MAPPING BLOCKCHAIN RESEARCH IN CONSTRUCTION: BIBLIOMETRIC STUDY

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Abstract

Technology usage in construction has increased since the beginning of the twenty-first century through the transformation in personal computer hardware and software, as well as the development of standards for information exchange. Breakthroughs in the telecommunication industry have resulted in faster, more stable and affordable networks which have allowed new collaborative work practices. The combination of a reliable internet connection and affordable, powerful computers has enabled new technologies to emerge, such as cloud storage, cloud computing or Blockchain. Blockchain is a broad term that refers to using a distributed file system to manage, distribute and protect data. As a technology, Blockchain provides solutions for different industries regarding trust, transparency, and traceability. Blockchain technology provides the construction industry with solutions to improve the construction projects' workflow and address broken trust issues between project participants.

This paper attempts to identify which fields are currently being investigated by the built environment and construction researchers to implement Blockchain in the industry through a bibliometric study. This study aims to clarify three aspects: (1) Blockchain uses in construction, (2) research methods used in the literature, and (3) construction technologies that could be empowered with Blockchain. Blockchain in construction is an emerging research field, and there is a limited amount of literature available about the topic. Therefore, no restriction was applied to the reviewed literature, such as journals impact factor or articles citations number. Conference proceedings are also included. This review can serve as a guide for researchers who are interested in Blockchain applications in construction.

1. Introduction

The term Bibliometrics was first used by Pritchard in 1969. This word replaced the previous term "statistical bibliography" [1]. Both terms mean using math and statistics to organise and

understand the available literature systematically. This approach will be used in this paper to shed light on the recent developments in the field of Blockchain in Construction.
Blockchain technology is commonly associated with cryptocurrency because of the Bitcoin booming in the recent few years. Blockchain is a digital, decentralised data ledger, distributed among participants [2]. As such, it can and indeed is adopted in other activities to ensure traceable communication between stakeholders, regardless of the level of trust between them.
The construction industry faces growing challenges to protect construction data and exchange it safely. To avoid this risk Blockchain is proposed by researchers as a tool to provide a safe construction data environment. This article tries to provide the reader with the current direction for Blockchain applications in the construction industry in addition to highlighting the authors, countries and research groups who are currently investigating this topic.
This article is divided into five parts: (1) Introduction, (2) Methodology, (3) Bibliometric study and (4) Content Analysis (5) Conclusion. The introduction provides a brief summary of Blockchain technology and construction data protection concerns. The methodology describes the software and the data retrieval method used in analysing the bibliometrics collected from indexing services. The bibliometric study section includes the software analysis results. The Content analysis provide a brief summary for the content retrieved. The Conclusion highlights the results of the bibliometric study and points towards expected developments in this field.

2. Methodology

2.1. Data Retrieval

Data was collected on the 28th of January 2020 from two indexing services: Web of Science and Scopus. There was no restriction applied to the collected data. The search sentence was Construction AND Blockchain on both websites. The search in Scoups returned 244 documents. After filtration based on title and abstract, a total of 37 records were considered for this review. The search in the Web of Science returned 88 documents, of which nine records were considered for this review. After merging and removing duplicates, a total of 38 records were selected for this review. The articles were filtered manually by examining the title and the abstract then the whole article if the title and abstract did not give a conclusive diagnosis. The research string was not specific to ensure inclusion which explains the difference between the retrieved articles and the considered articles for this study.

2.2. Data Analysis

The collected data were processed using Bibliometrix R package [3]. The data processing procedure is summarised as follows: (1) The collected data was downloaded in BibTeX file format; (2) the Bibliometrix source file was modified to function properly with the collected data; (3) extract the results from the console and plots section.

3. Bibliometric study

The source file of Bibliometrix package contains a collection of analysis regardless of the sample size and its time span [3]. As discussed in this section, some of the results obtained from the analysis software are not meaningful in this case due to the small sample size and the short

time span (between 2017 and January 2020) that has elapsed since the first available results. The data analysis results are presented below.

3.1. Retrieved Data Categories

The data retrieved contains the following document types: 12 articles, one book chapter, 20 conference papers, one conference review, and four review articles. The high number of conference proceedings, when compared to the journal articles, can be justified as a result of a relatively low level of ideas maturity in the field. There are still no major journals or conferences dedicated to this topic, although the Construction Blockchain Consortium has held regular events since August 2018 [4].

3.2. Annual Scientific Production

Figure 1 shows the annual scientific production according to the available data. The relatively high document count in 2019 shows a growing interest in implementing the technology inside the construction industry. In 2020 it is expected to see more publications that discuss the technology implementation and case studies to help the construction industry overcome the three adoption obstacles (1) trust in the blockchain technology; (2) technology governance; and (3) cost of implementation [5].

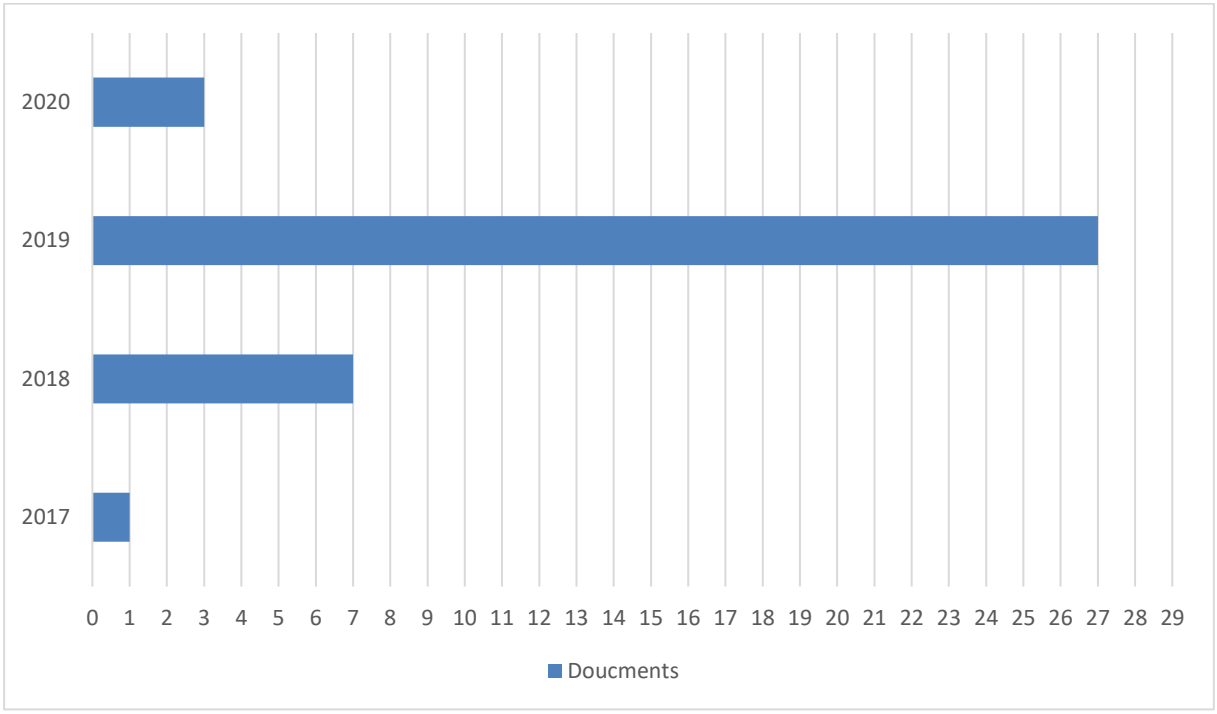

Figure 1: Annual Scientific Production.

3.3. Most Productive Authors

Table 1 below shows the most productive authors. The analysis shows that Nawari and Ravindran from the University of Florida, USA are the most productive authors, with four articles published in 2019 related to Blockchain technology in construction [2, 6-8].

Table 3: Most productive authors

	Authors	**Articles**
1	NAWARI N	4
2	RAVINDRAN S	4
3	HAO X	2
4	JIANG J	2
5	LIU Z	2
6	REN W	2
7	SHOJAEI A	2
8	XIONG F	2
9	ZHENG R	2
10	ABLYAZOV T	1

3.4. Most cited manuscripts

As shown in table 2, Turk's [9] conference article published in 2017 is the top-cited manuscript with a total of 31 citations and 7.750 total citations per year. In this review, Turk [9] is the author of the first article published about the topic; therefore, this comparatively high citation count is expectable.

Table 4: Top manuscripts per citations

	Paper	**TC**	**TC per Year**
1	TURK, 2017, PROCEDIA ENG	31	7.750
2	LI S, 2018, PROC - IEEE INT CONF SMART INTERNET THINGS, SMARTIOT	8	2.667
3	LANKO A, 2018, MATEC WEB CONF	5	1.667
4	LI J, 2019, AUTOM CONSTR	4	2.000
5	NAWARI NO, 2019, J BUILD ENG	2	1.000
6	NAWARI NO, 2019, J INF TECHNOL CONSTR	2	1.000
7	SHOJAEI A, 2019, ISEC - INT STRUCT ENG CONSTR CONF	2	1.000
8	SIVULA A, 2018, PROC INT CONF IND ENG OPER MANAGE	2	0.667
9	YE Z, 2018, ISARC - INT SYMP AUTOM ROBOT IN CONSTR INT AEC/FM HACKATHON: THE FUTURE OF BUILD THINGS	2	0.667
10	NAWARI NO, 2019, J INF TECHNOL CONSTR	2	1.000

3.5. Most relevant keywords

Keywords show the interaction of a given topic with other topics. Table 3 shows the expected strong relationship between BIM and Blockchain. BIM is increasingly used in academia and in

professional activity to manage construction data and Blockchain provides an efficient way to protect and organise it.

Table 5: Keywords occurrence

	Author Keywords	**Occurrence**
1	BLOCKCHAIN	24
2	BIM	14
3	SMART CONTRACT	9
4	CONSTRUCTION	9
5	SMART CONTRACTS	7
6	DISTRIBUTED LEDGER	6
7	HYPERLEDGER FABRIC	5
8	SMART CITY	5
9	AEC	5
10	BUILDING INFORMATION MODELLING	5

3.6. Most productive countries

As illustrated in Figure 2, the USA and China lead the most productive countries with four articles each. All of the American articles are authored by Nawari and Ravindran. Articles produced in china are shared among multiple authors who work on the topic, including Rongyue Zheng [10, 11] and his co-authors from Ningbo University.

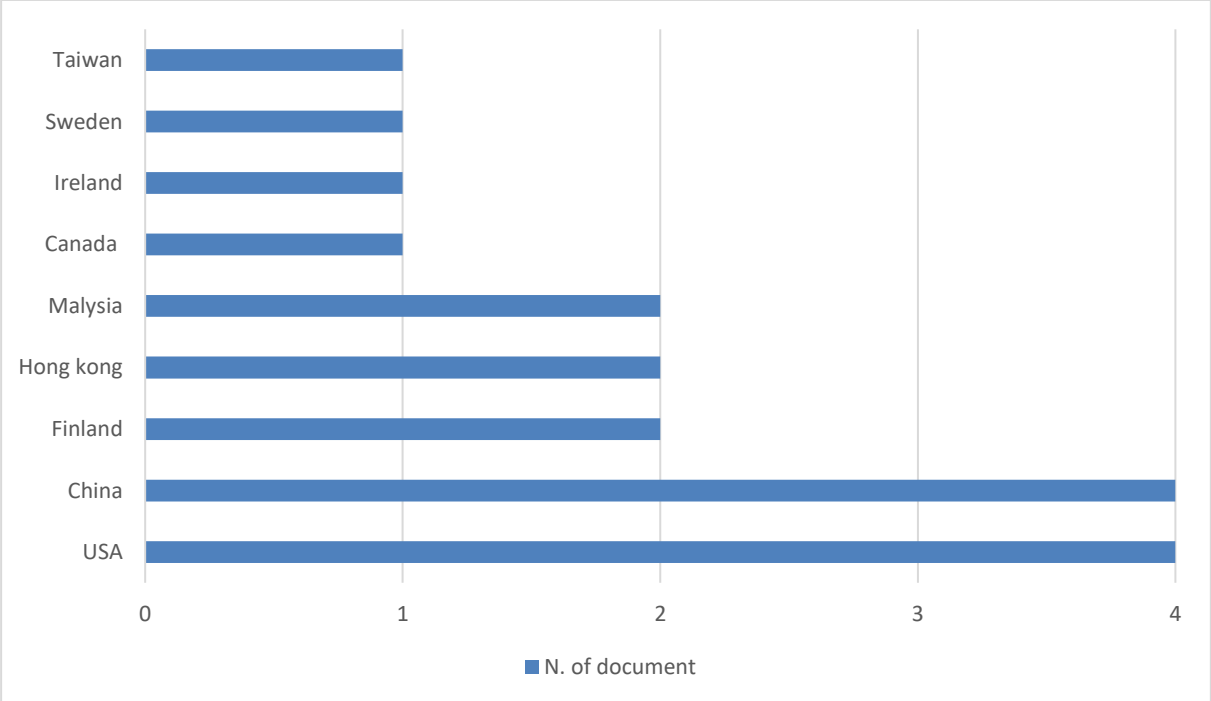

Figure 2: Most productive countries.

3.7. Authors' coupling

Author coupling analysis shows the authors who work together frequently, which helps to identify research themes and groups. Although this relatively small sample is an obstacle to the development of this type of assessment, there are two main distinct groups that focus on the topics. From the USA, Nawari and Ravindran are in the first group. The second one is composed of Rongyue Zheng and his associates in China. Figure 3 shows the authors' coupling plot.

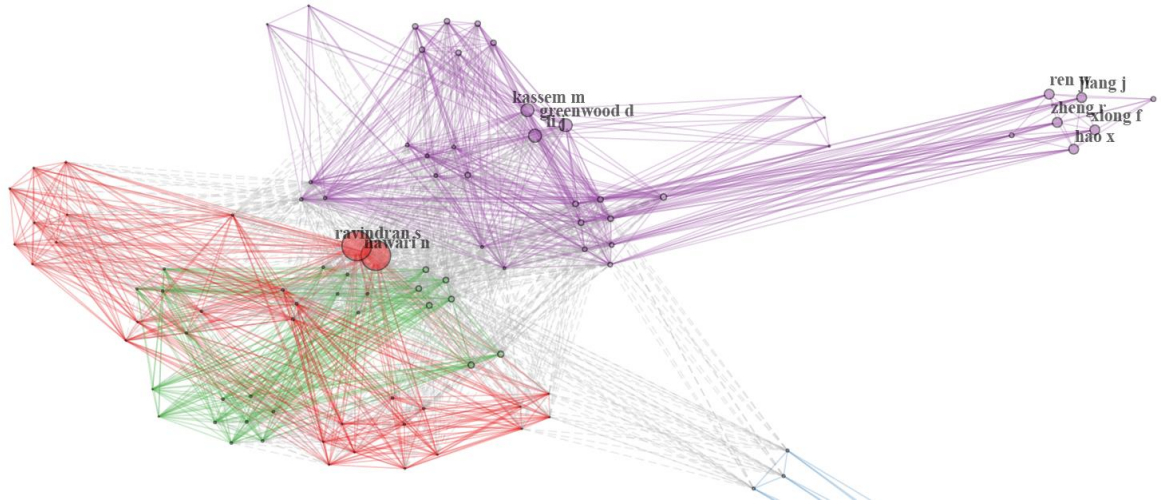

Figure 3: Authors' coupling.

4. Content analysis

The content of the retrieved articles covers a wide range of possible applications for Blockchain with different levels of exploration. However, the general theme of all these studies is to leverage the technology to improve data governance regardless of the application. This section highlights the main findings from selected research papers. A more extensive content analysis can be found in [12].

Zheng et al. [11] proposed the Context-aware Access Control mechanism (CaAC) system as a replacement for the currently used Role-Based Access Control (RBAC). CaAC system is a user and privileges manager where people involved. However, CaAC depends on other technologies to function efficiently to capture the context properly, such as Augmented Reality (AR), Artificial Intelligence (AI), and Internet of Things (IoT).

Automated Code-checking and Compliance (ACCC) framework was proposed by Nawari and Ravindran [6] by combining BIM and Blockchain. The framework requires converting the building requirements code and other related laws to programable code as rules checking system. The authors expect that such a solution be useful in emergencies and post-disaster situations where there is a need for fast, accurate and automated permitting process.

Structural health monitoring was also discussed by Jo [13], where Blockchain was combined with IoT to create an early alarm system with content protection by Blockchain. The proposed framework uses Blockchain to encrypt the data interpretation instead of encrypting the raw data. The reason for that is the raw data in this context is meaningless where its interpretation holds sensitive information, especially when the technology is used for strategic buildings.

As discussed before, topics examined in regard to adopting the technology vary. However, there is an agreement between the researchers about the value expected from adopting such technology. BIM is

present in most of the studies in parallel with Blockchain. Blockchain and BIM were presented as a foundation for future communication in construction, where BIM appears as a tool for authoring and managing data and Blockchain as a means to protect it [14-16].

5. Conclusion

Blockchain has made cryptocurrencies possible. The fact that people invest their own money or agree to replace their banknotes with computer codes shows how powerful this technology is. The construction industry can benefit from this technology on different levels; however, more literature is needed to clarify how to overcome implementation challenges. There is also a paucity of available empirical data about Blockchain implementation in real construction projects, which will be required to assess the effectiveness of this technology as a data management and data protection tool.

This Bibliometric study shows a growing interest in the field of Blockchain for Construction among researchers. The number of publications has grown from only 2 in 2017 to 27 in 2019. Furthermore, the study shows a strong relationship between BIM and Blockchain using the keywords re-occurrence. The study also shows the most productive authors and most productive countries based on the correspondence authors. The authors coupling plot shows two emerging research groups, although the short available time span does not allow the extraction of robust conclusions in this regard.

The content of the articles retrieved illustrate possible use-cases for Blockchain in the construction industry. Discussed topics include: BIM, cyber threats in construction, construction supply chain, concrete quality, code checking, smart cities, and IoT in construction. A combination of these topics and Blockchain was presented in order to enrich the literature regarding using Blockchain in construction.

Digitalisation is unavoidable for the construction industry [5], and companies try to adopt new technologies such as Blockchain to have an advantage over each other. Blockchain applications in construction are currently being explored, and more researchers are now involved in the topic. It is expected that in the future, this will be reflected in the industry and will facilitate the technology adoption process.

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