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Research Article

Block by block: a bibliometric analysis of blockchain in real estate

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ABSTRACT

Blockchain technology is a novel and disruptive innovation that has the potential to transform various industries, such as finance, supply chain, and healthcare. However, the application and impact of blockchain technology in real estate remain largely unexplored. This study aims to investigate the characteristics, development, and structure of the research field of blockchain in real estate using bibliometric analysis. The study analyzes 352 publications indexed by the Web of Science database from 2016 to 2022 using different methods and tools, such as descriptive statistics, network analysis, co-citation analysis, and co-word analysis. The results show that blockchain in real estate is an interdisciplinary and rapidly growing research area that covers various topics and applications. The study also identifies the most influential publications, authors, journals, and countries in this field, as well as the main research themes and gaps. The study discusses the implications and contributions of the bibliometric analysis of the blockchain in real estate research and practice and suggests directions for future research on this topic.

Keywords: Blockchain, Real Estate, Bibliometrics Analysis, Web of Science Database.

INTRODUCTION

Blockchain technology is a type of distributed ledger that allows the secure and transparent sharing and verification of information across a network of computers. It was first developed for Bitcoin, the first cryptocurrency, in 2008. A blockchain consists of a series of blocks that contain encrypted records of transactions or data. Each block is linked to the previous and next blocks using cryptography, making the blockchain immutable and verifiable (McKinsey, 2022). Blockchain technology enables transactions to occur without intermediaries, creating efficient and innovative solutions for various domains and industries, such as finance, health care, supply chain, education, and energy (Amani et al., 2018; Andoni et al., 2019).

One of the most significant and promising fields for blockchain applications is real estate. Real estate is defined here as property consisting of land and buildings, immovable property of this nature, an interest vested in this, an item of real property, and buildings or housing in general (Saari, Vimpari, & Junnila, 2022). It is one of the largest and most important sectors in the global economy and involves various processes and stakeholders, such as property owners, buyers, sellers, brokers, agents, lawyers, banks, governments, and registries. However, compared with other industries, the real estate sector has a low level of digitalization (Kassner, Cajias, & Zhu, 2022; Starr, Saginor, & Worzala, 2020), despite its significant contribution to the global economy, environment, and society (Saari, Vimpari, & Junnila, 2022). This implies that there is a large potential for productivity improvement by adopting digital technologies more extensively in the real estate sector (Ullah, Sepasgozar Samad, & Siddiqui, 2017; Ullah & Sepasgozar, 2020).

Blockchain technology offers significant benefits for the real estate sector by improving the efficiency, transparency, security, and trust of real estate processes. Blockchain also enables new forms of real estate transactions and investments, such as tokenization and smart contracts, that can lower the barriers to entry, reduce transaction costs, increase liquidity, and enhance market access. However, blockchain technology also faces technical, legal, institutional, organizational, and cultural challenges and limitations that hinder its adoption and diffusion in the real estate sector.

The existing literature on blockchain in real estate has explored various topics and applications of blockchain technology in this field. However, there is a lack of a

comprehensive and systematic overview of the current trends and future directions of this emerging field. Therefore, this study aims to fill this gap by conducting a bibliometric analysis of the literature on blockchain in real estate. Bibliometric analysis is a quantitative method that uses statistical techniques to analyze publications in a specific field or topic. Bibliometric analysis provides insights into the characteristics, development, and structure of a research field, such as the most influential publications, authors, journals, countries, research themes, and research gaps (Aria & Cuccurullo, 2017). More specifically, this study provides a comprehensive overview of the current state and prospects of blockchain in real estate research and offers insights and implications for researchers, practitioners, policymakers, and educators. The following research questions are addressed:

RQ-1: What are the main trends and patterns of publications in blockchain in real estate literature?

RQ-2: Who are the most influential authors, journals, and countries in blockchain in real estate literature?

RQ-3: What are the main research themes and topics in blockchain in real estate literature?

RQ-4: What are the research gaps and future directions in blockchain in real estate literature?

The rest of this study is organized as follows: Section 2 describes the methods used for data retrieval, data processing, and data analysis. Section 3 presents and interprets the results of the bibliometric analysis. Section 4 discusses the implications, contributions, limitations, and challenges of the study, and concludes this study with a summary and suggestions for future research.

METHODOLOGY

Data Retrieval

The data source used for this study was the Web of Science (WoS) database. WoS is a reputable and comprehensive database that covers various disciplines and sources, such as journals, books, and, conference proceedings. WoS was chosen because it provides high-quality and reliable data for bibliometric analysis (Gaviria-Marin, Merigó, & Baier-Fuentes, 2019). The search strategy for this study was based on the following keywords and phrases: “blockchain” AND (“real estate” OR “property” OR “housing”). These keywords and phrases were derived from the research problem and objective of this study and were used to capture the publications that focus on blockchain applications in real estate. The keywords and phrases were combined using Boolean operators (AND, OR) to refine the search results. The search was limited to the title, abstract, and keyword fields of the publications.

Data Processing

The selection criteria for this study were based on the following inclusion and exclusion criteria: (1) publication type: only journal articles were included, as they represent the most rigorous and influential form of scientific communication; (2) publication date: only articles published before 2023 were included, as they reflect the most recent developments and consistent trends in blockchain research in real estate; (3) publication language: only articles published in English were included, as they are more accessible and widely cited than articles published in other languages; (4) publication relevance: only articles that focus on blockchain applications in real estate were included, as they are more relevant to the research problem and objective of this study. The inclusion and exclusion criteria were applied manually by screening the titles, abstracts, and full texts of the publications. Any duplicates or missing data were also removed or corrected during this process.

Method of Bibliometric Analytics

This study adopted various bibliometric methods to provide a comprehensive and systematic overview of blockchain research in real estate (Zupic & Čater, 2015). Bibliometric methods are quantitative techniques that analyze the patterns and trends of scientific publications based on various indicators, such as authors, journals, citations, and keywords (Aria & Cuccurullo, 2017). The methods used in this study included performance analysis, citation analysis, co-citation analysis, and co-word analysis. The bibliometric analysis was performed using Microsoft Excel, the Biblioshiny app in RStudio (Aria & Cuccurullo, 2017), and VOSviewer (Van Eck & Waltman, 2010). Microsoft Excel was used for data cleaning and processing. Biblioshiny and VOSviewer were jointly used for generating and visualizing various bibliometric indicators and statistics and creating and analyzing bibliometric maps.

RESULTS AND DISCUSSION

Performance Analysis

General Performance Output of Articles

Table 1 summarizes the growth of research on blockchain in the real estate industry from 2016 to 2022 by showing the total number and breakdown of articles, authors, and sources related to this topic. The number of articles per year increased from 3 to 105, the number of authors per year increased from 6 to 344, and the number of sources per year increased from 2 to 85. The percentage of articles rose from 0.85% to 29.83%, the percentage of authors rose from 0.55% to 31.64%, and the percentage of sources rose from 0.89% to 37.78%. These numbers indicate that blockchain in the real estate industry is a fast-growing and evolving field that attracts more scholars and draws on more sources over time. This result suggests that blockchain technology has high potential to transform the real estate industry and that there is a growing interest in and demand for research on this topic. This finding also implies that blockchain in the real estate industry is an interdisciplinary and diverse field that incorporates various perspectives and approaches from different sources.

Table 1. Descriptive Statistics of the Articles

Year	No. of Articles (of 352)	No. of Authors (of 1087)	No. of Sources (of 225)
2016	3	6	2
2017	6	11	5
2018	19	41	18
2019	41	145	33
2020	81	248	67
2021	97	344	75
2022	105	344	85

Performance of Scientific Sources

Table 2 shows the top 14 sources that published more than four articles on blockchain in the real estate industry from 2016 to 2022. The total number of articles in this field was 352, and the total number of sources was 225. The most prolific source was IEEE Access, with 29 articles, followed by four sources with six articles each: Journal of Property Planning and Environmental Law, Peer-to-Peer Networking and Applications, Symmetry-Basel, and Electronics. The remaining nine sources had five or four articles each. The table illustrates the diversity of sources that cover this topic, ranging from engineering and computer science journals to law and business journals.

Table 2. Distribution of Articles by Source Title

Source titles	No. of Articles
IEEE Access	29
Journal of Property Planning and Environmental Law	6
Peer-to-Peer Networking and Applications	6
Symmetry-Basel	6
Electronics	5
Frontiers in Blockchain	5
Future Generation Computer Systems-The International Journal of E-science	5
IEEE Internet of Things Journal	4
IEEE Transactions on Vehicular Technology	4
Information Sciences	4
Journal of Cleaner Production	4
Journal of Property Investment & Finance	4
Strategic Change-Briefings in Entrepreneurial Finance	4
Wireless Communications & Mobile Computing	4

Performance of Countries and International Collaborations

The distribution of the articles by country of affiliation is displayed in **Figure 1**.

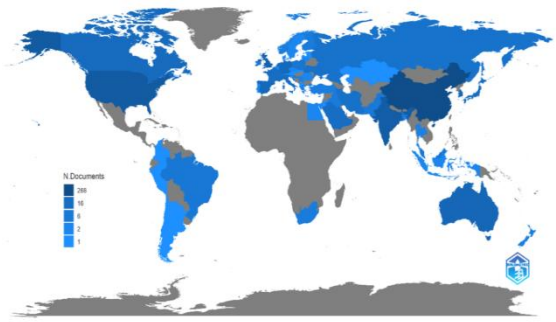

Figure 1. Distribution of Articles by Country of Affiliation
(Source: Author's Self-elaboration Through Biblioshiny)

The articles are affiliated with 62 different countries, indicating a high degree of international collaboration and dissemination in the field. The figure below illustrates the number of articles on blockchain and real estate published by authors from different countries and regions between 2016 and 2022. It showed that China led the field with 268 articles, followed by the USA (84 articles) and India (65 articles). Other countries with more than 15 articles each included the UK, Australia, Spain, South Korea, Germany, Canada, and the Netherlands. The figure also revealed that Europe was the most prolific region in this field, with 38 countries contributing 246 articles in total. Asia came in second with 16 countries and 240 articles in total. North America ranked third with 2 countries and 103 articles in total. The figure suggested that blockchain and real estate research was unevenly distributed across countries and regions, with China and Europe being the most active while others lagged.

The top 10 countries of affiliation of correspondence authors in terms of the number of publications on blockchain in the real estate industry vary in their productivity and international collaboration. Productivity is measured by the total number of publications, while international collaboration is measured by the ratio of multiple-country publications (MCP) to single-country publications (SCP). As shown in **Figure 2**, China is the most productive country

with 98 articles, followed by the USA with 36 articles and India with 28 articles. Together, they account for almost half of the total publications in the dataset (46%). On the other hand, Australia has the highest degree of international collaboration with an MCP ratio of 0.538, meaning that more than half of its publications are co-authored with authors from other countries. The United Kingdom and France also have high MCP ratios of 0.375 and 0.25, respectively, indicating more diverse and extensive research networks and partnerships on blockchain in the real estate industry. In contrast, Korea has no international collaboration at all, with an MCP ratio of zero. This suggests that Korea has a more self-reliant or isolated research community on blockchain in the real estate industry. Italy and Spain also have low MCP ratios of 0.273 and 0.25, respectively. The mean MCP ratio for the top 10 countries is 0.285, which means that on average, only 28.5% of their publications are international collaborations. There is a weak negative correlation between productivity and international collaboration for the top 10 countries (r=-0.24), but this correlation is not statistically significant.

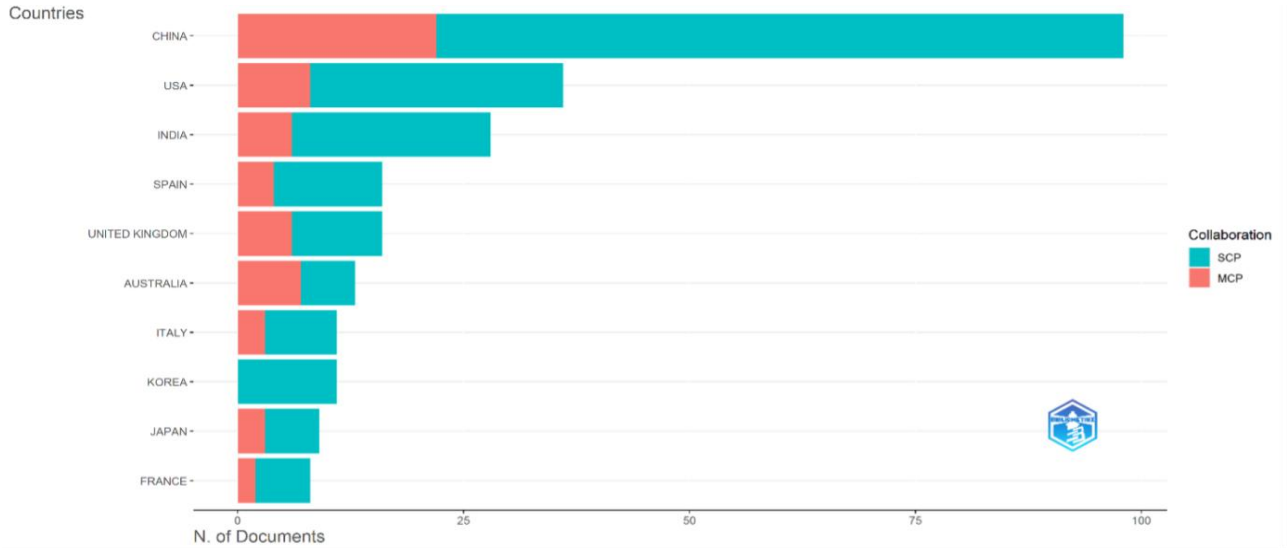

Figure 2. Top 10 Countries of Correspondence Authors' Country of Affiliation
(Source: Author's Self-elaboration Through Biblioshiny)
Note: SCP=Single Country Publication, MCP=Multiple Country Publication.

The performance analysis indicates that blockchain research in real estate is an emerging and interdisciplinary field that draws scholars from various backgrounds and locations. The field has witnessed a surge in publications and citations in recent years, demonstrating its importance and influence for both academic and practical domains. However, the field also exhibits some patterns of concentration and disparity, as some journals, countries, and authors prevail in the field and garner more recognition than others.

Citation Analysis

The trends of citations for articles on blockchain and real estate published from 2016 to 2022 are summarized in **Table 3**. It reports the average number of citations for each article (Mean Times Cited per Article), the total number of articles (Number of Articles), and the average number of citations for each year (Mean Times Cited per Year) for each year. It also shows how many years each article has been eligible for citation (Citable Years), which is the difference between 2023 and the year of publication.

Table 3. Citation Analysis of Articles

Year	Mean TC per Article	No. of Articles	Mean TC per Year	Citable Years
2016	13.67	3.00	1.71	8
2017	63.5	6.00	9.07	7
2018	35.47	19.00	5.91	6
2019	28.8	41.00	5.76	5
2020	13.72	81.00	3.43	4
2021	10.35	97.00	3.45	3
2022	3	105.00	1.50	2

Note: TC=Total Citations.
The reference cutoff year for citable years of citation therein refers to 2023.

Table 3 indicates that the research interest and output on blockchain and real estate have grown significantly over time, as the number of articles increased from 3 in 2016 to 105 in

2022. However, the table also suggests that the research impact and quality have declined over time, as both the mean times cited per article and the mean times cited per year decreased over time. The highest mean times cited per article was obtained in 2017, with an average of 63.5 citations for each article. This may imply that the articles published in 2017 were of high quality or relevance to the field. The lowest mean times cited per article was observed in 2022, with an average of 3 citations for each article. This may imply that the articles published in 2022 were too recent to be widely cited or recognized by the field. The table identifies several factors that may influence the citation performance of articles on blockchain and real estate, such as the recency of the publications, the saturation of the literature, the novelty or originality of the research, or the difficulty of measuring the actual benefits and challenges of blockchain applications in real estate.

In addition, as displayed in **Figure 3**, it ranks the top ten most cited articles on blockchain and real estate based on three citation indicators: the total number of citations (Total Citations), the average number of citations per year (TC per Year), and the normalized number of citations (Normalized TC) (Aria & Cuccurullo, 2017). The normalized number of citations is computed by dividing the total number of citations by the mean number of citations per article in the same year. The figure indicates that the article by Zhang and Wen (2017), which proposes a blockchain-based framework for peer-to-peer rental markets, is the most cited article, with 281 total citations, 40.14 citations per year, and 4.43 normalized citations. The article by Al Omar et al. (2019), which presents a blockchain-based smart contract system for property leasing, is the second most cited article, with 157 total citations, 31.40 citations per year, and 5.45 normalized citations. The article by Davidson, De Filippi, & Potts (2018), which examines the economic implications of blockchain technology for real estate intermediation, is the third most cited article, with 152 total citations, 25.33 citations per year, and 4.28 normalized citations.

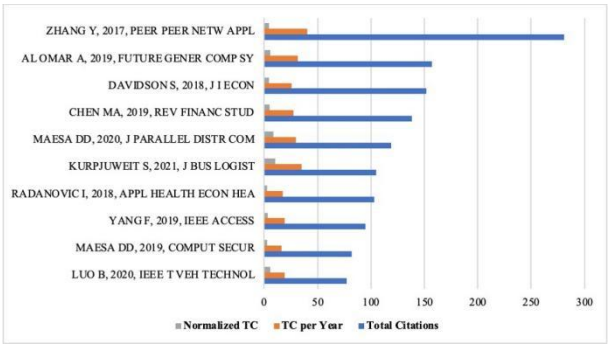

Figure 3. Top 10 Most Cited Articles
(Source: Author's Self-elaboration Through Biblioshiny and Microsoft Excel)

Some interesting patterns and trends are also presented in **Figure 3**. First, the articles published in more recent years (2019-2021) have higher normalized citations than the articles published in earlier years (2017-2018), suggesting that they have more impact or attention compared to their peers in the same year. For instance, the article by Kurpjuweit et al. (2021) has the highest normalized citation of 10.14, followed by the article by Maesa and Mori (2020) with an 8.68 normalized citation. Second, the articles published in more prestigious or specialized journals have higher total citations and citations per year than the articles published in less prestigious or general journals. For instance, the articles published in Review of Financial Studies, Journal of Industrial Economics, Journal of Business Logistics, Applied Health Economics and Health Policy have better citation performance than the articles published in IEEE Access, Computer Security, or Peer-to-Peer Networking and Applications. Third, the articles that focus on specific applications or domains of blockchain technology for real estate have better citation performance than the articles that provide a general overview or survey of blockchain technology for real estate. For instance, the articles that address topics such as peer-to-peer rental markets, smart contract systems, property leasing, land administration, or vehicle-to-grid integration have better citation performance than the articles that discuss topics such as blockchain challenges and opportunities, blockchain adoption and diffusion, or blockchain innovation and sustainability.

Co-citation Analysis

The co-citation network counts how often each pair of references is co-cited by other articles on blockchain and real estate in the bibliographic database. The cluster groups reference similar co-citation patterns. The figure shows the clusters of the co-citation network of the top 50 most cited references using the Leading Eigenvalues clustering algorithm, which partitions the network based on the eigenvalues and eigenvectors of the co-citation matrix (Aria & Cuccurullo, 2017). In this study, the relevance of co-citation analysis was also measured by the betweenness centrality, the closeness centrality, and the PageRank in the Biblioshiny app.

Figure 4 shows that there are four clusters of references in the co-citation network, each representing a different theme or topic related to blockchain and real estate. The first cluster (cluster 1, in red) consists of references that focus on the applications and implications of blockchain technology for various domains within real estate, such as peer-to-peer rental markets, property leasing, land administration, vehicle-to-grid integration, innovation, and sustainability. The second cluster (cluster 2, in blue) consists of references that provide a general overview or survey of blockchain technology and its challenges and opportunities for real estate. The third cluster (cluster 3, in green) consists of references that explore the technical aspects and protocols of blockchain technology, such as consensus algorithms, smart contracts, and cryptography, that are relevant to real estate transactions and operations. The fourth cluster (cluster 4, in purple) consists of references that address the security and privacy issues and solutions of blockchain technology, such as attacks, vulnerabilities, and verification methods that are important for real estate data and records.

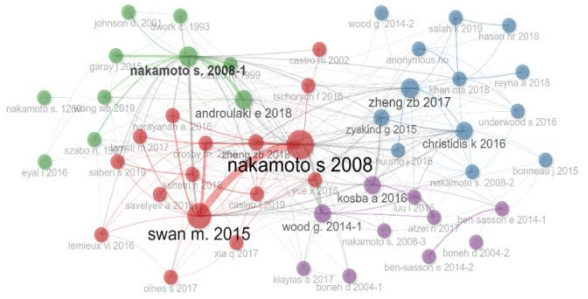

Figure 4. Co-citation Analysis of Articles Based on References
(Source: Author's Self-elaboration Through Biblioshiny)

The figure also indicates that some references have higher network measures than others, suggesting their importance or influence in the co-citation network. For example, the reference by Nakamoto (2008), which introduces the concept and design of Bitcoin as a decentralized digital currency based on blockchain technology, has the highest betweenness centrality (378.68), closeness centrality (0.01), and PageRank (0.056) in cluster 1, as well as the highest betweenness centrality (163.20) and PageRank (0.039) in cluster 3. This suggests that this reference is a core or landmark reference in both clusters and connects different themes or topics related to blockchain and real estate. Another example is the reference by Wood (2014), which describes Ethereum as a platform for decentralized applications based on blockchain technology and smart contracts. This reference has the highest betweenness centrality (100.08) and PageRank (0.034) in cluster 4, as well as the highest closeness centrality (0.009) in cluster 3. This suggests that this reference is a key or representative reference in both clusters and bridges different technical and security aspects of blockchain and real estate.

Co-words Analysis

The co-words are the pairs of keywords that co-occur in the titles and abstracts of the articles (Cobo et al., 2011). The co-word analysis aims to reveal the main themes or topics of research output in this field over time. **Figure 5** shows the co-word network of the articles based on the author's keywords. The co-word network was generated using VOSviewer software and visualizes the co-occurrence and association of keywords in the titles and abstracts of the articles (Heersmink et al., 2011). The size of each node represents the frequency of each keyword, while the distance between nodes represents the similarity or dissimilarity of keywords based on their co-occurrence. The color of each node represents the cluster or theme to which each keyword belongs based on a modularity-based clustering algorithm (Mora-Valentín, Ortiz-de-Urbina-Criado, & Nájera-Sánchez, 2018).

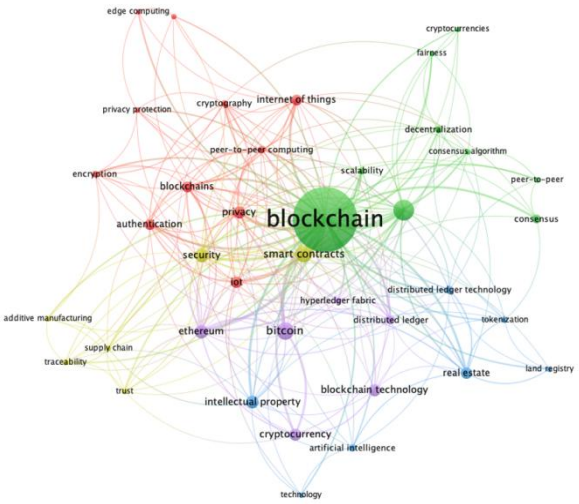

Figure 5. Co-word Network of Articles Based on Author's Keywords
(Source: Author's Self-elaboration Through VOSviewer)

The co-word network identifies five main clusters or themes in blockchain research in real estate:

Cluster I (in red): Blockchain-based IoT Systems for Enhancing Security and Privacy in Smart Buildings (Keywords: authentication, blockchains, cryptography, edge computing, encryption, internet of things (IoT), peer-to-peer computing, privacy, and privacy protection). This theme explores how blockchain can provide authentication, encryption, and peer-to-peer communication for IoT devices, such as sensors, actuators, and cameras, that are used to monitor and control various aspects of smart buildings, such as energy consumption, temperature, lighting, security, etc. Blockchain can also protect the privacy of the data generated and exchanged by these devices, by ensuring that only authorized parties can access and modify the data. Blockchain can also enable smart contracts that can automate and enforce certain actions or services based on predefined rules and conditions.

Cluster II (in green): Fundamentals and Challenges of Blockchain Technology for Real Estate Applications (Keywords: blockchain, consensus, consensus algorithm, cryptocurrencies, decentralization, fairness, peer-to-peer, scalability, smart contract). This theme explores how blockchain works and what the main features and issues are that affect its adoption and performance in the real estate sector. For example, consensus algorithms are the mechanisms that ensure the validity and consistency of the data stored on the blockchain, but they also have trade-offs in terms of speed, security, and energy consumption. Cryptocurrencies are the digital tokens that enable transactions on the blockchain, but they also face volatility, regulation, and adoption barriers. Smart contracts are self-executing agreements that can automate and enforce real estate processes, but they also require standardization, verification, and dispute-resolution mechanisms.

Cluster III (in blue): Artificial Intelligence and Distributed Ledger Technology for Real Estate Innovation (Keywords:

artificial intelligence, distributed ledger technology, intellectual property, land registry, real estate, technology, tokenization). This theme explores how artificial intelligence and distributed ledger technology can work together to create new solutions and opportunities for real estate stakeholders, such as enhancing property valuation, market analysis, asset management, and transaction security. Artificial intelligence can provide data-driven insights and automation for real estate processes, such as predicting market trends, optimizing pricing strategies, detecting fraud, etc. Distributed ledger technology can provide transparency and trust for real estate transactions and records, such as verifying property ownership, tracking property history, facilitating payments, etc.

Cluster IV (in yellow): Additive Manufacturing and Blockchain for Improving Efficiency, Quality, and Sustainability of Real Estate Supply Chains (Keywords: additive manufacturing, security, smart contracts, supply chain, traceability, trust). This theme explores how additive manufacturing and blockchain can improve the efficiency, quality, and sustainability of real estate supply chains, such as construction, renovation, and maintenance. Additive manufacturing can reduce material waste, transportation costs, and lead times for real estate projects, by enabling on-demand and customized production of parts and structures. Blockchain can provide traceability, security, and smart contracts for real estate transactions and records, such as ensuring the quality and origin of materials, verifying the completion and compliance of work orders, facilitating payments and warranties, etc.

Cluster V (in purple): Blockchain Platforms and Protocols for Enabling and Facilitating Real Estate Transactions (Keywords: bitcoin, blockchain technology, cryptocurrency, distributed ledger, Ethereum, Hyperledger fabric). This theme explores how different blockchain platforms and protocols can enable and facilitate real estate transactions, such as buying, selling, renting, and investing in properties. Blockchain platforms and protocols are the software systems that provide the infrastructure and rules for creating and validating transactions on the blockchain. Some examples are Bitcoin, Ethereum, and Hyperledger Fabric. Each platform and protocol has its advantages and disadvantages in terms of scalability, security, functionality, and interoperability.

CONCLUSION

This study has presented a comprehensive and systematic review of blockchain in real estate literature using bibliometric methods. It has analyzed 352 publications from the Web of Science database and revealed the interdisciplinary and dynamic nature of this research area, as well as its various topics and applications. The article has also uncovered the most influential publications, authors, journals, and countries in this field, and the main research themes and gaps. The article has demonstrated that blockchain technology can offer significant benefits for the real estate sector by enhancing the efficiency, transparency, security, and trust of real estate processes. Blockchain can also enable new forms of real estate transactions and investments, such as tokenization and smart contracts. However, the article has also pointed out some challenges and limitations of blockchain in real estate, such as technical issues, regulatory barriers, and paradigm shifts.

Moreover, this study has two main contributions. Firstly, it provides a comprehensive and systematic overview of blockchain in real estate literature that can help researchers and practitioners gain insights into this emerging field. Secondly, it identifies the research gaps and opportunities for further exploration, such as more empirical and comparative studies across different subsectors and regions.

The limitations of this study were mainly related to the data sources and methods used. It only covers publications from the Web of Science database, which may exclude some relevant publications from other sources. It also only uses bibliometric methods to identify the research themes, which may simplify or lose some nuances of the publications. Moreover, it only includes publications until December 2022, which may not capture the latest developments or trends in this field. Based on these limitations, some suggestions for future research are proposed. First, future studies could include other databases or platforms such as Scopus, Google Scholar, or ResearchGate to expand the data sources. Second, future studies could use qualitative methods such as content analysis to complement the bibliometric methods and provide a deeper understanding of the publications. Third, future studies could update the analysis periodically to capture the latest developments or trends in this field.

In conclusion, this study shows that blockchain technology has great potential to transform the real estate sector by providing innovative solutions and opportunities for various stakeholders. However, there are also many challenges and uncertainties that need to be addressed before blockchain can be widely adopted and implemented in real estate. Therefore, more research is needed to explore the technical, legal, social, economic, and environmental aspects of blockchain in real estate.

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