations for individuals possessing pertinent experience or competence within the subject. The researcher will proceed with conducting individual interviews based on the newly acquired list of respondents. This approach will allow for an in-depth exploration of similar concerns and facilitate the gathering of further recommendations. The procedure will systematically and

incrementally augment the sample size until it attains the requisite sample size necessary for the investigation.

By employing the snowball sampling method, the researcher can progressively establish a sample group comprising individuals possessing expertise in the pertinent domain. While the initial sample size may be limited, it will progressively expand as the snowball effect persists. This approach aims to comprehensively investigate the practical implementation of blockchain technology in the management of construction supply chains, while also capturing a wide range of perspectives and experiences.

3.3 Interview Process

The interview process is divided into three stages, as shown in Figure 2. The questionnaire design was designed as in Appendix A.

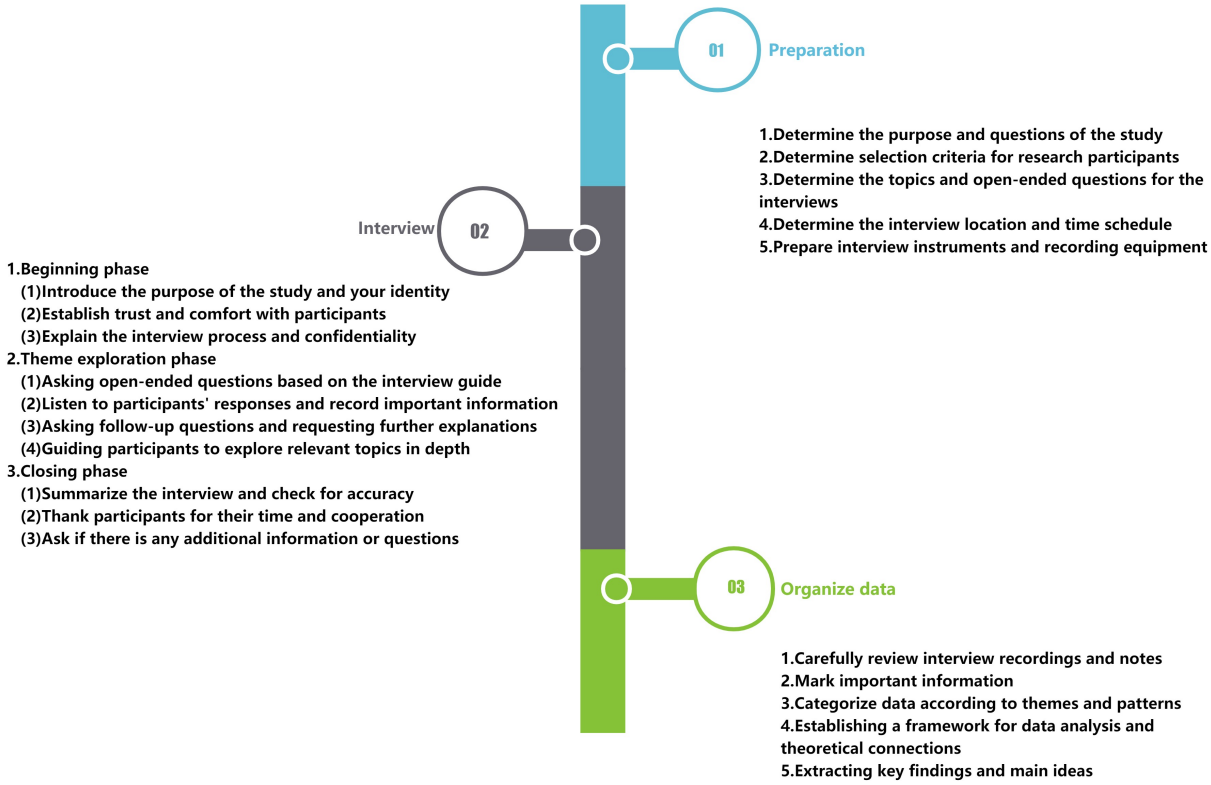

Fig. 2. Interview Process

3.4 Analytical Method

3.4.1 Three-level coding

The three-level coding is a hierarchical coding approach aimed at analyzing and organizing interview data in a more detailed manner. It allows researchers to code the data under more specific themes and sub-themes, enabling a deeper exploration of the interview content [5] .

The coding process can be outlined as follows:

Initial Coding: The researcher first reads and comprehends interview data. Based on the study questions and interview content, the researcher builds preliminary coding nodes for each question. These nodes usually represent question-related keywords or concepts.

Second-level Coding: After initial coding, the research refines the nodes into more specific sub-nodes in second-level coding. Deeper data analysis and understanding are required. A second-level node is created for certain themes and sub-themes by the researcher.

Third-level Coding: After second-level coding, the researcher divides the nodes into even more particular sub-nodes in third-level coding. It may take several readings, comparisons, and analyses to grasp subtle variations and underlying meanings in the interviews.

3.4.2 Content analysis

Content analysis is a method of systematic textual data analysis that aims to extract, code, and analyze certain elements, patterns, and relationships in text. It is relevant to a range of text forms, including interview texts, books, news stories, and so on, and can be utilized for both qualitative and quantitative research.

(1) Defining the research objectives and research questions.
(2) Selecting acceptable text samples.
(3) Designing coding rules and criteria.
(4) Completing coding and data extraction.
(5) Analyzing and interpreting the results are typical procedures in content analysis.

The purpose of content analysis is to use systematic analysis to find patterns, themes, and meanings in text data to derive conclusions about the study issues.

4. Results

This research acquired eight interview data texts through semi-structured interviews with eight professionals and scholars from various businesses, interviewee information as shown in Table 1. This section processes these interview data using NVivo software and analyses thematic coding, content, and clustering to understand the current issues of transaction security, transaction cost, and transaction speed faced by supply chain management in the construction industry, and how blockchain technology can be adopted to optimise the above three aspects and provide suggestions on how blockchain technology can be implemented at the supply chain level.

Table 1
Interviewer Information

INTERVIEWER INFORMATION					
Interviewee	**Position**	**Industry**	**Interview Date**	**Interview Method**	**Length of Interview**
Interviewee 1	Senior Technical Management 1	Construction	20/05/2023	Online 1v1	40min
Interviewee 2	Scholar 1	Construction	20/05/2023	Online 1v1	40min
Interviewee 3	Expert 1	Construction	21/05/2023	Online 1v1	40min
Interviewee 4	Blockchain Technology Specialist 1	Blockchain	21/05/2023	Online 1v1	40min

Interviewee 5	Scholar 2	Construction	22/05/2023	Online 1v1	40min
Interviewee 6	Senior Technical Management 2	Construction	22/05/2023	Online 1v1	40min
Interviewee 7	Blockchain Technology Specialist 2	Blockchain	23/05/2023	Online 1v1	40min
Interviewee 8	Expert 2	Construction	23/05/2023	Online 1v1	40min

4.1 Data Analysis

4.1.1 Coding analysis

In the research, a three-level coding process was conducted on the interview data from eight participants representing different industries and positions related to the supply chain of construction industry and blockchain, as shown in Table 2.

Table 2
Coding table

First-level coding	Second-level coding	Third-level coding
Supply Chain Management	Definition and Scope of Supply Chain Management in the Construction Industry	Coordinating End-to-End Activities
		Controlling the Flow of Resources
	Challenges of Supply Chain Management in the Construction Industry	Supply Chain Complexity and Fragmentation
		Lack of Information Flow and Communication
		Poor Logistics and Transportation Efficiency
		Insufficient Supply Chain Visibility and Traceability
	Application of Blockchain Technology in Supply Chain Management in the Construction Industry	Decentralized Transaction Records
		Application of Smart Contracts
		Material Traceability and Verification
		Enhanced Supply Chain Visibility and Collaboration
		Reducing Fraud and Improving Trust
	Improving Transaction Speed through Blockchain Management	Reducing Administrative Delays
		Automation of Processes
		Eliminating the Need for Intermediaries
		Procurement Costs

Transaction Costs	Key Aspects of Transaction Costs in the Construction Industry	Contract Negotiation and Management Costs
		Payment Processing Costs
		Transportation and Logistics Costs
		Quality Control and Dispute Resolution Costs
	Current Challenges of Transaction Costs in the Construction Industry	Inefficient and Time-consuming Procurement Processes
		Complex Contract Negotiation and Management
		Manual and Paper-based Payment Systems
		Issues with Logistics and Supply Chain Coordination
		Quality Issues and Disputes Arising from Contract Misunderstandings
	Application of Blockchain Technology to Reduce Transaction Costs in the Construction Industry	Automation and Simplification of Procurement Processes
		Automated Execution and Management of Smart Contracts
		Secure and Instant Digital Payments
		Improvements in Logistics and Supply Chain Coordination
		Transparent and Immutable Transaction Records
Transaction Security and Reliability	Transaction Security and Reliability Issues in the Construction Industry	Fraud Risks
		Unauthorized Modification of Transaction Records
		Authenticity Issues with Documents and Certificates
		Risks of Data Tampering
	Current Challenges of Transaction Security and Reliability in the Construction Industry	Vulnerabilities in Traditional Paper-based Systems
		Difficulties in Verifying the Authenticity of Documents and Certificates
		Lack of Transparency and Accountability in Transaction Processes

How Blockchain Technology Ensures Transaction Security and Reliability in the Construction Industry		Application of Encryption Algorithms and Decentralized Networks Tertiary Code Data Tampering and Transaction Risks
		Immutable Transaction Records and Verification Mechanisms Tertiary Code
		Use and Advantages of Multi-party Consensus Tertiary Code
		Methods to Prevent data tampering and transction risks

These three-level codes delve into the impact of blockchain on the construction industry from various perspectives. Firstly, from the first-level code "*Supply Chain Management*", it encompasses the definition, scope, and challenges of supply chain management. In the second-level code "*Definition and Scope of Supply Chain Management in the Construction Industry*", the emphasis is placed on the coordination and resource flow control roles of supply chain management in the construction industry. This reveals that optimizing supply chain processes is crucial for improving efficiency and resource utilization in the construction industry. The second-level code "*Challenges of Supply Chain Management in the Construction Industry*" further enumerates challenges such as supply chain complexity, information flow barriers, logistics inefficiency, and inadequate visibility, which directly impact the industry's operations and effectiveness.

Under the first-level code "*Transaction Costs*", a deeper exploration of different aspects of transaction costs is conducted. In the second-level code "*Key Aspects of Transaction Costs in the Construction Industry*", it covers costs in various areas including procurement, contract management, payment processing, logistics, and quality control. This underscores that transaction costs are a pivotal factor influencing the industry's profitability. The second-level code "*Current Challenges of Transaction Costs in the Construction Industry*" delves into practical issues like inefficient procurement processes, complex contract management, and manual payment systems, which impede the industry's competitiveness and efficiency.

Under the first-level code "*Transaction Security and Reliability*", the focus is on discussing issues pertaining to transaction security and reliability. The second-level code "Transaction Security and Reliability Issues in the Construction Industry" lists problems such as fraud risks, unauthorized alterations to transaction records, authenticity concerns with documents and certificates, and the risks of data tampering. This underscores the importance of ensuring transaction security in the construction industry. In the second-level code "*Current Challenges of Transaction Security and Reliability in the Construction Industry*", it underscores actual challenges like vulnerabilities in traditional paper-based systems and difficulties in verifying document and certificate authenticity.

The third-level codes further dissect each topic, discussing specific issues and solutions. For instance, in the topic "*Application of Blockchain Technology in Supply Chain Management in the Construction Industry*", through codes like "*Decentralized Transaction Records*" and "*Application of Smart Contracts*", it illustrates how blockchain can enhance visibility, collaboration, and trust in supply chain management. In the topic "*Improving Transaction Speed through Blockchain Management*", aspects such as reducing administrative delays, automating processes, and eliminating intermediaries are explored.

In summary, these three-level code analyses provide an in-depth examination of how blockchain impacts supply chain, transaction costs, and transaction security in the construction industry. This offers clear insights for decision-makers in the construction industry to better apply and adapt blockchain technology in their operations.

4.1.2 Content analysis

For the responses provided by different participants, we selected questions for analysis. We examined the diverse answers given by the participants to the same question, extracting valuable insights. View comparison and analysis as shown in Figure 3.

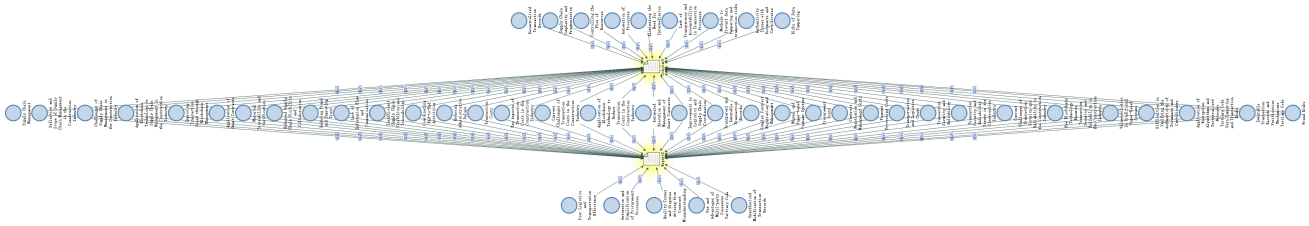

Fig. 3. View comparison and analysis

Based on the Figure 3, analysing blockchain's impact on supply chain speed. As shown in Table 3.

Table 3
Interview text analysis (Transaction speed)

Key Themes and Differences	Analysis
Interviewees 1, 2, 3, 4, 6, and 8 emphasize fragmented supply chains, lack of information flow, and limited visibility.	Indicates a consensus on transparency and complexity issues.
Multiple interviewees (2, 4, 6, 8) mention coordination and communication challenges among stakeholders.	Underlines the importance of effective collaboration.
Interviewees 4 and 8 highlight complex procurement processes leading to delays.	Emphasizes the need for streamlined procurement.
Participants 2, 5, and 6 point to inventory and material tracking difficulties.	Reinforces challenges in optimizing material flow.
Interviewee 8 focuses on quality control and compliance throughout the supply chain.	Signals a concern for maintaining high standards.
Despite variations, common threads emerge: fragmented supply chains, transparency gaps, coordination issues, complex procurement, inventory inefficiencies, and quality control concerns.	Identifies key issues for industry efficiency and collaboration.

While there are variations in how the challenges are articulated, there is a common thread among the interviewees regarding the significant supply chain management challenges in the construction

industry. Fragmented supply chains, lack of transparency, coordination and communication issues, procurement complexities, inventory management difficulties, and quality control concerns emerge as key issues. These findings suggest that addressing these challenges is crucial for enhancing efficiency, collaboration, and overall effectiveness within the construction supply chain.

Based on the Figure 3, examining blockchain's impact on transaction cost reduction. As shown in Table 4.

Table 4
Interview text analysis (Transaction cost)

Consensus Viewpoints	Analysis
Interviewees unanimously agree that blockchain eliminates intermediaries for direct transactions.	Shows alignment in intermediary removal benefit.
Automation through smart contracts reduces manual processes, increasing efficiency.	Highlights smart contract impact on cost reduction.
Blockchain enhances transaction transparency, trust, reducing disputes and legal costs.	Indicates a consensus on transparency's cost-saving effect.
Fast and secure digital payments expedite settlements and reduce costs.	Agrees on payment speed and cost reduction.
Smart contracts simplify contract management, reducing disputes and administrative costs.	Shows alignment in contract management simplification.
Blockchain improves logistics, minimizes resource wastage, and reduces costs.	Indicates the technology's role in resource optimization.
Consensus: blockchain lowers costs through intermediary removal, process automation, transparency, swift payments, simplified contract management, and improved logistics.	Highlights the technology's potential for cost-effective transactions.

In conclusion, interviewees unanimously hold the view that blockchain technology can significantly reduce transaction costs in the construction industry through methods such as intermediary elimination, process automation, enhanced transparency and trust, swift payment settlement, simplified contract management, and optimized logistics and supply chain coordination. These consensus viewpoints underscore the potential of blockchain technology in the construction sector, promising a more efficient and cost-effective transaction environment for the industry.

Based on the Figure 3, analysing blockchain's role in transaction security. As shown in Table 5.

Table 5
Interview text analysis (Transaction security)

Common Perspectives	Analysis
All interviewees unanimously agree blockchain enhances security through decentralization and immutability.	Highlights consensus on blockchain's security features.
Transactions recorded on blockchain are encrypted and timestamped, enhancing security.	Agrees on encryption and timestamping benefits.
Distributed nature of blockchain increases trust and reliability by involving multiple participants.	Shows alignment in trust enhancement due to distribution.
Transactions on blockchain's transparent and auditable ledger enhance reliability and reduce fraud risks.	Consensus on transparency's impact on reliability and fraud prevention.
Consensus: blockchain ensures security and reliability through decentralization, encryption, distributed validation, and transparency.	Emphasizes blockchain's potential for secure transactions.

In conclusion, interviewees unanimously hold the view that blockchain technology can significantly enhance the security and reliability of transactions in the construction industry through methods such as decentralization and immutability, encryption and timestamping, distributed validation mechanisms, and transparency and auditability. These consensus viewpoints underscore the potential of blockchain technology in safeguarding transaction security and reliability in the construction sector, creating a more secure and trustworthy transaction environment for the industry.

5. Conclusions

This research investigates how blockchain technology can be used to optimise these aspects by conducting an in-depth analysis of transaction security, transaction costs, and transaction speed in construction supply chain management, as well as providing conclusions for implementing blockchain technology at the supply chain level.

The findings show that blockchain technology can be used to improve supply chain management in the construction industry in a variety of ways, including decentralised transaction records, smart contract implementation, material traceability and verification, improved supply chain visibility and collaboration, and fraud reduction and trust enhancement [20]. Simultaneously, blockchain management can improve transaction speed by decreasing administrative delays, automating operations, and eliminating the need for middlemen [4]. Furthermore, blockchain technology can reduce transaction costs in the construction industry by automating and streamlining procurement processes, automating smart contract execution and management, secure and instantaneous digital payments, improved logistics and supply chain coordination, and transparent and tamper-proof transaction records [37].

This research offered suggestions and solutions for strengthening transaction security, speeding up transactions, and lowering transaction costs through a thorough examination of the use of

blockchain technology in supply chain management in the construction sector. This study has significant ramifications for improving supply chain management in the construction sector that are inexpensive, efficient, and secure. It also serves as a reference for academic study and real-world applications in related research disciplines. Future studies can increase the sample size even more, integrate different types of data, and investigate how blockchain technology is used in other sectors of the economy.

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Appendix A Structure of the questionnaire

Dear Participants,

Thank you for taking the time to respond to our survey. The goal of this survey is to examine how blockchain technology can improve supply chain management and transaction speed in the construction industry, as well as to investigate its applicability in lowering transaction costs, increasing information transparency, and data sharing. We will be able to acquire insight into the prospects and potential impact of blockchain technology in the construction business thanks to your valuable experiences and insights. Please answer the questions as completely and accurately as possible; your responses will be kept totally confidential and used solely for research reasons.

Yours Sincerely

Interviewer Information Completion Form

INTERVIEWER INFORMATION COMPLETION FORM	
Interviewee	Interviewee 1\2\3....
Position	Fill in the interviewee's position in the company or organization
Industry	fill in the interviewee's industry, such as construction industry
Interview date	Fill in the date of the interview
Interview method	fill in the interview method, such as online one-on-one interviews
Interview length	fill in the estimated length of the interview

Interview Questionnaire

INTERVIEWER QUESTIONNAIRE		
Interviewee	Interviewee 1	
Position	Senior Technical Management	
Industry	Construction Industry	
Interview Date	23/05/2023	
Interview Method	Online 1v1	
Length of Interview	40min	
1.Supply chain management & transaction speed.		
Question	Category	Answer

What is supply chain management in the construction industry?	Background	
What are the current supply chain management challenges in the construction industry?	Background	
How can blockchain technology be applied to supply chain management in the construction industry?	Approach	
What are the benefits of using blockchain technology for supply chain management in the construction industry?	Methods	
How can blockchain technology improve the speed of transactions?	Method	
What are some success stories that demonstrate the effectiveness of blockchain technology in construction supply chain management?	Examples	
2.Transaction costs.		
Question	Category	Answer
What are the main aspects of transaction costs involved in the construction industry?	Background	
What are the current challenges in the construction industry in terms of transaction costs?	Background	
How can blockchain technology reduce transaction costs in the construction industry?	Methods	
How can blockchain technology improve information transparency and data sharing in the construction industry?	Methods	
What are some successful case studies that demonstrate the effectiveness of blockchain technology in reducing transaction costs and improving information transparency and data sharing in the construction industry?	Examples	
3.Security and reliability of transactions.		

Question	Category	Answer
What are the transaction security and reliability issues in the construction industry?	Background	
What are the current transaction security and reliability challenges in the construction industry?	Background	
How can blockchain technology ensure the security and reliability of transactions in the construction industry?	Methods	
How can blockchain technology prevent data tampering and transaction risks?	Approach	
What are some successful case studies that demonstrate the effectiveness of blockchain technology in ensuring transaction security and reliability, preventing data tampering and transaction risks in the construction industry?	Examples	

Concluding remarks:

Thank you very much for taking part in this survey interview; your thoughts and views are valuable to our study. Please email us if you have anything to add or other ideas. We will thoroughly examine and research your replies to give better solutions and creative applications to the construction industry. Thank you once more for your precious time and cooperation!

Development of interview questions: Based on the goal of the survey and research from other literature sources, specific research questions were devised. The table below shows: Sources of interview questions

1.Supply chain management & transaction speed.	
Question	Literature source
What is supply chain management in the construction industry?	Segerstedt & Olofsson (2010), Doran & Giannakis (2011)
What are the current supply chain management challenges in the construction industry?	Nasir et al. (2017)
How can blockchain technology be applied to supply chain management in the construction industry?	Shojaei (2019)

What are the benefits of using blockchain technology for supply chain management in the construction industry?	Kim et al. (2020)
How can blockchain technology improve the speed of transactions?	Niranjanamurthy et al. (2019)
What are some success stories that demonstrate the effectiveness of blockchain technology in construction supply chain management?	Sivula et al. (2021)

2.Transaction costs

Question	Literature source
What are the main aspects of transaction costs involved in the construction industry?	Arditi et al. (2013)
What are the current challenges in the construction industry in terms of transaction costs?	Nasir et al. (2017), Qian et al. (2015)
How can blockchain technology reduce transaction costs in the construction industry?	Niranjanamurthy et al. (2019), Dakhli et al. (2019)
How can blockchain technology improve information transparency and data sharing in the construction industry?	Niranjanamurthy et al. (2019), Pattini et al. (2020)
What are some successful case studies that demonstrate the effectiveness of blockchain technology in reducing transaction costs and improving information transparency and data sharing in the construction industry?	Niranjanamurthy et al. (2019), Dakhli et al. (2019), Pattini et al. (2020), Dutta et al. (2020)

3.Security and reliability of transactions

Question	Literature source
What are the transaction security and reliability issues in the construction industry?	Greenwood *et al*., [20]
What are the current transaction security and reliability challenges in the construction industry?	Nasir et al. (2017), Greenwood et al. (2019)
How can blockchain technology ensure the security and reliability of transactions in the construction industry?	Niranjanamurthy et al. (2019), Perera et al. (2020), Greenwood et al. (2019)
How can blockchain technology prevent data tampering and transaction risks?	Niranjanamurthy et al. (2019), Iqbal & Matulevičius (2019)

What are some successful case studies that demonstrate the effectiveness of blockchain technology in ensuring transaction security and reliability, preventing data tampering and transaction risks in the construction industry?	Dutta et al. (2020)