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REVIEW

Research Trends and Impacts of Blockchain Technology in Construction Sector: Scientistometric Study

Investigación Tendencias e Impactos de la Tecnología Blockchain en el Sector de la Construcción: Estudio cienciométrico

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ABSTRACT

Construction is a critical business that contributes greatly to a country's economic development. There is an increasing need for greater quality, more safety, and project completion on schedule. The world's fast shift from manual to digital processes is boosting the industry. This article outlines research into where and how this technology may be used in the construction sector. In this study, a literature review was conducted to identify the potential of blockchain applications in the construction industry. Examples of such technologies include smart contracts, BIM, Smart City, supply chain management, real estate management, precast construction, equipment leasing, document file sharing, asset management, construction management, payment management, and trash management. A scientometric study was carried out to better understand the present level of blockchain application in the construction business. Documents published in the Scopus and Web of Science databases between 2011 and 2024 were considered for the study. Scientistometric analysis identifies the most significant and prolific authors, articles, and the development of blockchain in the construction industry. More in-depth study is needed in the near future to develop real-world, on-the-spot solutions for the construction industry. The research reviewed 889 articles published between 2011 and 2024 and conducted a qualitative content analysis. The study's purpose is to look at how this technology may be used in the building industry. Future studies might concentrate on conducting case studies of real-world blockchain uses in building projects. This paper identifies and analyzes research gaps concerning the use of blockchain technology in civil engineering.

Keywords: Blockchain; Constriction Industry; Scientometric Study; Smart Contract; Building Information Modelling.

RESUMEN

La construcción es una actividad fundamental que contribuye en gran medida al desarrollo económico de un país. Cada vez es más necesaria una mayor calidad, más seguridad y la finalización de los proyectos en los plazos previstos. El rápido paso de los procesos manuales a los digitales está impulsando el sector. Este artículo esboza una investigación sobre dónde y cómo puede utilizarse esta tecnología en el sector de la construcción. En este estudio, se realizó una revisión bibliográfica para identificar el potencial de las aplicaciones de blockchain en la industria de la construcción. Algunos ejemplos de estas tecnologías son los contratos inteligentes, el BIM, la Smart City, la gestión de la cadena de suministro, la gestión inmobiliaria, la construcción de prefabricados, el arrendamiento de equipos, el intercambio de archivos de documentos, la gestión de activos, la gestión de la construcción, la gestión de pagos y la gestión de la basura. Se llevó a cabo

un estudio cienciométrico para comprender mejor el nivel actual de aplicación de blockchain en el negocio de la construcción. Para el estudio se tuvieron en cuenta los documentos publicados en las bases de datos Scopus y Web of Science entre 2011 y 2024. El análisis cienciométrico identifica los autores y artículos más significativos y prolíficos, así como el desarrollo de blockchain en el sector de la construcción. Se necesita un estudio más profundo en un futuro próximo para desarrollar soluciones reales y sobre el terreno para la industria de la construcción. La investigación revisó 889 artículos publicados entre 2011 y 2024 y realizó un análisis de contenido cualitativo. El objetivo del estudio es analizar cómo puede utilizarse esta tecnología en el sector de la construcción. Los estudios futuros podrían centrarse en la realización de estudios de casos de usos reales de blockchain en proyectos de construcción. Este artículo identifica y analiza las lagunas en la investigación sobre el uso de la tecnología blockchain en la ingeniería civil.

Palabras clave: Blockchain; Industria de la Construcción; Estudio Cienciométrico; Contrato Inteligente; Modelado de Información de Construcción.

INTRODUCTION

The construction industry includes a wide range of constructions, from small-scale residential or commercial buildings to power plants, bridges, highways, dams, airports, and harbors. It is an essential part of human civilization and has developed appropriately. Development in the construction industry is directly linked to the development of the country's economy. According to Statista Research Department[1] China's infrastructure investments as a proportion of GDP have grown by 5,8 % since 2019. The majority of infrastructure projects are dedicated to public utility services, which require large quantities of building supplies, timely completion, good project management systems, security and openness in handling funds, and genuine paperwork. Incorporating current approaches and smart technologies into an interdisciplinary approach may increase productivity in this field. The construction industry confronts challenges from both cast-in-situ and non-constructional perspectives. Some of the main obstacles encountered in the construction business include a qualified workforce, safety measures, project delays, and the changing nature of the task. Non-construction challenges include legal obstacles, government regulations, environmental concerns, technical acceptability, and political and social influences.[2] The resultant network is huge and difficult to administer. It is generally recognized that timely project completion requires a consistent supply of supplies as well as effective logistics management. Delays in the procurement of supplies for a building project have a significant impact on both construction costs and productivity. Supply chain management, genuine paperwork, safe transactions, and transparency may all be easily managed using the newest technology and smart solutions. Integration of blockchain technology is capable of overcoming some of the aforementioned difficulties, such as managing large volumes of secure transactions with transparency among many stakeholders, which is critical in the construction industry.

METHOD

Block Chain Technology: Classification and Characteristics

"According to the Korea Institute of Science and Technology Information (2018), the worldwide blockchain technology market has increased dramatically from around $130 million in 2015 to more than $550 million in 2018, nearly doubling every two years." This growing trend is expected to continue, with the global blockchain business projected to reach $3,74 billion by 2022.[3]

A block chain is a collection of linked, identifiable blocks of encrypted data that are used to create a single structure of honest data. Each block is identifiable by its hash value and is related to an older block known as the parent block. Thus, the parent block assures connection and at least one predecessor for each block.[4] Each block holds data in encrypted form, ensuring digital security. Furthermore, all of these blocks are protected and connected to one another. A block chain is a time-stamped collection of unmodified record entries produced by a distributed network of computers.[5] All necessary data from a transaction is recorded on a blockchain in seconds in a transparent way. The transaction procedure on a blockchain network is immediate and permanent. Every node in the system replicates and stores data. Any changes made in one ledger are immediately reflected in all other ledger copies. These features aid in avoiding mediators in the process. The proof-of-work approach for checking the validity of a block is much less costly than the proper solution.[6] Thus, blockchain technology serves as a reliable decentralized shared platform with an immutable ledger. Block chain technology allows for the examination and identification of acceptable data in the shortest period of time, in the most appropriate place, and to the correct person, ensuring a continuous flow of information. These qualities contribute to the creation of a shared digital history, which is essential for managing large building projects, as well as all records such as notary services, user identities, reputations, and data traceability.[7]

The three most critical alignments in the block chain are nodes, blocks, and miners. A node is an electrical device that keeps copies of the block chain and ensures the network's functionality. Every node in the network has a replica of the block chain and is linked to all other nodes. The network is connected in the notes via a 'peer-to-peer' connection.[8] The network's nodes run the distributed ledger using block chain technology. Every block contains data, its own nounce (a 32-bit integer), a 256-bit hash value associated with the nonce number, and a reference to the previous block in the chain. Miners add more blocks to the chain as they mine. When a block is successfully mined, all network nodes accept the change, and the miner receives monetary compensation.[9] Mining a block is difficult, particularly on long chains.

Block chains are grouped into four types: public, consortium, private, and hybrid block chains. A public block chain allows anybody with an internet connection to connect to the block chain network with an authorized distributed ledger. The most popular types of public block chains are Bitcoin, Ethereum, and Litecoin. The security standards must be rigorously followed while utilizing this form.[9] Private block chains are used for a variety of purposes, including democratic governance, enhanced personhood, resource ownership, and so on. This creates a constrained record framework that the association manages with full security consents and availability. The Consortium Block Chain is a semi-decentralized organization supported by several groups. In this kind of blockchain, a few companies may collaborate with the organization and share information. Banks, government offices, and other such organizations often use a consortium blockchain. A hybrid blockchain is a kind of block chain that combines both private and public blocks. It is a very adaptable kind of hub in which data may be kept visible or hidden depending on the individual's preferences.

Brief Information About the Evolution of Blockchain Development

Blockchain has evolved significantly since its introduction in 2008 as the technology that powers Bitcoin, the original cryptocurrency. The following is a simplified list of the most critical milestones on the route to the present state of blockchain technology:

1. Bitcoin was the first blockchain-based cryptocurrency developed in 2008 by an unknown individual or group using the name Satoshi Nakamoto. It was created to facilitate private, decentralised peer-to-peer transactions between users without the need of centralised institutions like banks.
2. Other cryptocurrencies, or altcoins, emerged over time, each with its own blockchain, such as Ethereum, Litecoin, and Ripple.
3. Smart contracts emerged in the wake of Ethereum's 2015 introduction of the idea, which allowed programmers to build contracts that could execute themselves without a third party's intervention.
4. The rise of dApps: with the advent of smart contracts, programmers have been able to construct dApps on blockchain platforms like Ethereum, opening up new possibilities for their usage beyond basic monetary transactions.
5. Enterprise blockchain solutions arose when the potential of blockchain technology to disrupt sectors outside banking became more widely understood, allowing organisations to reap the advantages of blockchain in supply chain management, healthcare, and other areas.
6. To facilitate communication and data sharing across various blockchain networks, interoperability solutions have been developed as the number of blockchain networks and platforms has grown.
7. With the development of blockchain technology, decentralised apps, and other cutting-edge innovations, developers have begun toying with the idea of Web3, which seeks to build a more user-centric, distributed internet.

Advantages of Using Block Chain are Listed Below

- Transparency: public Blockchain, every transactions are the transparent & visible to public. Data of movement can be completed public so all market participants can see them, or the degree of transparency can be limited as needed.
- Security: security features are embedded in the block chain using encryption algorithms based on asymmetric public-key cryptography. This ensures legitimacy of the information.
- Immutability: although distributed throughout a group of people, data stored in a Blockchain is continuous. It prevents exchanges from scattering once records have been uploaded to the blockchain, changing the record into a permanent record of every single prior exchange.
- Auditability: transaction is verified and published on the Blockchain with a timestamp, allowing clients to easily trace previous records by visiting to any hub in the network's scattered network.
- Decentralization: in Block chain distributed ledger system, there is a provision for decentralized data storage mechanism or decentralized administrator. Decentralization helps to reduce postponements and single purpose of disappointment.
- Veracity: as a comparable copy of the obvious records and duplicated records are kept inside the network of hubs, blockchain provides legitimacy to the put records.

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- Disintermediation: blockchain innovation diminish the contribution of outsiders, keeping away from the need to trust the delegates. Functional costs can be cut down while growing the capability of the sharing assistance.
- Trust: blockchain fosters more trust among its users. When adding data to the Blockchain, the maximum participants must approve for it to become a part of the final Blockchain. Intermediation can be avoided because of the trust established.
- Scalability: the ability to handle both workload and capacity in such a circumstance by increasing the number of assignments or objects. According to a vast number of analysts, one of the key challenges to Blockchain innovation is scalability.

These features of the block chain can be mapped to some of the challenges of the construction industry, such as clarity and accountability in dealings, authenticity and record-keeping of documents, etc. Smart contracts and block chain-based supply chain management help efficiently tackle the above problems. Moreover, this helps to streamline the procurement process and automate the contractual process. Block chains embedded with BIM prove to be an efficient information model that stores all necessary information in one place. The majority of processes and methods used in the construction industry still use conventional techniques. The resistance to change and the availability of skilled manpower with the latest technology pose a major threat in this area.

Scientometric Study on Blockchain Technology in Construction

This research was conducted using data gathered between 2011 and 2024, and a qualitative content analysis was undertaken to identify potential areas of blockchain usage in the construction industry. After reading the keywords and abstract, a list of categories was generated. The categories were selected after analyzing all of the texts and synthesizing the collected data. In addition, a descriptive analysis was performed, which is discussed in the next section.

Initially, the systematic mapping approach concentrated on high-quality, peer-reviewed papers found in scientific databases (Science Direct, Scopus, IEEE Explore, Mendeley, and the Web of Science). In addition, the top 250 Google Scholar results were searched for relevant 'grey literature.' The search strings used in this study were selected after numerous database searches for appropriate search phrases.

Blockchain in the construction industry, construction management, BIM Construction, Construction Supply Chain Management, Construction Smart Contract, Construction Real Estate, Precast Construction, and Construction Smart City. Scopus: Blockchain development; IEEE Xplore and Google Scholar: Blockchain development

VOSviewer is an application used for data analysis in addition to Scopus analysis. It provides a very effective approach for analyzing authors, countries, keywords, bibliographic couplings, advantages, countries, and so on. The Scopus database is analyzed in two ways: statistical database analysis and network analysis. Scopus is used for statistical analysis, while the VOS viewer 1.6.16 software is used for network analysis.

Statistical Analysis, Year of Publication, Type and Geographic Distribution

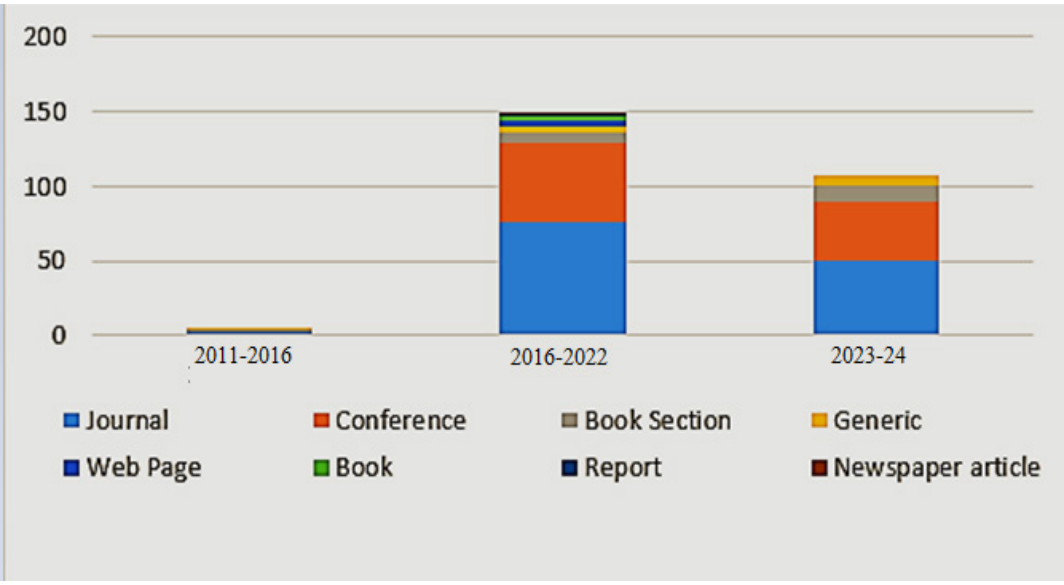

Figure 1. Increasing trend of research work in Blockchain Technology

Over the previous five years, the number of publications on blockchain applications in the construction industry has grown (figure 1). It has also been noticed that knowledge of blockchain technology has expanded dramatically during the previous five years. Between 2011 and 2016, the concept of blockchain technology remained relatively unknown. This demonstrates that blockchain is a new and growing area of study in the construction sector. A significant surge in conference papers and journal articles started in 2017 and peaked quickly in 2019. This was due to greater understanding and the introduction of blockchain applications with enhanced scalability appropriate for use in the building sector. In the last year (2023-2024), the number of publications on blockchain in the construction industry climbed by over 50 % over the previous five years. Journals, conference papers, and newsletters were among the publication types investigated during this mapping research. The mapping approach was systematic at first, with an emphasis on peer-reviewed and high-quality papers published in scientific databases (Science Direct, Scopus, IEEE Explore, Mendeley, and Web of Science).

Analysis According to Country

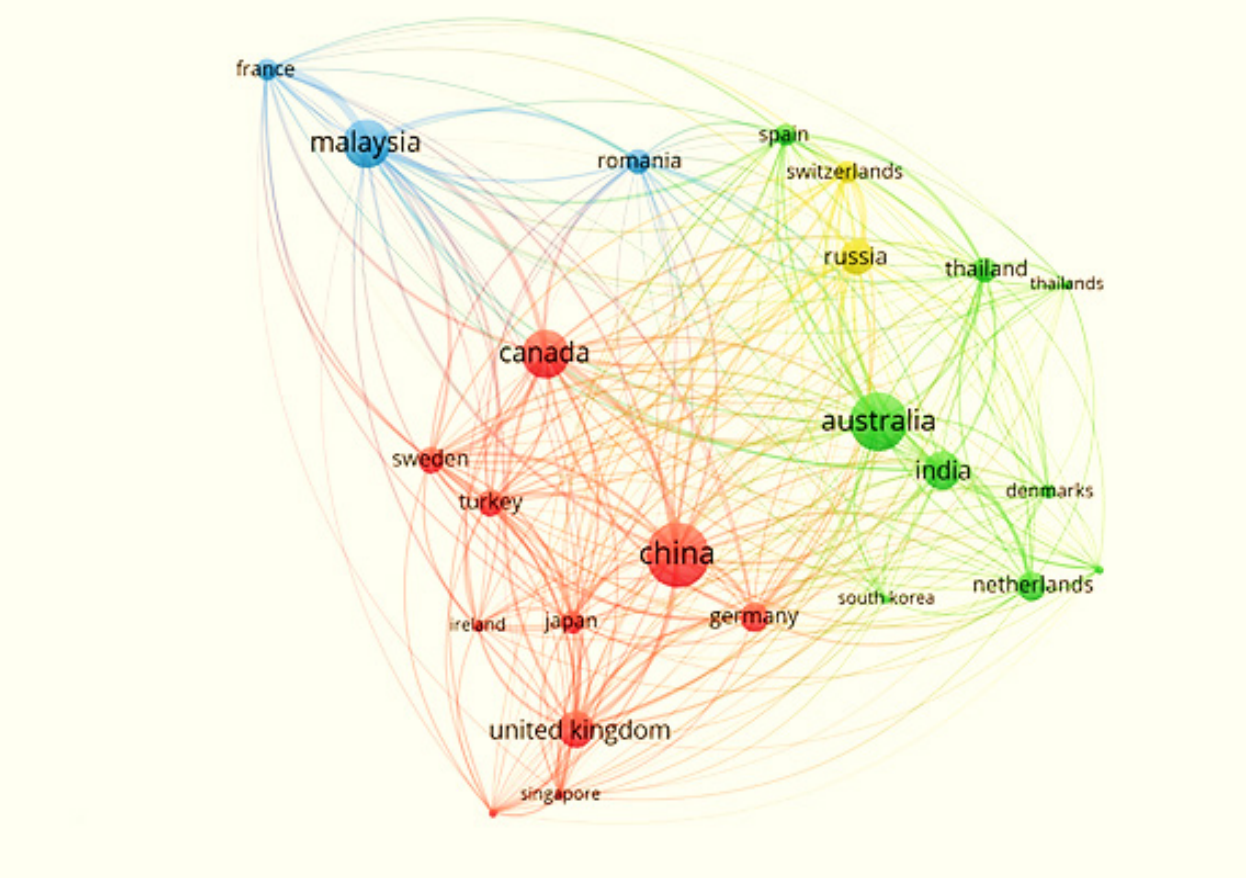

Figure 2. Authorship and Co-Authorship analysis according to country

Figure 2 depicts the geographical distribution of selected items from different countries. The geographical distribution of the papers picked demonstrates how the blockchain technology construction industry has grabbed the interest of scholars all around the globe. The network map for the co-authorship research by nations divides 21 countries into four major categories (figure 2). Cluster 1 (red) has nine countries, Cluster 2 (green) contains seven, Cluster 3 (blue) contains three, and Cluster 4 (yellow) contains two (figure 2).

The number of papers co-authored by countries determines the thickness of the link, while the size of the node is proportional to the number of publications. China has the most papers and linkages to other nations, with a focus on its close relationship with Italy.

Some of the chosen papers are conceptual, while others are empirical in nature. Surveys are the most common research method in empirical studies, followed by case studies.

Potentials of the Blockchain Application in Construction Sector

Blockchain technology has changed the way businesses, commerce, and finance operate. As blockchain technology advances, it has the potential to significantly impact the construction industry. The majority of

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articles concentrate as much on supply chain management, BIM, and smart contracts as possible. Blockchain adoption industries, since they are critical procurement variables for project success in design, material logistics, and construction projects. Figure 3 depicts the growth of blockchain technology in the construction business since 2011.

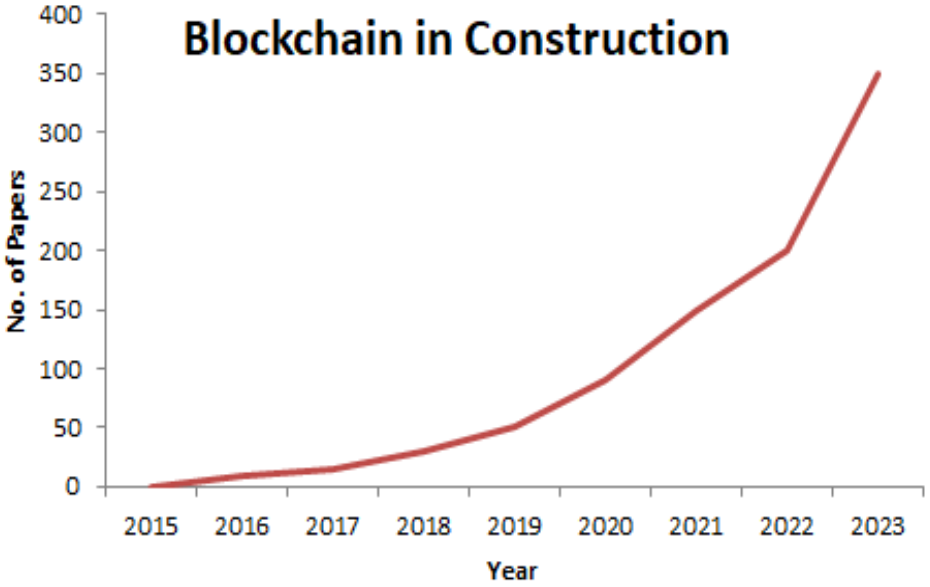

Figure 3. Blockchain in Construction Industry

Network Analysis

All 598 papers retrieved from the Scopus database and 598 documents from the Web of Science database were evaluated using the VOSviewer software.[15,7]

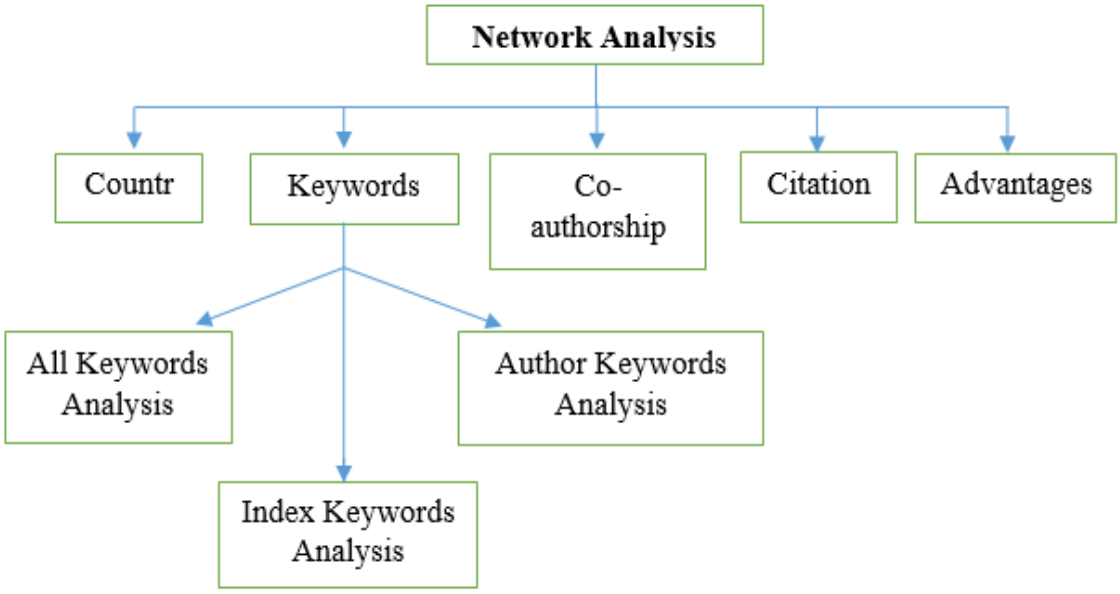

Figure 4. Network analysis using VOSviewer software

Co-Occurrence Analysis for all Keywords

A co-occurrence analysis must be undertaken to determine the essential logical issue addressed by the present study. This was accomplished through the use of co-occurrence analysis for all keywords, co-occurrence analysis for author keywords, and co-occurrence analysis for index keywords. The co-occurrence analysis was done using 2517 authors and 2285 indexed keywords to better grasp the underlying intellectual issue that the previous study addressed.

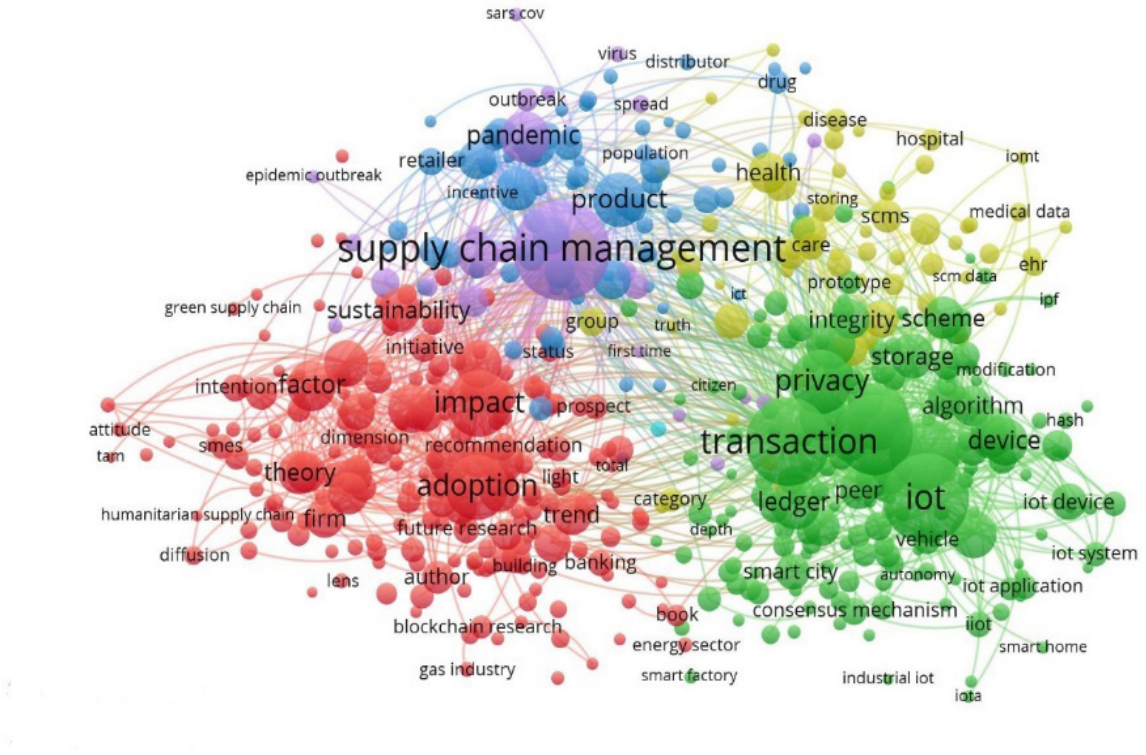

Figure 5. Network and density figures for all keywords analysis

Co-Occurrence Analysis for Author Keywords

The co-occurrence of author keyword searches is investigated using a minimum threshold of 5 per author. The criteria were fulfilled by 87 of the authors' 1219 keywords.

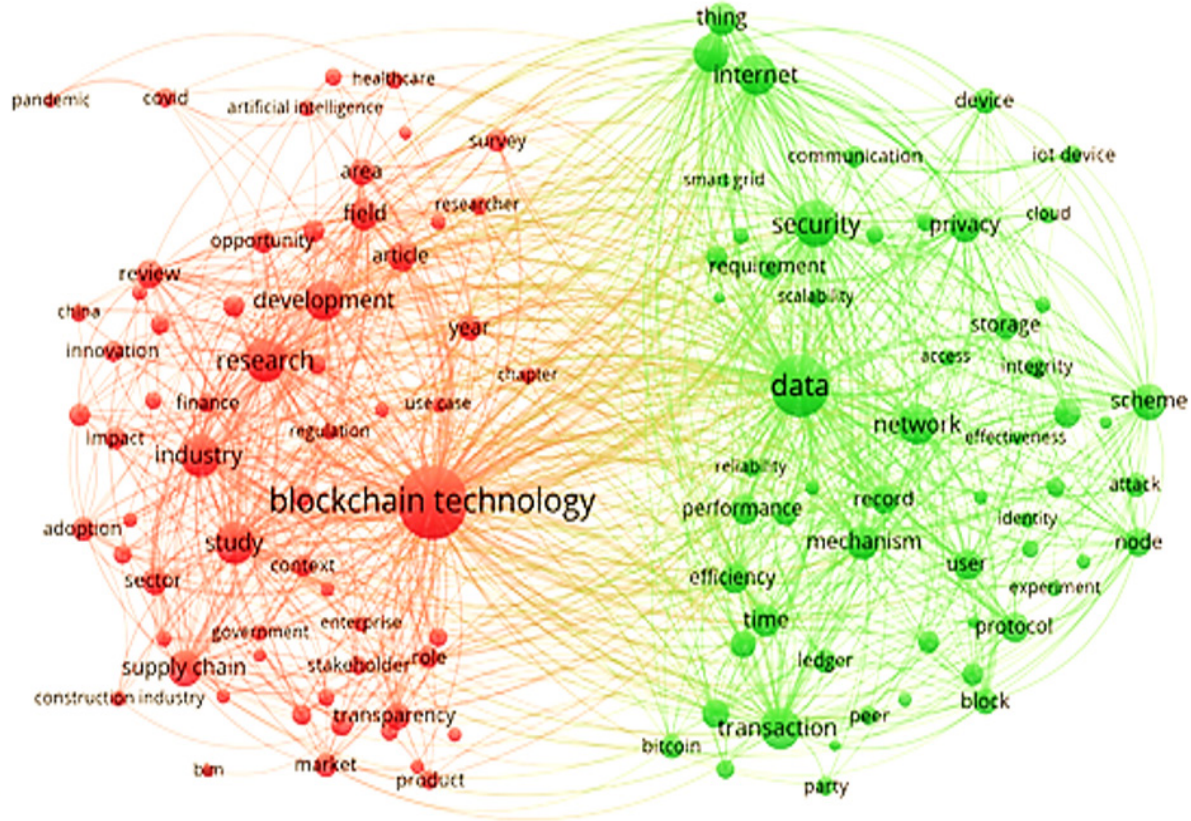

Figure 6. Network and density diagrams for author keywords

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Data, security, and cryptocurrency emerged as major keywords in the biggest combined network among the author keywords, as shown in figure 6, which may be characterized by examining the connection lines between the keywords. These lines demonstrate the relevance of the links between the nodes (keywords) and their strength. The research required terms that occurred at least four times. The size of the nodes indicates how often they occur. The curves that link the nodes in the same publication reflect their co-occurrence. The greater the distance between two nodes, the more often the two terms appear together. The size of the font represents the frequency of occurrence.

Co-Occurrence Analysis for Index Keywords

Index keywords also consider co-concurrence; only 342 of 3598 matched the condition, as shown in figure 7.

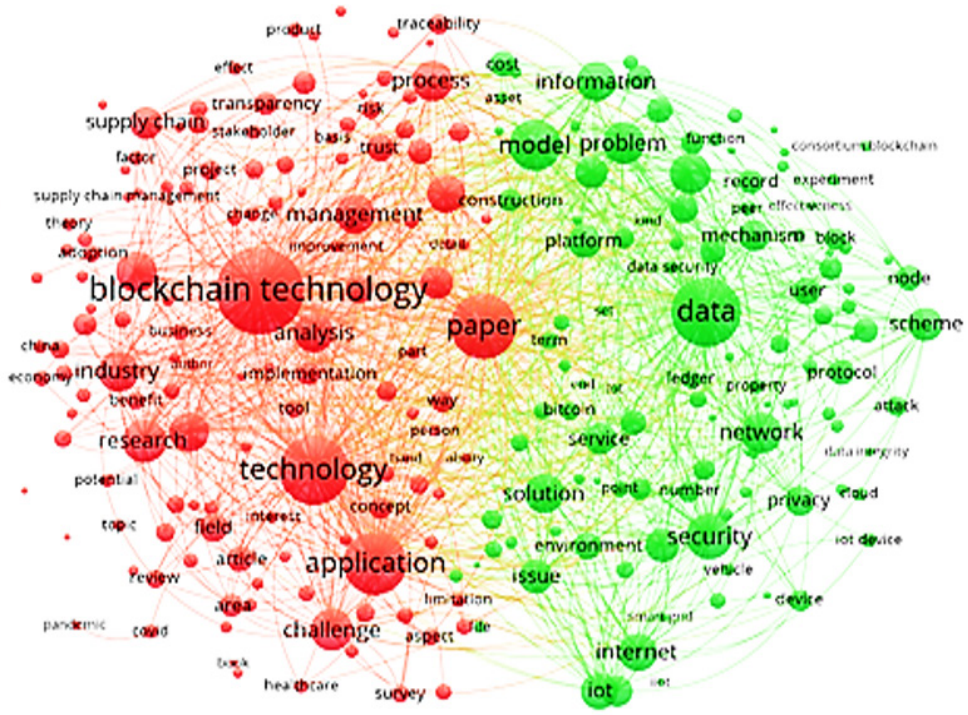

Figure 7. Network and density figures for index keywords

Similarly, the index keywords reflect an increased study concentration on data management, SCM, and energy management, as well as research procedures and associated topics like ethereum, algorithms, and consensus protocols.

Co-authorship Analysis

This analytical parameter is evaluated with three additional parameters. This parameter takes into consideration authors, organizations, and countries. This analysis eliminates documents with a large number of authors. This number is referred to as 30. The minimum number of articles necessary for an author is set at 2. It can be shown that 350 writers out of 2593 satisfied the Scopus database standards. The total co-authorship strength is calculated collaboratively with the other writers. The network connections were discovered to be somewhat different from the coupling analysis findings. Cluster 1 writers collaborate effectively (23 authors, green). Cluster 2 consists of 18 writers (blue). Cluster 3 (12 authors, yellow) and the 4th Cluster (27 writers in red). In contrast, Cluster 5 has four writers and is colored purple. This approach determines the connection's strengths. Zhang Y. has the greatest connection strength at 36. In this research, 165 writers were found to have a co-authorship connection with 11 or more than 18 link strengths.

However, the majority of these writers are located in similar geographical locations, particularly in Southeast Asian nations like China and Thailand. The research emphasizes the significance of contributing writers' physical locations, since they may choose to cooperate and network with authors living nearby. Citation analytics and co-authorship were used to better understand the structure of academic resources in this field. Co-authorship analysis identifies five important cooperative clusters and calculates the number of shared publications among authors, therefore contributing to the advancement of knowledge in this area of study. At a resolution of 1.0, the most evident and distinct co-authorship groupings appeared (figure 8).

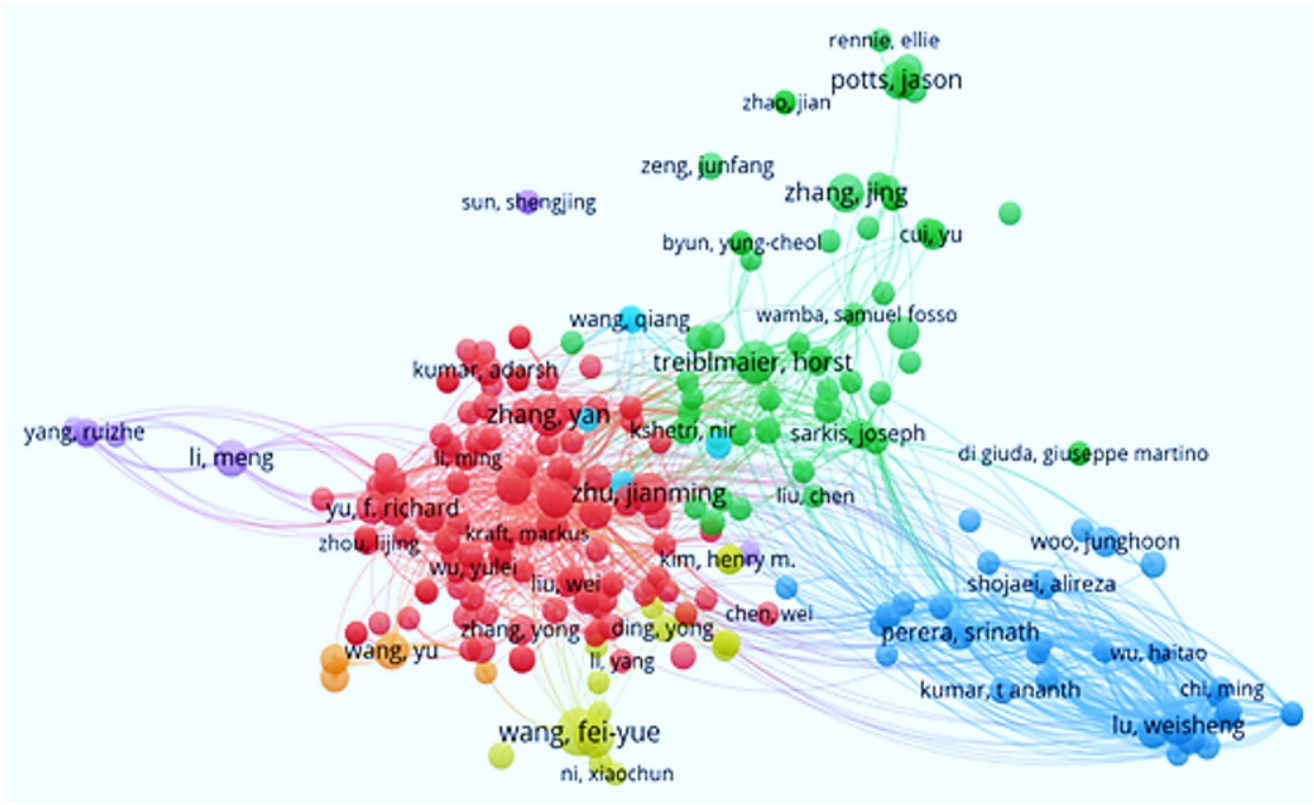

Figure 8. Co-authorship analysis for authors
Note: threshold criteria least of 5citations; resolution—1.0; 64 of 256 authors are linked

Citation analysis

The network of citations between blockchain construction supply chain management documents is depicted in figure 8. After filtering by a minimum of six citations per document, there are only 25 articles within the network. Kumar Neeraj et al. (2020) have the most citations (175) as well as three links to other journal documents.

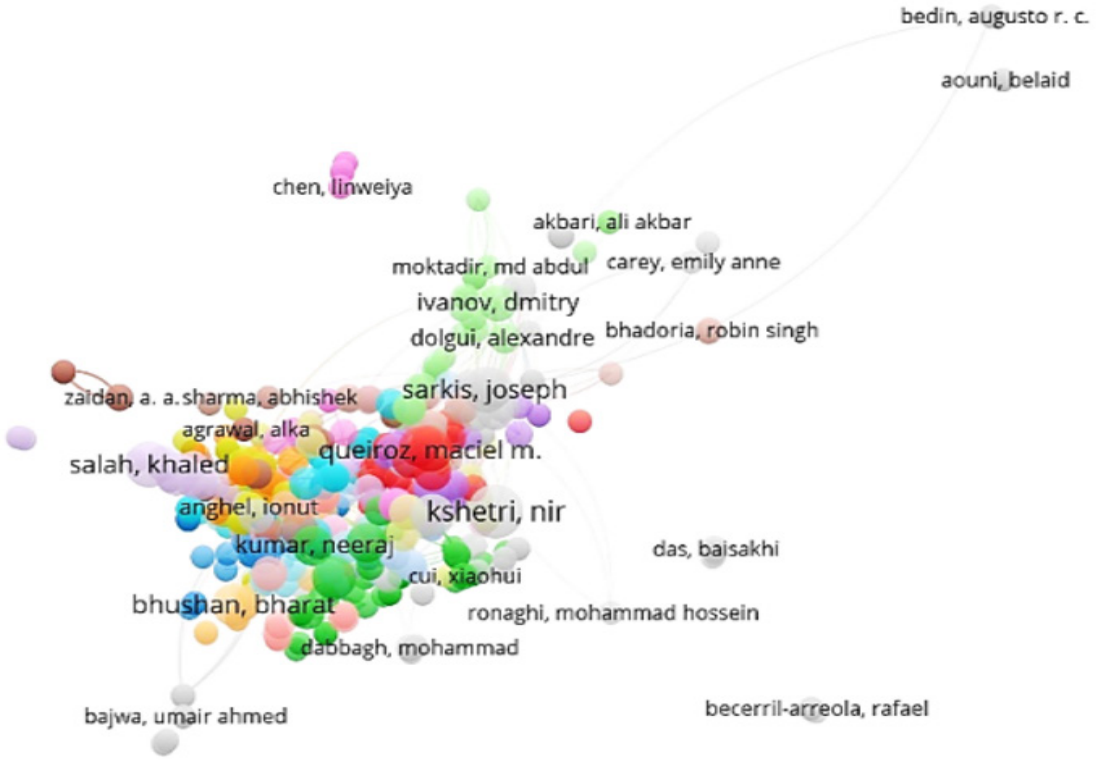

Figure 9. Analysis of document citations

Blockchain Advantages Analysis

Figure 10 demonstrates that the blockchain has various advantages. Figure 10 represents the number of researchers proposing particular advantages, such as transparency, security, decentralization, immutability, and disintermediation, which have been quoted by 1156 researchers.

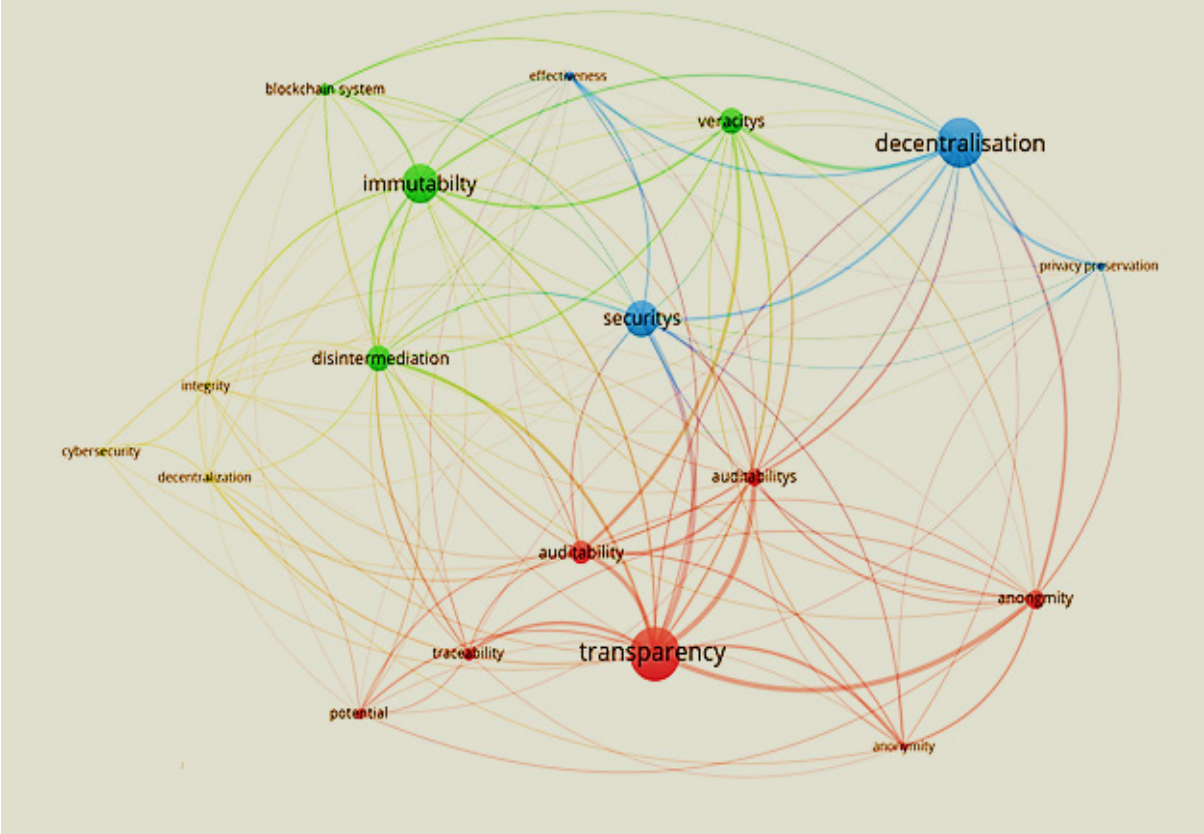

Figure 10. Network and density diagrams for Benefits of Blockchain

Blockchain Technology in Construction

The mapping study identified research topics in the construction sector that are related to blockchain, as well as current research needs for future studies. Figure 11 shows a bar graph chart connecting the frequency of paper nature with each type of possible blockchain use in the building sector.

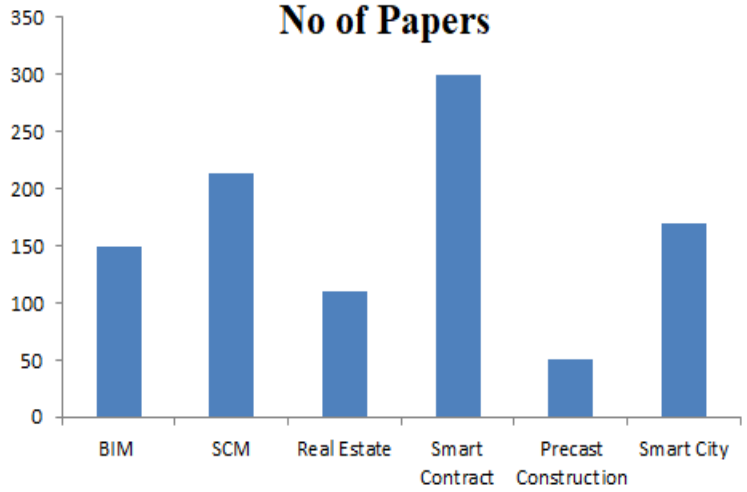

Figure 11. Research in Blockchain Technology for various sectors in Construction Industry

According to this graph, there is more development in the construction sector adopting blockchain technology in smart contract and building information modeling. Supply Chain and Smart Cities are two emerging blockchain sectors. Blockchain technology is presently being implemented in the real estate and precast building sectors.

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There are several disputes in the construction sector, including payment, transfer of technology, instrument leasing, and house sales, as well as issues such as inadequate tracking and a lack of real-time data, failure to deliver, quality faults, and higher expenses. Blockchain technology helps solve challenges in building businesses.

Blockchain in Building Information Modelling

Block chain technology can interface with BIM. Blockchain's peer-to-peer nature correlates well with a BIM model developed collaboratively by many parties to improve collaboration. In today's construction industry, BIM is extensively used to improve collaboration, data exchange, information flow, and project execution.[11,12,13,14,15] Smart Contract, Strong Trust, and Security The blockchain-based BIM project integrated management platform includes building information modeling collision checks, digital inspection, engineering start changes, vibrant construction management, payment, work flow accounting, and other specific project management and assessment mechanisms.[16,17,18] Building construction digitalization may save time, labor, and money by using smart contracts to confirm the payment stream, penetrating payment, workload accounting, clearing the approval procedure, realizing one click, and so on.[19,20,21] This platform may help to promote data exchange, increase cooperation efficiency, optimize business processes, and save operational costs. The blockchain's goal is to chronicle the previous method for updating building information modeling records. A simple BIM consists of several BIM records, which may speed up the transmission of BIM data updates. The necessary BIM information must be pushed in order to retain the history of change, which traditional BIM cannot accomplish.[22] Using a permissioned blockchain might be a far more practical choice for many BIM projects. The BCT platforms will largely serve as record-keeping devices, capturing changes to the building information model throughout the structure's design and construction phases.[23] The BIM model is a collection of smart elements[24] that represent physical components like columns and doors, as well as intelligent objects.[25] As a result, information flows amongst BIM experts[26] who include structural engineers, architects, and building service engineers. Combining BIM and blockchain technology may also make it simpler to utilize good contracts, which are computerized commercialism systems designed to enforce project agreements, rather than mutual trust on third-party 'intermediaries'.[27] The combination of blockchain and BIM has enabled batch (block) information transmission without the capacity to reverse the transaction; encryption ensures anonymity and forgery quality, resulting in the absence of a third party. It is affordable to implement the technology in the growing number of method houses. As a consequence, blockchain is ideal for model generation when information about a building's many aspects comes from several departments (architecture, utilities, building structures, elements, planning, estimates, and so on.[28]

Despite fast breakthroughs in blockchain technology and its extensive use across several fields, there remains a significant research gap regarding its deployment inside the Building Information Modeling (BIM) framework in civil engineering. While BIM has transformed the construction industry by increasing cooperation and efficiency, using blockchain technology might provide new advantages such as immutable record-keeping, improved data security, and simplified project management. However, few studies have looked at the unique obstacles, possibilities, and possible synergies of integrating blockchain and BIM in civil engineering projects. Bridging this research gap is critical for realizing blockchain technology's full potential in transforming building methods and enabling the smooth integration of digital advances into the built environment.

Supply chain management

One of the major issues with the present supply chain is a lack of dependable and accessible sources of information. Blockchain technology has the ability to address these issues by establishing a decentralized, permissioned ledger system. Blockchain-based supply chain management (SCM) enhances payment security, ensures product authenticity and compliance, accelerates payment processing, lowers financing costs, fosters confidence between suppliers and consumers, and increases audit transparency.[29] Human people, physical assets, data, processes, and financial contracts are all components of the industrial supply chain, which transports goods from producer to consumer. Getting a comprehensive picture of all transactions inside a large supply chain system is difficult.[30] This data is often stored in many places, and only certain entities within the system have access to it. Clients, whether they are end users or larger organizations farther down the supply chain, often do not have complete access to the data in these systems.[31] It is not unusual for a supplier to see data as a commodity. Low degrees of transparency need trust among system actors in order to make transactions manageable.[32] Blockchain technology, with its distributed ledger, immutable data records, and restricted user access, has the potential to address industrial supply chain transparency and traceability issues. This distributed data block may include protected, distributed data about transactions for each unique item, as well as product information.[30] Blockchain(s) will be used throughout the product's life cycle to collect, store, and manage critical product data. This creates a secure, standard trade record as well as product-specific data for each product. Blockchain streamlines carrier decision-making, distribution plan formulation, freight bill payment and auditing, information systems, freight distribution, product returns, freight consolidation, product descriptions, and route and network management.[33]

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There are numerous reasons to switch to Blockchain:

- Focus on key processes and activities.
- Improve the quality of service.
- Integrate the whole supply chain, reducing Overall conflict and reciprocity on mutually objective topics.
- Enhancing the efficiency, consistency, and flexibility.
- Improve productivity.
- Make the most of your resources. There are no underutilized or overutilized resources.
- Improve expertise, market information, and access to data.
- Achieve a competitive edge locally or worldwide.
- Lower labor and equipment expenses.

Because of its qualities of transparency, authenticity, security, trust, reduced costs, disintermediation, operational efficiencies, and lowered waste, it has the potential to alter SCM.[34,35,36,91] The SCM in the construction sector is a network of dissimilar organizational units and linkages[37] including information flow, service and product flow, and financial flow between the customer, designer, contractors, material flow, consultant, and provider. Nir Kshetri[38] the final purpose of supply chain management is to create a supply chain that is both smooth and agile in order to save money and meet the objectives of the project owner. Due to competing interests among the network's members[39] determined that reaching this goal in the current supply chain is nearly impossible. Blockchain technology might be utilized to address efficiency and proficiency difficulties in the construction sector, in addition to removing fragmentation.[40]

There is a substantial research gap in the use of blockchain technology for supply chain management in civil engineering. Despite increased interest in blockchain's potential to transform supply chain operations by increasing transparency, traceability, and trust, there is a scarcity of detailed research concentrating on its deployment in civil engineering projects. The particular intricacies of building supply chains, such as multi-tiered subcontractor networks, procurement issues, and severe regulatory constraints, provide different challenges that demand customized blockchain solutions. Addressing this research gap is critical for harnessing blockchain's transformational powers in optimizing supply chain operations, minimizing risks, and promoting improved efficiency and sustainability in civil engineering projects.

Real Estate Management

The rights and obligations resulting from asset ownership agreements (on and off-system assets) may be formalized on blockchaiThe blockchain can store and preserve the record of actual commodities as they move from one owner to the next.[31] When property is turned into "smart property" on blockchain, it becomes a valuable asset that can be transferred via smart contracts, Ramage M.[42] Blockchain, a decentralized, irreversible ledger, enables the permissioned ledger to perfectly record all current and past real estate payments.[44] This reduces the chance of fraud and paper-based errors in asset title transfers. Blockchain technology in the property ownership and transfer ledger improves service availability while lowering costs.[45] There is a substantial research gap in the integration of blockchain technology into real estate management in civil engineering. While blockchain has potential for improving transparency, efficiency, and security in property transactions and asset management, there has been a dearth of significant research into its particular use within the complex dynamics of civil engineering-driven real estate developments. Bridging this gap is critical for realizing blockchain's disruptive promise in streamlining real estate operations, maintaining data integrity, and improving sustainable civil engineering methods.

Smart contract

A contract is a legally binding agreement that defines and controls the rights and duties of the parties involved.[5] The word "contract" most often refers to "traditional contracts," which are formed with present parties and specify the tasks necessary to perform a certain activity. A smart contract is computer software made up of if/then statements that divides a project into smaller, quantifiable work units while automating compliance and payment processes.[9] Smart contracts, unlike traditional contracts, may be implemented on virtual platforms, and physical presence is not necessary when creating payment arrangements. Smart contracts are a computerized, code-based method.[9,46] Self-executing Smart contracts are collections of rules that exist over a distributed, decentralized blockchain network[47,48,49] with the conditions of the buyer-seller agreement clearly documented in lines of code. Smart contracts are computer programs that run on blockchain networks that, depending on the circumstances, may automate a number of functions. When compared to traditional software solutions, smart contracts provide more consistency, accuracy, interoperability, effectiveness, accountability, fraud resistance, integrity, and a variety of other advantages. The most significant effects of smart contracts are self-satisfaction, lack of materiality, and disintermediation. Smart contracts are very scalable and performant.

Blockchain-based solutions provide advantages over conventional systems in terms of decentralization, immutability, auditability, anonymity, security, honesty, transparency, trust, and disintermediation.[50] The major advantage of blockchain and smart contract technology is an increase in trust between parties.[51] Blockchain and smart contract technologies provide significant security advantages.[51] Blockchain and smart contracts contribute to greater transparency and trust[51,52] It is claimed that a blockchain-based supply chain will improve compliance. System standardization is a critical criterion for corporate-level applications.[53] Blockchain and smart contract technologies provide fair outcomes for all stakeholders by providing considerable financial incentives.[52] Blockchain and smart contract technologies are effective accelerators of non-physical automation efficiency.[52] Smart contracts provide outstanding transparency and the capacity to lower the overall frequency of conflict points, as well as an immutable record of project progress that may be used for dispute resolution if needed.[54] The cryptographic signature of records protects the transaction data kept on the blockchain.[55] The smart contract is a fundamental component of the blockchain idea; it is referred to as "smart" because of its capacity to autonomously self-execute complex coupled agreements that are not conceivable alone.[56,57] Smart contracts, unlike conventional contracts, are supposed to be clear and predictable software code.[58] According to the statistics, blockchain adoption might save 8,3 percent of the total cost of residential construction, with a standard deviation (SD) of 1,26 percent.[59] Among current blockchain uses, the smart contract' has been recognized as the most promising.[60]

Following are the advantages of smart contract in construction industry:

- Self-executing and self-enforcing.
- Contracts can be evaluated automatically.
- Reduce paperwork.
- Improve overall the project's flow, service delivery, and material management.
- A reduction in the number of persons engaged in contract management.
- Increase in productivity.
- Increase project governance's performance.

There is a significant research gap in the use of blockchain technology for smart contracts in civil engineering. Despite blockchain's promise to automate and secure contract execution procedures, there has been little research on its particular usage in civil engineering projects. Addressing this gap is critical for exploiting blockchain's capabilities to improve the efficiency, transparency, and dependability of smart contracts in handling complicated construction agreements, payment milestones, and project delivery timeframes in the civil engineering industry.

Precast construction

The precast construction technique involves pouring concrete into reusable molds, or "forms," which are then treated and transported in a controlled environment. Lifted to a location from a building site. Precast concrete construction Various precast elements, such as walls, are used in technology. Beams, slabs, columns, a stairwell, a landing, and other custom-made elements were standardized and developed for consistency, the building's endurance, and structural integrity.

Problems in precast supply chain:

1. Operating records can be altered without being found.
2. Participants may be dishonest.
3. Pursue personal profits and breach the contract.
4. Lack the record of operation details.
5. Information gaps resulting in inefficiencies.
6. Failure of on-time delivery.
7. Planned schedules cannot be executed exactly.

The stated current problems in the precast construction can be overcome by using the digital Blockchain:

1. Information exchange management.
2. Real-time schedule control.
3. Data traceability.
4. Keeps track of the causes of disagreements.
5. Reduces construction time.
6. Productivity increase.

There is a substantial research gap in the use of blockchain technology in precast construction within civil engineering. Despite its promise to increase supply chain transparency, quality control, and project coordination, there has been little research on blockchain's particular use in precast concrete manufacturing,

transportation, and assembly processes. Bridging this gap is critical for maximizing blockchain's potential in precast construction processes, reducing logistical problems, and improving communication among civil engineering players.

Smart City

Smart Healthcare

Healthcare services manage and generate massive amounts of sensitive data, necessitating stringent security and access controls.[61,63,63] Blockchain innovation has the potential to provide many improvements in the sphere of brilliant medical care. According to Kundu[64] a blockchain-enabled medical care framework ensures the dependability and interoperability of clinical health information, works on the nature of arbitration in protection claims, and provides excellent patient-centered services. One important issue with health records is that they are stored in compartmentalized, correct record-keeping frameworks across several medical care associations, making accessible patient information tough to reach for medical care providers when it is needed.[65] Blockchain technology makes medical care better by combining and protecting health data[64,66] allowing researchers to change health data[64,67] and making it easier for patients to access and move their health records.[61,68]

Smart Logistics and Supply Chains

Blockchain innovation can possibly work on the presentation of shrewd city-coordinated factors and store network tasks. It can work with correspondence and data dividing between the many accomplices occupied with coordinated factor processes.[69] Essentially, blockchain innovation empowers savvy city clients to screen and follow the beginnings of their items or administrations, supporting consumer loyalty and certainty.[70] The framework works on the adequacy of trace-back tasks, wipes out duplication and misrepresentation[69] and improves an assortment of planned operations and store network exercises the board exercises like item conveyance, stock administration, and request satisfaction.[70] Under smart with blockchain technology, Smart Mobility[71,72,73] Smart Energy[74,75], Smart E-Voting[66,67,68,69,70,71,72,73,74,76] Smart Home[66] and Smart Education[77,78,79,80,81] are done.

There is a significant research gap in the use of blockchain technology in the context of smart city development in civil engineering. While blockchain has the potential to improve data security, interoperability, and citizen engagement in smart city initiatives, there has been little investigation into its specific integration in infrastructure management, urban planning, and service delivery within the context of civil engineering projects. Addressing this gap is critical for realizing blockchain's transformational promise in creating resilient, sustainable, and technologically sophisticated smart cities, thereby increasing the quality of life for urban populations.

Country

To answer this requirement, Hughes D.[82] proposed that using blockchain technology, workers with adequate talents and capacities may be identified by way of a digital identity card, which can then be sent to the appropriate authorizing authority. For instance, in Malaysia, a qualified engineer working on a project would have to go through a blockchain-enabled screening process since the Department of Standards Malaysia must approve their digital ID.[83] In Malaysia, it is proposed that the government's current BIM initiative be linked with blockchain, which stores digital IDs of construction industry partners. More specifically, the authors propose that relevant authorities digitize paper-based certificates (e.g., identification cards, contractor working licenses) and ownership documents (e.g., land titles, home ownership titles).[83] BIM technology serves as the basis for digitizing investment and construction processes; nonetheless, blockchain technology has grown in popularity in the Russian Federation.[84] Building Information Modeling (BIM), Big Data, Blockchain, the Internet of Things (IoT), 3D printing, resource-saving technologies, and new building materials are just a few of the cutting-edge technologies employed in Russian construction.[84] Blockchain has the ability to create a dependable infrastructure for data management across the construction project's life cycle.[85]

Equipment leasing

Traditional leasing is inefficient and time-consuming. The rising difficulty of development projects and the increased demand for heavy equipment to aid in the delivery of their responsibilities. Leasing might be a profitable alternative for both large and small contractors looking to save costs on building projects.[9]

There is a substantial research gap in the integration of blockchain technology into equipment leasing in civil engineering. Despite its promise to improve contract administration, asset monitoring, and payment processing, there has been little research into blockchain's particular applicability in equipment leasing operations in civil engineering. Addressing this gap is critical for using blockchain's capabilities to improve transparency, efficiency, and confidence in equipment leasing agreements, resulting in optimal resource usage and project results in civil engineering projects.

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File sharing for document management

Documentation is an essential part of any project, and construction projects are huge and involve a large number of stakeholders. Various document types are produced on a regular basis for every construction sector. The biggest problem is managing this massive amount of data, which might be in the form of reports, drawings, legal papers, and so on. Organizations confront several challenges in data storage and management due to the huge quantity of storage space required.[86] Another data-related difficulty is storing documentation for finished projects. As a good practice, data from finished projects should be saved for future use, which necessitates a large amount of storage space.

A research need exists for the use of blockchain in file sharing for document management in civil engineering. While blockchain has the potential to provide advantages such as increased security, traceability, and decentralized access control, there has been little research on its particular integration into the file sharing procedures required for civil engineering projects. Addressing this gap is critical for exploiting blockchain's capabilities to increase collaboration, data quality, and version control in document management, thereby increasing project efficiency and lowering the risks associated with information sharing in civil engineering projects.

Asset Management

Most businesses are beginning to recognize the importance of good asset management in their operations.[86] Throughout the asset life cycle, all vital information and data relevant to the asset must be traced. However, because development efforts are dispersed across several locations, supply chain forms are complicated, and there are a large number of small businesses contributing to the process, effectively maintaining asset data at every stage can be an important challenge in the construction sector.[17] There will be no record destruction, and all information from various firms will be maintained in a unified blockchain network. Blockchain will enhance asset life cycle management while decreasing obstacles.

There is a research vacuum in the study of blockchain's applicability in asset management and document management in civil engineering. Despite the potential advantages of blockchain, such as increased security, transparency, and traceability, there has been little study into its particular integration into asset management procedures, including document management in civil engineering projects. Bridging this gap is vital for exploiting blockchain's capabilities to enhance the organization, monitoring, and preservation of key documents and assets, resulting in optimized project processes and regulatory compliance in the civil engineering industry.

Construction Management

The first challenge that construction businesses face is a lack of trust between suppliers and consumers, as well as how they interact with one another.[87] Because of its immutable data record, blockchain technology has the ability to alter present construction engineering management procedures and drastically minimize disputes and lawsuits. Although process automation can help you save money and time, there are various hurdles to using it in real-world building projects.[88]

There is still a research gap in the use of blockchain technology for document management in civil engineering projects. While blockchain has potential for improving openness, security, and efficiency in document handling, there has been a paucity of significant research on its particular incorporation into construction management procedures. Addressing this gap is critical for realizing blockchain's promise to simplify document sharing, version control, and project collaboration, resulting in better project results and lower risks in civil engineering construction projects.

Payment Management

Late payments and revenue worries are two of the most typical challenges in the construction industry. The construction industry has a far more linked payment and reimbursement system than other businesses.[89] In addition to the lengthy settlement process, the building industry experiences severe payment delays. In the construction industry, there are a large number of partial payments and non-payments.[41] This incurs additional expenses to fulfill payment stays, affecting the contract price to be hiked to finance the purchase. Many major construction firms are dealing with cash flow management issues. As a result, controlling cash flows is crucial in building projects and organizations.[31]

There is a need to study blockchain's applicability in payment administration and document management in civil engineering. Despite its potential to improve transparency, security, and efficiency in payment procedures, there has been little research into its particular integration into document management systems in civil engineering projects. Bridging this gap is critical for using blockchain's capabilities to enhance payment monitoring, lower transaction costs, and resolve payment disputes, eventually improving financial operations and ensuring accountability in civil engineering projects.

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Waste Management

The trash created by the development industry is seen as a serious issue that has a direct negative influence on the environment. A precise estimate of building and demolition garbage is a key component for the successful implementation of a waste management strategy. Appropriate trash management has become critical, with precise waste assessment being particularly necessary in emerging nations like China.[90] This technology might be used to develop a waste management system that sees garbage as a resource and offers solutions for construction waste management. Smart technology checking and tracing would provide a complete solution for improving accurate waste estimation and management processes in building projects.[34]

There is a substantial research vacuum in investigating blockchain's possible applications in waste management and document management within civil engineering. While blockchain provides chances to improve transparency, traceability, and efficiency in waste management operations, there has been little research into its particular incorporation into document management systems in civil engineering projects. Addressing this gap is critical for harnessing blockchain's capabilities to enhance trash creation, disposal, and recycling paperwork, resulting in better waste management practices and compliance with environmental requirements in civil engineering projects.

Analysis of Blockchain Application in Construction

According to the network diagram for the co-authorship study based on the use of blockchain technology in building, six applications can be classified into six major clusters (figures 12, 13, 14, 15, 16 and 17). These figures look to be closely linked in the network, indicating that the articles that begin in these construction blockchain applications receive a higher number of citations.

The two standard weight attributes are the links and the total link strength attributes. The attributes links strength and total link strength of a certain object represent the number of links an element has with other elements, as well as the total strength of the links an element has with other elements.

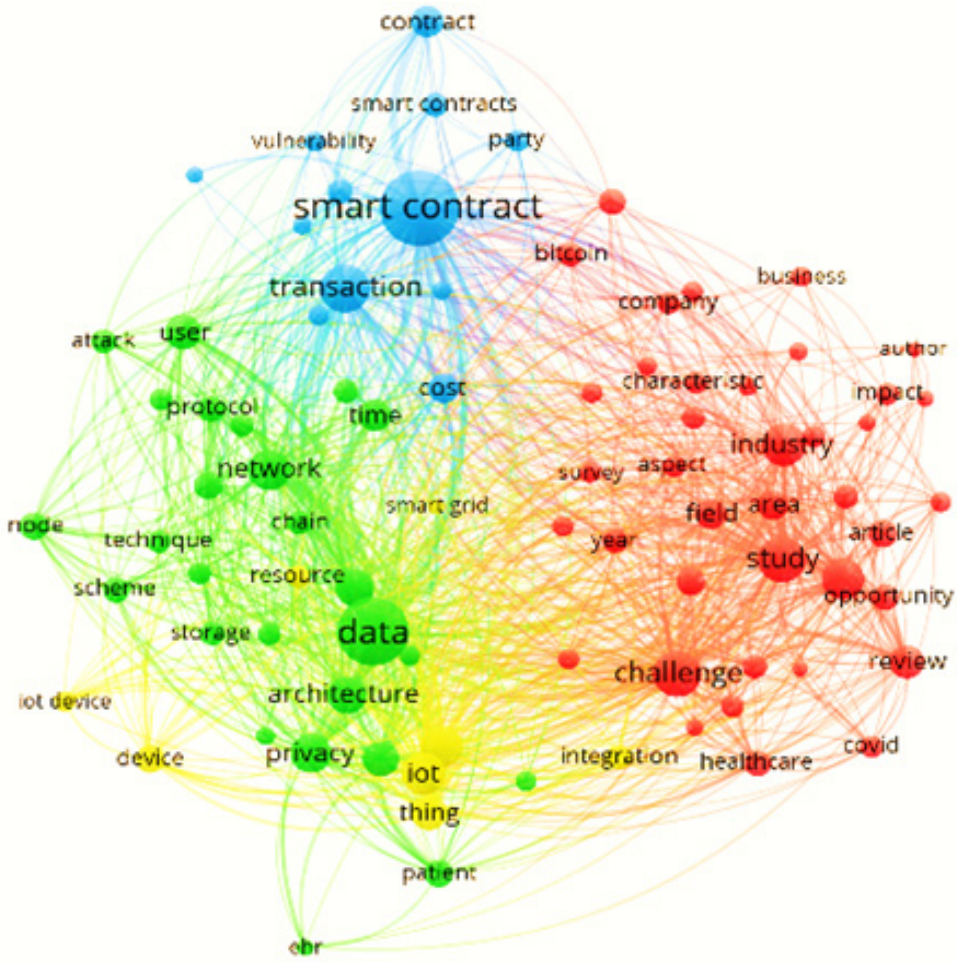

Figure 12. Network and density figures for Smart Contract

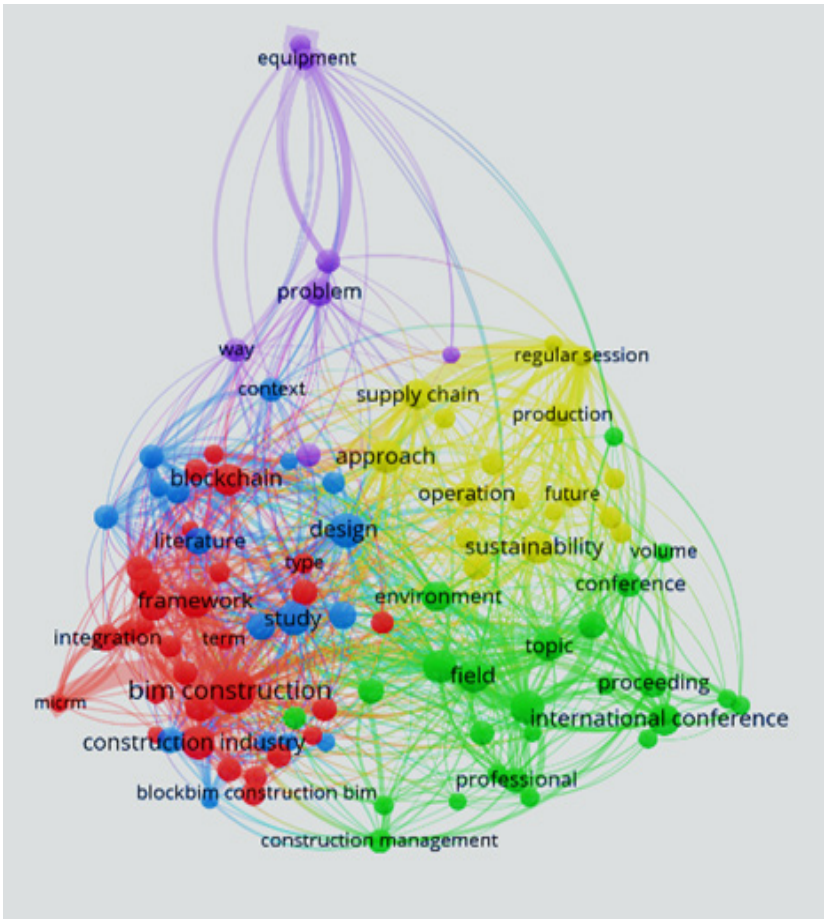

Figure 13. Network and density figures for BIM

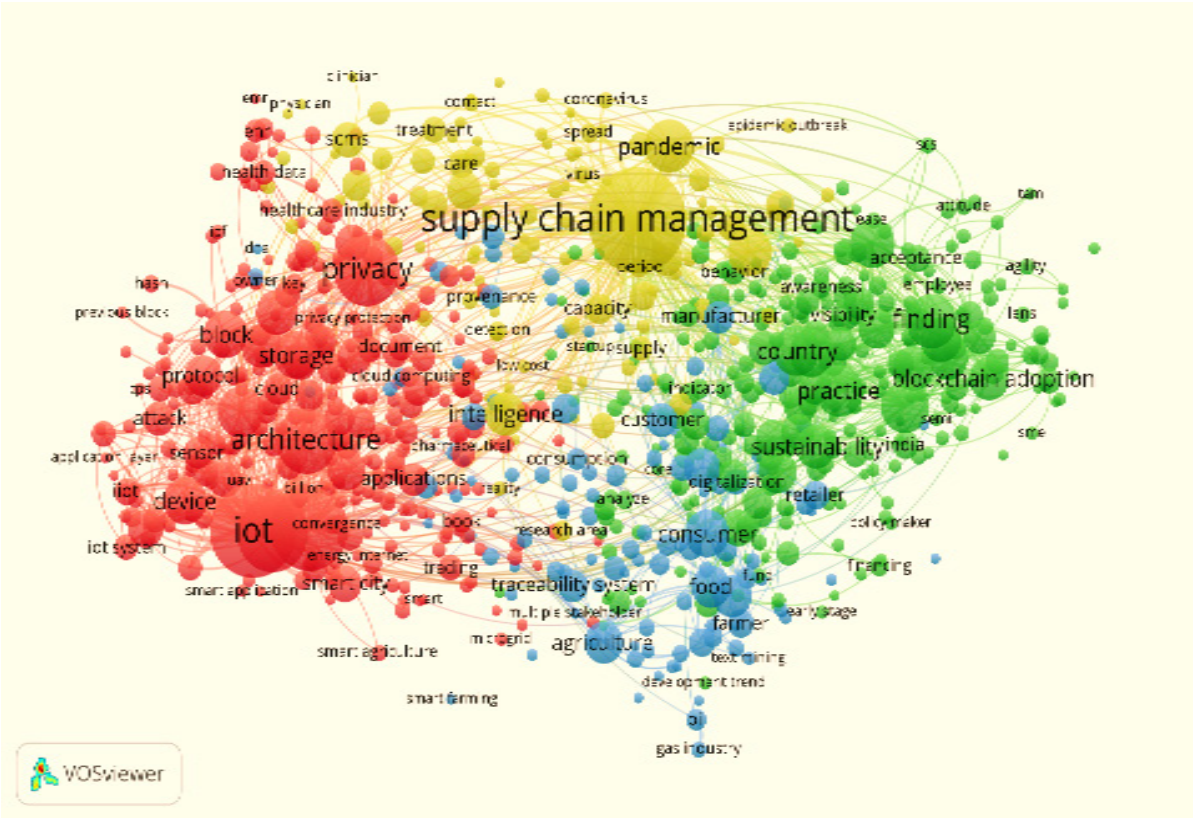

Figure 14. Network and density figures for Supply Chain Management

https://doi.org/10.56294/dm2024.369

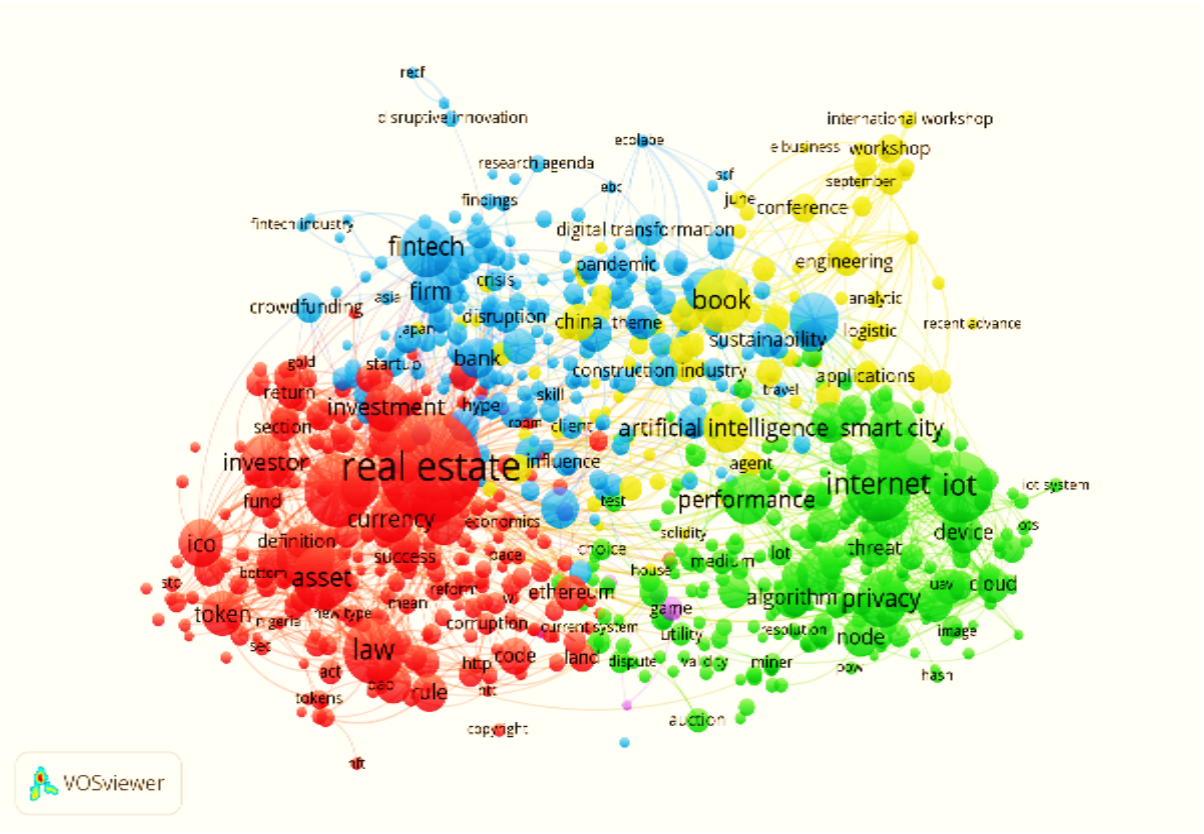

Figure 15. Network and density figures for Real Estate

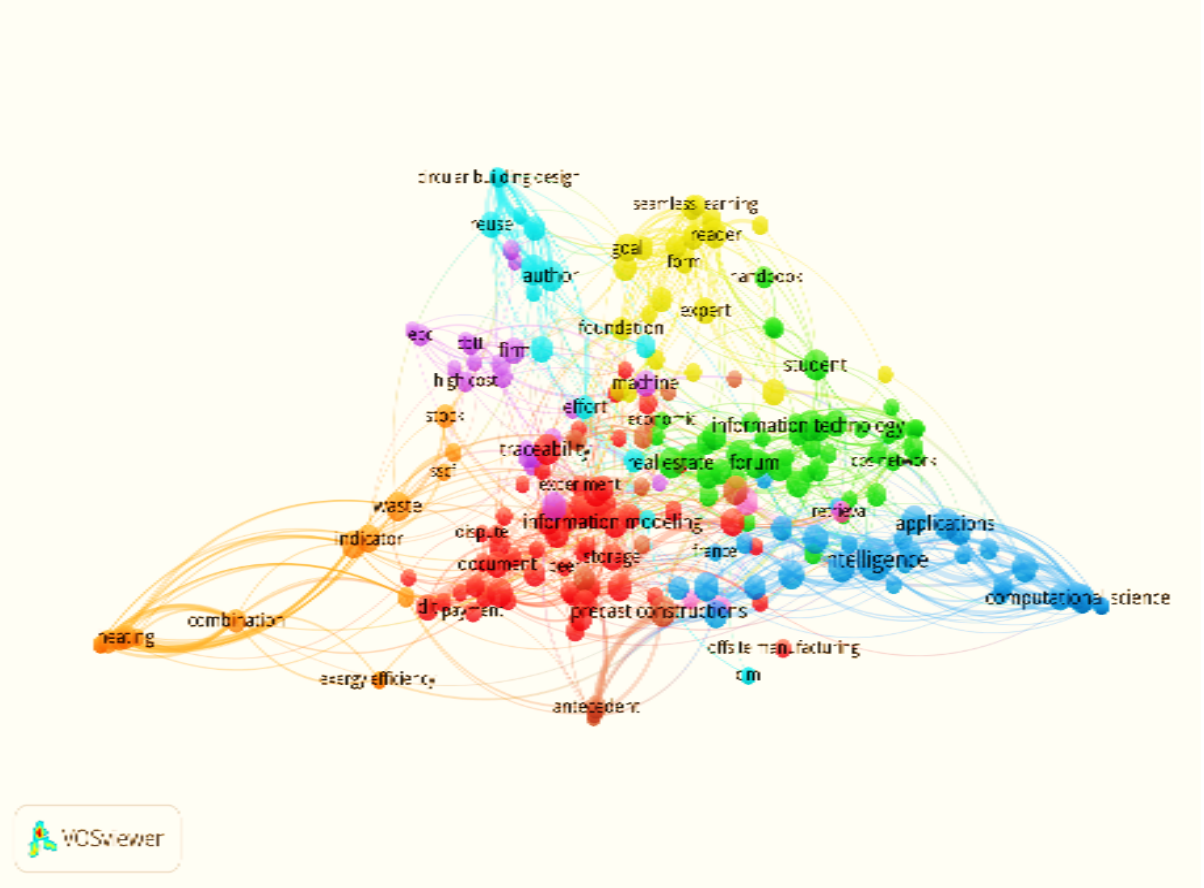

Figure 16. Network and density figures for Precast Construction

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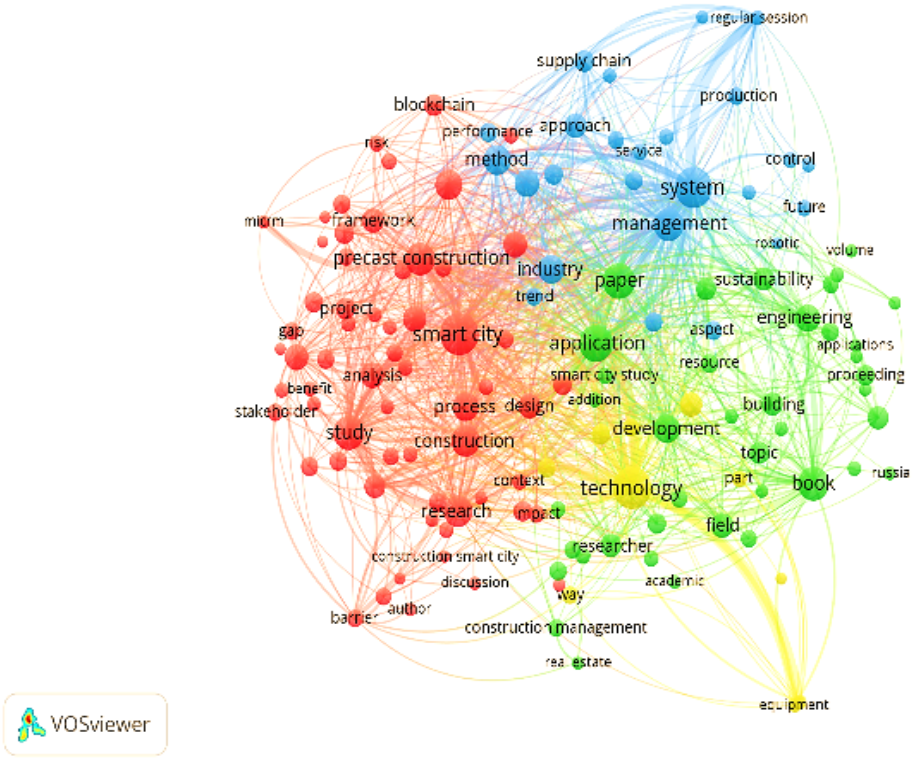

Figure 17. Network and density figures for Smart City

Table 1. TLS and links for the Applications of Blockchain Technology in Construction

Applications of Blockchain in Construction	Links	Total Link Strength (TLS)
Smart Contract	84	25944
BIM	465	7740
Supply Chain Management	706	14155
Real Estate	703	16667
Precast Construction	51	231
Smart City	136	4678

In the field of civil engineering, there is still a significant research gap in understanding the entire range of applications for blockchain technology. While blockchain has enormous potential to transform various aspects of civil engineering projects, such as construction management, asset tracking, supply chain optimization, and document management, there has been a lack of comprehensive research into its specific integration in this domain. Bridging this gap is critical for harnessing blockchain's disruptive potential, which may improve transparency, efficiency, and confidence in civil engineering operations. Furthermore, understanding the difficulties, possibilities, and best practices for adopting blockchain in civil engineering is critical for guaranteeing its effective adoption and maximizing its advantages in terms of infrastructure development, sustainability, and project delivery.

DISCUSSION AND CONCLUSIONS

The goal of this research is to undertake a thorough review of the current literature on blockchain in the construction sector as well as assess the potential areas for its implementation in the industry. A systematic analysis of all 889 articles was performed in order to identify potential areas where blockchain may be effectively utilized to address present difficulties in the construction industry and establish future research paths. The bulk of the publications reviewed focused on how blockchain technology may be used in project management and the construction sector, namely in building information modeling and supply chain management.

The mapping of the construction industry's difficulties to the properties of blockchain technology underlines the urgency of its deployment in the construction sector. Blockchain technology is more suited to the construction business due to the following characteristics:

- The utilization of blockchain technology in the management of construction projects has the potential to enhance transparency and security while also reducing or eliminating the need for centralized data audits.
- This research determined that the benefits of blockchain technology include decentralization, security, immutability, transparency, disintermediation, and trust, among other things, and that it is effective in dealing with many challenges in the construction sector.
- This study examines 889 valid blockchain articles from the core collection of WoS from 2011 to 2024 to provide a visual and methodical evaluation of current blockchain themes. The following are a few key findings from the analysis.
- The number of publications on blockchain technology has skyrocketed since 2016.
- In the analysis of cooperation between countries and institutions, China topped all others, while the United States, England, South Korea, and India contributed significantly and creatively.
- Keywords, theoretical knowledge, and hot research topics on blockchain include the following: a) Bitcoin; b) a smart contract; c) transparency; d) safety; and e) trust.
- This study made use of VOS viewer to stay up-to-date on the blockchain industry and acquire a deeper comprehension of blockchain research topics.
- The study carried out in the context of the various domains of the construction sector has revealed that in a few areas, the application of blockchain has major potential and has already started; however, there is still huge scope for the same. The following conclusions are derived from this part of the study.
- Smart City, supply chain management, smart contracts, building information modeling (BIM), real estate management, precast construction, equipment leasing, file sharing for document management, asset management, construction management, payment management, and waste management are examples of blockchain applications in the construction industry.
- The study identifies BIM, construction management, supply chain management, smart contracts, real estate management, and smart cities as six potential areas for blockchain research in the construction industry. The work on the practical application of blockchain technology in all six of the aforementioned areas is still in its infancy, but there is a lot of room for improvement when considering a holistic approach to blockchain application.

The bulk of the papers studied remain conceptual. As a result, future studies may focus on performing case studies of real blockchain applications in building projects and assessing how compatible they are with current construction systems. Despite the fact that there is still a big gap between the digitization of the construction industry and the potential of blockchain, econometric research may help transform the sector's existing level of awareness, adoption, and acceptance. This illustrates that the construction sector is still in the early stages of adopting blockchain technology. The potential of future case studies, stimulation research, and prototype design studies on the use of this technology is vast.

BIBLIOGRAPHIC REFERENCES

1. Statista Research Department, May 31, 2022, https://www.statista.com/statistics/566787/average-yearly-expenditure-on-economic-infrastructure-as-percent-of-gdp-worldwide-by-country.

2. Ukessays, "Problems and Challenges Facing the Construction Industry", 2018. https://www.ukessays.com/essays/construction/problems-and-challenges-facing-the-construction-industry-construction-essay.php?Vref=1.

3. Kyeon'gbaek Kim, Gayeoun Lee, and Sangbum Kim, "A Study on the Application of Blockchain Technology in the Construction Industry. KSCE Journal of Civil Engineering, 24(9):2561-2571, 2020. DOI 10.1007/s12205-020-0188-x pissn 1226-7988, eissn 1976-3808 www.springer.com/12205.

4. Thomas Bocek, Bruno B. Rodrigues, Tim Strasser, Burkhard Stiller, "Blockchains Everywhere - A Use-Case of Blockchains in the Pharma Supply-Chain", 2017.

5. S. Ahmadisheykhsarmast, R. Sonmez, "Smart Contracts In Construction Industry", 2018.

6. S. Ammous, "Blockchain Technology: What Is It Good For?" Center on Capitalism and Society at Columbia University Working Paper, 2016 Retrieved from https://goo.gl/v4edw7 on 8 March 2017.

7. Elyes Ben Hamid, Kei Leo Brousmiche, Hugo Levard and Eric Thea, "Blockchain for Enterprise: Overview, Opportunities and Challenges", 2017.

8. Zakaria Sdakhli, Zoubeir Lafhaj and Alan Mossman, “The Potential of Blockchain in Building Construction”, 2019.

9. Alireza Shojaei, “Exploring Applications of Blockchain Technology In The Construction Industry”, 2019.

10. S. Ahmadisheykhsarmast, R. Sonmez, “Smart Contracts In Construction Industry”, 2018.

11. Chong H Y, Lopez R, Wang J, Wang X, Zhao Z, “Comparative analysis on the adoption and use of BIM in road infrastructure projects”, Journal of Management Engineering, 32(6): 05016021, 2016.

12. Shou W, Wang J, Wang X, Chong H Y, “A comparative review of building information modelling implementation in building and infrastructure industries”, Archives of Computational Methods in Engineering, 2015, 22(2): 291–308

13. Wang J, Zhang X, Shou W, Wang X, Xu B, Kim M J, Wu P, “A BIM-based approach for automated tower crane layout planning. Automation in Construction”, 59: 168–178, 2015.

14. Wang J, Sun W, Shou W, Wang X, Wu C, Chong H Y, Liu Y, Sun C, “Integrating BIM and lidar for real-time construction quality control”, Journal of Intelligent & Robotic Systems, 79(3–4): 417–432, 2015.

15. Wang J, Wang X, Shou W, Chong H Y, Guo J, “Building information modeling-based integration of MEP layout designs and constructability”, Automation in Construction, 61: 134–146, 2016.

16. L. W. Thomas, “Legal issues surrounding the use of digital intellectual property on design and construction projects”, NCHRP Legal Research Digest Issue Number: 58, Transportation Research Board, 2013.

17. C. Eastman, C. M. Eastman, P. Teicholz, R. Sacks, K. Liston, “BIM handbook: A guide to building information modeling for owners, managers, designers, engineers and contractors”, John Wiley & Sons, 2011.

18. L. L. Foster, “Legal issues and risks associated with Building Information Modeling Technology”, Proquest, 2008.

19. B. Cubitt, R. Coldwell, “A brief legal guidance: where BIM is implemented on a project”, Lexology 2014. Lexology.com. Retrieved from https://goo.gl/UT8SW1 on 8 March 2017.

20. M. Lohry, “Blockchain Enabled Co-Housing, 2017, Retrieved from https://goo.gl/lvziwi on 8 March 2017.

21. Samudaya nanayakkara, srinath perera, h.m.n. Dilum bandara , g. Thilini weerasuriya, and jason ayoub, “blockchain technology and its potential for the construction industry”, 2019, conference paper · November, doi: 10.6084/m9.figshare.10315331.v3.

22. Rongyue Zheng, Jianlin Jiang, Xiaohan Hao, Wei Ren, Feng Xiong, and Yi Ren, “bcbim: A Blockchain-Based Big Data Model for BIM Modification Audit and Provenance in Mobile Cloud”, Volume 2019, Article ID 5349538, 13 pages https://doi.org/10.1155/2019/5349538.

23. Nawari O. Nawari and Shriraam Ravindran, “Blockchain and Building Information Modeling (BIM): Review and Applications in Post-Disaster Recovery”, 19 June 2019, doi:10.3390/buildings9060149

24. Ibrahim, M.; Krawczyk, R., “The level of knowledge of CAD objects within the building information model”, In Proceedings of the ACADIA, 2003, Conference, Muncie, Indiana, USA, 24–27 October 2003, 172–177.

25. Halfawy, M.R.; Froese, T., “Modeling and implementation of smart AEC objects: An IFC perspective”. In Proceedings of the CIB w78 conference - Distributing Knowledge in Building, Aarhus School of Architecture, Denmark, 2002.

26. Succar, B., “Building information modelling framework: A research and delivery foundation for industry stakeholders”, Autom. Constr, 18, 357–375, 2009.

27. Zhen Liu, Lijun Jiang, Mohamed Osmani and Peter Demian, “Building Information Management (BIM)

and Blockchain (BC) for Sustainable Building Design Information Management" Framework, 2019, 8, 724; doi:10.3390/electronics8070724.

28. Bukunova O.V., Bukunov A.S., "Tools of Data Transmission at Building Information Modeling". International Science and Technology Conference, 2019.

29. Zakaria Dakhli, Zoubeir Lafhaj and Alan Mossman, "The Potential of Blockchain in Building Construction, Buildings", 9, 77, 2019, doi:10.3390/buildings9040077

30. Haq, I., Monfared, etal, A., "A new vision for the automation systems engineering for automotive powertrain assembly", International Journal of Computer Integrated Manufacturing (IJCIM), vol. 23, 2010, pp. 308-324, 2010.

31. Monfared, R.P., "Enterprise Modelling: A componentbased Approach to Design and Construction of Change Capable Manufacturing Cell Control Systems", 1st ed. Vol. 1. Saarbrücken-Germany: VDM Verlag. ISBN 3639177568, 2009.

32. Saveen a. Abeyratne, radmehr p. Monfared, "blockchain ready manufacturing supply chain using distributed ledger", volume: 05 issue: 09, sep-2016, available @ http://ijret.esatjournals.org.

33. Bushra Mukri, "Blockchain Technology in Supply Chain Management: A Review", Volume: 05 Issue: 06 | June-2018 www.irjet.net.

34. Pankaj Duttaa, Tsan-Ming Choib, Surabhi Somanic, Richa Butalac, "Blockchain technology in supply chain operations: Applications, challenges and research opportunities", https://doi.org/10.1016/j.tre.2020.102067 ,2020.

35. Philipp, R., Prause, G., Gerlitz, L., "Blockchain and smart contracts for entrepreneurial collaboration in maritime supply chains", Transport Telecommun. J. 20 (4), 365–378, 2019.

36. Gurtu, A., Johny, J., "Potential of Blockchain technology in supply chain management: a literature review", Int. J. Phys. Distrib. Logist. Manage. 49 (9), 881–900, 2019.

37. Xue X, Wang Y, Shen Q, Yu X, "Coordination mechanisms for construction supply chain management in the Internet environment", International Journal of Project Management, 25(2): 150–157, 2007.

38. Nir Kshetri, "Will blockchain emerge as a tool to break the poverty chain in the Global South?", Third World Quarterly, 38:8, 1710-1732, 2017, DOI: 10.1080/01436597.2017.1298438

39. Wang J, Wu P, Wang X, Shou W, "The outlook of Blockchain technology for construction engineering management", Frontiers of Engineering Management, 4(1): 67–75, 2017.

40. Gjorgji shemov, borja garcia de soto, hoda alkhzaimi, "blockchain applied to the construction supply chain: a case study with threat model, front" Eng. Manag, 2020, Https://doi.org/10.1007/s42524-020-0129-x.

41. Aste T, Tasca P, Di Matteo T., "Blockchain technologies: the foreseeable impact on society and industry" Computer (Long. Beach. Calif). 50(9):18–28, 2017.

42. Ramage M., "BIM and Blockchain In Construction: What You Need To Know, Trimble Inc., 2018. [Online]. Available: https://constructible.trimble.com/construction-industry/from-bim-to-Blockchain-in-construction-what-you-need-to-know. [Accessed: 30-Jul-2018].

43. Swam M., "Blockchain Blueprint for a New Economy" 1st ed. United States of America: O'Reilly Media , 2015.

44. Schneider J, Blostein A, Lee B, Kent S, Groer I, Beardsley E., "Blockchain:Putting Theory into Practice", United States, America, 2016.

45. De Leon DC, Stalick AQ, Jillepalli AA, Haney MA, Sheldon FT. (2017) Blockchain: properties and misconceptions. Asia Pcfc Jrnl Innvtn & Entrprnshp. 11(3):286–300.

46. Mathews, M., Robles, D. & Bowe, B., "BIM+Blockchain: A Solution to the Trust Problem in Collaboration?", 2017,

47. HANS RUDOLF, T., "Smart Contracts", Zurich: Walder Wyss Ltd, 2017.

48. LUU, L., CHU, D.-H., OLICKEL, H., SAXENA, P. & HOBOR, A., "Making Smart Contracts Smarter. ACM SIGSAC Conference on Computer and Communications Security - CCS'16", 2016.

49. SILVERBERG, K., FRENCH, C., FERENZY, D. & BERG, S. V. D., "Getting Smart: Contracts on the Blockchain", Washington: The Institute of International Finance, 2016.

50. RODRIGO, M. N. N., PERERA, S., SENARATNE, S. & JIN, X., "Blockchain for Construction Supply Chains: A literature Synthesis", Proceedings of ICEC-PAQS Conference 2018. Sydney, Australia, 2018.

51. ABEYRATNE, S. A. & MONFARED, R. P., "Blockchain ready manufacturing supply chain using distributed ledger", 2016.

52. KINNAIRD, C., GEIPEL, M. & BEW, M., "Blockchain Technology. London: Arup, 2017.

53. Samudaya Nanayakkara, Prasad Perera, Shantha Fernando, "Universal Communication Interface Through Web Servicesfor Heterogeneous Systems", With DynamicSystem Life Cycle, IJCST VOL. 5, SPL - 1,ISSN : 0976-8491 (Online), International Journal Of Computer Science, 2014.

54. Alireza shojaei, "Exploring applications of blockchain technology in the construction", 2019.

55. Pilkington, M., "Blockchain technology: Principles and applications", In F. X. Olleros & M. Zhegu (Eds.). Research handbook on digital transformations, 2016, (pp. 1–39). Edward Elgar Publishing.

56. Mohita Gangwar Sharma and Sunil Kumar, "The Implication of Blockchain as a Disruptive Technology for Construction Industry", journals.sagepub.com/home/ksm, 2020, DOI: 10.1177/2277975220932343

57. Morrison, A., "How smart contracts automate digital business", 2016. Http://usblogs.pwc.com/emerging-technology/howsmart-contractsautomate-digital-business/.

58. Jun WANG, Peng WU, Xiangyu WANG, Wenchi SHOU, "The outlook of Blockchain technology for construction engineering management, Front. Eng. Manag, 4(1): 67–75, 2017. DOI 10.15302/J-FEM-2017006

59. Zakaria Dakhli, Zoubeir Lafhaj and Alan Mossman, "The Potential of Blockchain in Building Construction, Buildings", 9, 77, 2019, doi:10.3390/buildings9040077.

60. Kyeongbaek Kim, Gayeoun Lee, and Sangbum Kim, "A Study on the Application of Blockchain Technology in the Construction Industry, KSCE Journal of Civil Engineering, 24(9):2561-2571, 2020, DOI 10.1007/s12205-020-0188-x pissn 1226-7988, eissn 1976-3808 www.springer.com/12205.

61. Horst Treiblmaier, Abderahman Rejeb and Andreas Strebinger, "Blockchain as a Driver for Smart City Development: Application Fields and a Comprehensive Research Agenda, Smart Cities", 2020, 3, 853–872; doi:10.3390/smartcities3030044.

62. Hu, Y.; Bai, G., "A systematic literature review of cloud computing in ehealth". Health Inform. Int. J., 3, 11–20, 2014.

63. Muhammed, T.; Mehmood, R.; Albeshri, A.; Katib, I. Ubehealth, "A personalized ubiquitous cloud and edge-enabled networked healthcare system for smart cities", 2018, IEEE Access, 6, 32258–32285. [crossref]

64. Kundu, D., "Blockchain and trust in a smart city". Environ. Urban. ASIA, 10, 31–43, 2019, [crossref]

65. Stafford, T.F.; Treiblmaier, H., "Characteristics of a Blockchain ecosystem for secure and sharable electronic medical records", 2020, IEEE Trans. Eng. Manag., 1–23. [crossref]

66. Li, J.; Greenwood, D.; Kassem, M., "Blockchain in the built environment and construction industry: A systematic review", conceptual models and practical use cases., 2019, Autom. Constr, 102, 288–307. [crossref]

67. Boulos, M.N.K.; Wilson, J.T.; Clauson, K.A., "Geospatial Blockchain: Promises, challenges, and scenarios in health and healthcare. Int. J. Health Geogr., 17, 25, 2018. [crossref]

68. Ismail, L.; Materwala, H., "A review of Blockchain architecture and consensus protocols: Use cases, challenges, and solutions", 2019, Symmetry, 11, 1198. [crossref]

69. Liao, D.-Y.; Wang, X., "Applications of Blockchain technology to logistics management in integrated casinos and entertainment", 2018, Informatics, 5, 44. [crossref]

70. Ferdous, M.S.; Biswas, K.; Chowdhury, M.J.M.; Chowdhury, N.; Muthukkumarasamy, "Integrated platforms for Blockchain enablement. In Advances in Computers; Kim, S., Deka, G.C., Zhang, P., Eds.; Role of Blockchain Technology in iot Applications; Academic Press: Cambridge, MA, USA; Volume 115, pp. 41–72, 2019.

71. Benevolo, C.; Dameri, R.P.; D'Auria, B., "Smart mobility in smart city. In Empowering Organizations", Torre, T., Braccini, A.M., Spinelli, R., Eds.; Springer International Publishing: Cham, Switzerland, 2016, pp. 13–28.

72. Chun, B.-T.; Lee, S.-H., "Review on ITS in Smart City", Adv. Sci. Technol. Lett, 98, 20155, 52–54.

73. Jindal, A.; Aujla, G.S.; Kumar, N., "SURVIVOR: A Blockchain based edge-as-a-service framework for secure energy trading in SDN-enabled vehicle-to-grid environment", Comput. Netw, 153, 36–48, 2019. [crossref]

74. Aggarwal, S.; Chaudhary, R.; Aujla, G.S.; Kumar, N.; Choo, K.-K.R.; Zomaya, A.Y., "Blockchain for smart communities: Applications, challenges and opportunities". J. Netw. Comput. Appl., 144, 13–48, 2019. [crossref]

75. Jindal, A.; Aujla, G.S.; Kumar, N., "SURVIVOR: A Blockchain based edge-as-a-service framework for secure energy trading in SDN-enabled vehicle-to-grid environment". Comput. Netw., 153, 36–48, 2019. [crossref]

76. Mostafa, M.M.; El-Masry, A.A., "Citizens as consumers: Profiling e-government services' users in Egypt via data mining techniques". Int. J. Inf. Manag., 33, 627–641, 2013. [crossref]

77. Li, H.; Han, D., "Edurss: A Blockchain-based educational records secure storage and sharing scheme", 2019. IEEE Access, 7, 179273–179289. [crossref].

78. Druckman, J.N.; Green, D.P.; Kuklinski, J.H.; Lupia, A. Cambridge Handbook of Experimental Political Science; Cambridge University Press: Cambridge, UK, 2011; ISBN 978-0-521-19212-5.

79. Vu, P.; Adkins, M.; Henderson, S., "Aware, but don't really care: Students' perspective on privacy and data collection in online courses", Journal of Open, Flexible and Distance Learning, 23(2), 2020, https://files.eric.ed.gov/fulltext/EJ1247149.pdf.

80. Fadeyi, O.; Krejcar, O.; Maresova, P.; Kuca, K.; Brida, P.; Selamat A., "Opinions on sustainability of smart cities in the context of energy challenges", posed by cryptocurrency mining. Sustainability, 12, 169, 2020. [crossref].

81. Sheraz Ahmed, Muhammad Arif Shah, and Karzan Wakil, "Blockchain as a Trust Builder in the Smart City Domain: A Systematic Literature Review", 2020. DOI 10.1109/ACCESS.2020.2993724, IEEE Access.

82. Hughes D., "The Impact of Blockchain Technology on the Construction Industry", 2017. Retrieved from: https://www.linkedin.com/pulse/impactblockchain-technology-constructionindustry-david-hughes

83. Adriana Erica Amaludin and Mohammad Radzif Bin Taharin, "Prospect of Blockchain Technology for Construction Project Management in Malaysia", ASM Sc. J., 11, Special Issue 3, 2018 for SANREM, 199-205, 2018.

84. Elena Aleksandrova, Victoria Vinogradova, Galina Tokunova, "Integration of digital technologies in the field of construction in the Russian Federation", Volume 11, Issue 3, 2019, pages: 38-47, 2019, DOI: 10.2478/emj-2019-0019.

85. Ž. Turk, and R. Klinc, "Potentials of Blockchain technology for construction management", Procedia Engineering, vol. 196, 2017, pp. 638- 645.

86. Redmond, A. Hore, M. Alshawi, R. West, "Exploring how information exchanges can be enhanced through Cloud BIM". Automation in Construction, 24, 2012, pp.175-183.

87. Taylor D., "Construction And Blockchain: How Can It Help The Industry?", Published In Capterra Construction Management, 2017, Blog. Http://Blog.Capterra.Com/Construction-And-Blockchain-How-Can-Ithelp-The-Industry/.

88. Žiga Turk, and Robert Klinc, "Potentials of Blockchain Technology for Construction Management". Creative Construction Conference 2017, CCC 2017, 19-22 June 2017, Primosten, Croatia, (2017) doi: 10.1016/j.proeng.2017.08.052, 638 – 645.

89. Moumitadas, hanluo, Jack C.P.Cheng, "Securing interim payments in construction projects through a Blockchain-based framework", utomation in Construction, Volume 118, October 2020, 103284, https://doi.org/10.1016/j.autcon.2020.103284.

90. Praveen Kumare Gopalakrishnan, John Hall, Sara Behdad, "Cost analysis and optimization of Blockchain-based solid waste management traceability system", 2020, https://doi.org/10.1016/j.wasman.2020.10.027 0956-053X/.

91. R. Sawant, D. A. Joshi and R. Menon, "Blockchain Technology in Construction Supply Chain Management During Pandemic: A Bibliometric Analysis and Systematic Literature Review," 2022 International Conference on Computing, Communication, and Intelligent Systems (ICCCIS), Greater Noida, India, 2022, pp. 421-428, doi: 10.1109/ICCCIS56430.2022.10037673.

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