Contract Management of BIM-based Projects: A Bibliometric Literature Review

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This review paper presents a quantitative analysis of the literature on contract management of Building Information Modeling (BIM)-based projects spanning the past 15 years. The paper primarily focuses on statistical analysis of publications to identify previous research emphases and future research trends. This review includes 107 papers, selected through a systematic search and screening process, and employs a systematic review with a bibliometric analysis, using Microsoft Excel and VOSviewer for data analysis. The findings reveal a significant increase in the number of publications in the last five years, coinciding with an accelerated adoption of BIM in the construction industry. Analysis of annual distribution of published papers, the papers with the highest impact, and keywords indicates that legal contract issues are a barrier to BIM adoption. Additionally, the findings revealed the existence of connection between construction contract management and agile project management practices and the lack of research on the development of synergic BIM-contract models. Directions for future research, as the main contribution of this review, indicate the need to analyze the BIM impact on contracts management holistically, develop standards and models for BIM-based project contracts, and promote integration of BIM-contracts with agile project management practices.

Key Words: Virtual Design and Construction (VDC), Building Information Modeling, Systematic Review, Agile Project Management

Introduction

Since the late 1990s, the construction industry has been experiencing digital transformation driven by the adoption of Building Information Modeling (BIM) technology. Compared to other industries, the construction sector is the least receptive to the implementation of new technologies and has been suffering from issues related to BIM adoption, such as the need for new management practices (Gless et al., 2019, Alreshidi, Mourshed and Rezgui, 2017, Boton et al., 2021). BIM as the new technology available to the construction industry allows construction professionals, in addition to three-dimensional modeling and an integrated process, to share and discuss the project digitally before it is

executed (Liao & Teo, 2019). According to Bryde, Broquetas & Volm (2013), construction projects became significantly more complex and difficult to manage. This occurred due to the dynamic nature of the construction industry, including the increased number of uncertainties, development processes and participants, and a large variety of participants. Considering the complexity and long duration of construction projects, the contract management becomes an essential area of the project management. The contract management refers to the process that manages the negotiation, execution, performance, modification, and termination of contracts with various parties (Gutterman, 2023). The adoption of BIM transforms conventional, often highly fragmented, construction process into a collaborative effort that strengthens the working relationship among project participants. Thus, new contractual arrangements are needed to support BIM-based projects (Porwal & Hewage, 2013). Some of the major obstacles to BIM-adoption include perceiving BIM as a technological innovation only, and lack of understanding that BIM is a process that needs the integration of managerial vision (Gless et. al., 2019). Thus, it is necessary to develop new management tools and practices for the construction industry to enhance its capacity to execute projects within a BIM environment, while also addressing the resistance to change often encountered among practitioners (Boton et al., 2021). To help overcome the barriers to BIM adoption, Alreshidi et al. (2017) propose a BIM governance framework in which 'processes and contracts' are highlighted as key components that support BIM. However, the authors indicated the need for further research in this area.

A preliminary literature review of the BIM-based projects and contract management reveals that only specific aspects of the contractual context are typically considered. These aspects primarily include legal issues (Almarri, Aljarman & Boussabaine, 2019; Arshad et al., 2019), payment and financial matters (Chong & Diamantopoulos, 2020; Elghaish, Abrishami & Hosseini, 2020), and the encountered challenges (Porwal & Hewage, 2013; Alreshidi et al., 2017). Additionally, previous research emphasizes that the contract management is a pivotal factor affecting BIM implementation, and at the same time could be a significant barrier to BIM adoption. However, the literature review indicates a lack of comprehensive solutions to address these issues and a lack of systematic review addressing contract management of BIM-based projects. To address this gap, this paper investigated the prior research on contract management of BIM-bases projects using a bibliometric literature review. The following three research questions (RQ) were explored:

RQ1. What is the distribution of the academic papers on contracts management of BIM-based projects in terms of number of annually published papers, number of papers published in specific journals, and journal impact factor?
RQ2. What has been the research focus of literature on contract management of BIM-based projects?
RQ3. What are the possible future research directions in the area of contract management of BIM-based projects?

The paper is structured as follows: Section 2 presents the methodology used in the study, Section 3 the results and discussion, and Section 4 conclusions, limitations and future research directions.

Methodology

This research applied a systematic literature review methodology with a bibliometric analysis approach, including scientific mapping and descriptive statistical analysis of published articles on contracts management of BIM-based projects. A bibliometric analysis was selected because it enables summarizing and synthesizing large quantities of data and leads to a strong foundation upon which the explored field can advance (Donthu et al., 2021). The bibliometric analysis comprises annual distribution of the published papers, identification of journals in which articles were published and

countries that research focused on, keyword co-occurrence analysis, and the identification of research clusters, resulting in determining prior research interests and future research trends (Xiao & Watson, 2019). This study utilized the following four phases to conduct bibliometric review: design, conduct, analysis, and structuring and writing, as proposed by Snyder (2019) and shown in Figure 1 adapted from Donthu et al. (2021). In Phase 1, the main decisions about research protocol and search strategies were made, including search terms, databases, inclusion and exclusion criteria, data to be collected and analysis tool. Phase 2 consisted of data collection using systematic literature searches and data processing. As we intended to perform keyword co-occurrence mapping, it was necessary to identify synonyms for keywords during the data processing. Phase 3 included the data analysis. In Phase 4, the results were presented and discussed.
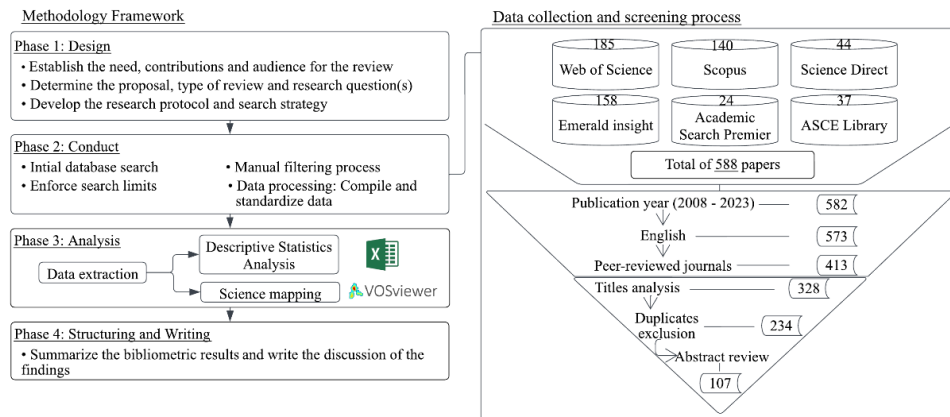

Figure 1. Research Methodology Framework (left) and Screening Process (right) (adapted from Donthu et al. (2021))

To achieve a broad literature review, the following six databases were used for the data search: Web of Science, Scopus, Science Direct, Emerald Management, ASCE Library and Academic Premier (Figure 1). The string (keyword, fields and Boolean operators) used to search each database individually was [TITLE-ABS-KEY] ((“Building Information Modeling” OR BIM OR VDC OR “Virtual Design and Construction”) AND (“Construction Management” OR “Project Life Cycle” OR “Construction project” OR AEC OR “Civil Engineering”) AND (Contract OR Procurement)). To ensure the relevance of the data used in this review, after the initial data search, a manual screening process was employed including the duplicate exclusion, a title analysis, and an abstract review. As a result, 107 papers were selected and considered in the bibliometric analysis. Microsoft Excel software was used to perform descriptive statistical analysis and obtain the annual distribution of published articles, journal impact factor classification, and country of origin of journal, and create corresponding graphs and tables. VOSviewer software was used for creating a keywords co-occurrence network and identifying the main focus within the research area and future research trends.

Results and Discussion

This section presents and discusses the results obtained using descriptive statistics and network analysis of the papers selected using the systematic process. All the result analysis and interpretation were cross-checked by the authors, and the conclusions were made based exclusively on the analysis

of the obtained results. This section is divided into four subsections presenting and discussing the findings as they relate to the research questions.

Historical Analysis of the Published Articles

Analysis of the annual distribution of the published articles on contract management of BIM-based projects indicates an increase in number of papers with an annual rate of 22.9% (Figure 2). Although the search was performed for the 2008–2023 time period, the first paper that met all the established criteria was published in 2010, 72% of the selected papers were published in the past five years and the average number of publications per year was 15.4. This indicates that BIM has been a widely explored topic, however, the topic of contract management of BIM-based projects has only recently become explored. The number of publications increased after 2018, which coincides with the upsurge of public initiatives aimed at promoting and regulating the use of BIM in public projects in the five countries, namely USA, UK, Finland, Hong Kong, and Singapore (Mustaffa, Salleh & Ariffin, 2017).
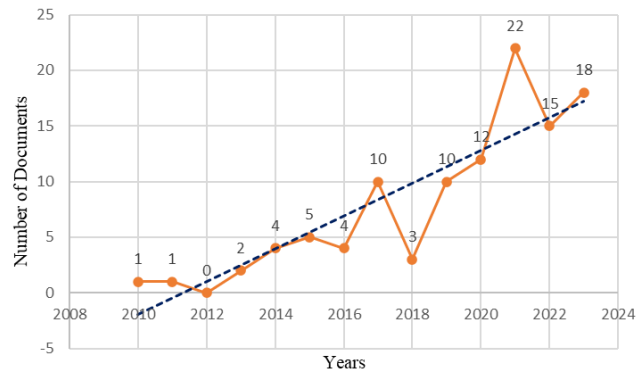

Figure 2. Annual Distribution of the Published Articles

Overview of the Main Journals and Topics of the Published Papers

The selected papers were published in 43 different sources, mostly engineering, management and legal-related journals. However, only 18 of those sources published more than one paper on the explored topic. Table 1 shows the distribution of papers across sources that published four or more papers from 2008-2013 and the Impact Factor (IF) of each journal, according to Journal Citation Reports (JCR) from Clarivate Analytics 2022. Almost half (49, 46%) of the selected papers were published in the top five sources, which indicates that this research topic is published in a small group of journals and needs to be further explored. The largest number of papers was published in the Journal of Legal Affairs and Dispute Resolution in Engineering and Construction, followed by Engineering Construction and Architectural Management, and Automation in Construction. As the subsequent results reaffirm, the scope of journals with the highest number of published papers on the topics suggests that one of the predominant research areas in the domain of contract management of BIM-based projects is the legal aspects of contracts.

Additionally, the IF is an indicator of the quality and credibility of research published in the journal and a high IF often represents a broader consensus within the scientific community. From this perspective, high number of papers published in journals with lower IF suggest that the research on contract management of BIM-based projects is still emerging and that high-impact journals might prioritize more established or broadly relevant BIM-related topics. It is also important to note that if a

journal is newly established or has a narrow target audience, the IF metrics is lower (Torres-Salinas, Valderrama-Baca & Arroyo-Machado, 2022).

Table 1
Source Ranking (based on number of published papers and journal impact factor)

Source Title	Papers	IF
Journal of Legal Affairs and Dispute Resolution in Engineering and Construction	15	2.5
Engineering Construction and Architectural Management	10	4.1
Automation in Construction	9	10.3
Journal of Construction Engineering and Management	8	5.1
Construction Innovation-England	7	3.3
Built Environment Project and Asset Management	4	2.2

The relevance of the selected papers was analyzed considering the average number of times paper was cited (TC) divided by number of years since paper was published (Y) because, for example, recently published paper has disadvantage if only the absolute number of citations is considered. The top 10 papers with TC/Y larger than 20 are presented in Table 2. Based on the content analysis, these highly relevant papers were classified into two main groups: 1) BIM adoption/implementation, and 2) BIM as a tool for contracts and integration with other technologies. The papers in Group 1 focus on the BIM implementation and treat the contract component as a primary factor or a potential barrier. The main paper contributions are related to the contractual aspects to be considered and potential issues. The papers in Group 2 focus on BIM integration with other technologies such as blockchain and smart contracts as an enabler for automated payments and lifecycle management. They also explore specific subjects within contract management, digital collaboration, and project delivery systems, and influences of the BIM use on these subjects.

Table 2
Paper Citations, Relevance, and Main Topics

Group	Authors of Paper (Year)	(TC)	(Y)	(TC/Y)	Main paper topics
#1	Porwal & Hewage (2013)	692	11	62.91	PDM and Best Value
#1	Chen *et al.* (2022)	58	1	58	Technologies Integration
#2	Elghaish, *et al.* (2020)	183	4	45.75	PDM +BC + BIM
#1	Alreshidi *et al.,* (2017)	218	7	31.14	BIM governance
#2	Franz *et al.* (2017)	212	7	30.28	PDM
#2	Götz, Karlsson and Yitmen (2022)	52	2	26	Life cycle management +BC + BIM
#1	Olanrewaju *et al.* (2020)	98	4	24.5	BIM Implementation + Barriers
#2	Chong & Diamantopoulos (2020)	97	4	24.25	BIM Implementation + Collaboration
#2	Merschbrock & Munkvold (2015)	206	9	22.89	BIM + Digital collaboration
#1	Al-Mohammad *et al.* (2023)	21	1	21	BIM Implementation + CF
BC = Blockchain; PDM = Project Delivering Method; SM= Smart Contracts; CF = Critical Factors					

These studies addressed high-interest societal issues, with a specific focus on the new technologies and operational challenges associated with BIM-based projects. Studies of Porwal and Hewage (2013), Merschbrock & Munkvold (2015), Alreshidi et al. (2017), Olanrewaju et al. (2020), and Al-Mohammad et al. (2023) provide valuable guidance to BIM users on how to potentially overcome implementation challenges. Furthermore, the integration of BIM with other technologies and practices paves the way for novel applications and enhanced functionalities as indicated by Franz et al. (2017), Chong and Diamantopoulos (2020), Elghaish et al. (2020), Götz et al. (2022), and Chen et al. (2022). It is important to emphasize that studies by Merschbrock and Munkvold (2015), Alreshidi et al.

(2017), and Al-Mohammad et al. (2023) not only contribute to but also support our research by highlighting contrasting issues and indicating the need for a deeper understanding of contracts within the context of BIM-based projects.

Main Themes of Papers on BIM and Contract Management

BIM has attracted a lot of attention globally; therefore, it is expected that BIM will be explored in a variety of viewpoints and contexts. A co-occurrence analysis of the authors' keywords using the VOSviewer software was employed to better understand current research focus and the interaction between themes, and to recommend potential future research directions. An analysis of co-occurrence considers the absolute number of occurrences of each keyword and the occurrences of keywords within the same paper. In the resulting network, the circle size assigned to each word represents the frequency of occurrences, and colors are assigned to groups of terms that often co-occur, creating clusters that may represent related themes, concepts, or topics. As stated earlier, the keywords went through a process of standardization by utilizing their synonyms.

Figure 4 shows the network of the keywords used three or more times; this constraint was applied to gather a better understanding of keyword interactions, excluding those that pertain exclusively to specific studies and might obscure the overall view. To interpret the network, it is important to note that size of circles expresses the intensity of utilization of the keyword, the thickness of the connection lines the intensity of the interactions between the connected words, and the grouped colors indicate cluster of keywords, related to the relationship between them in the literature.
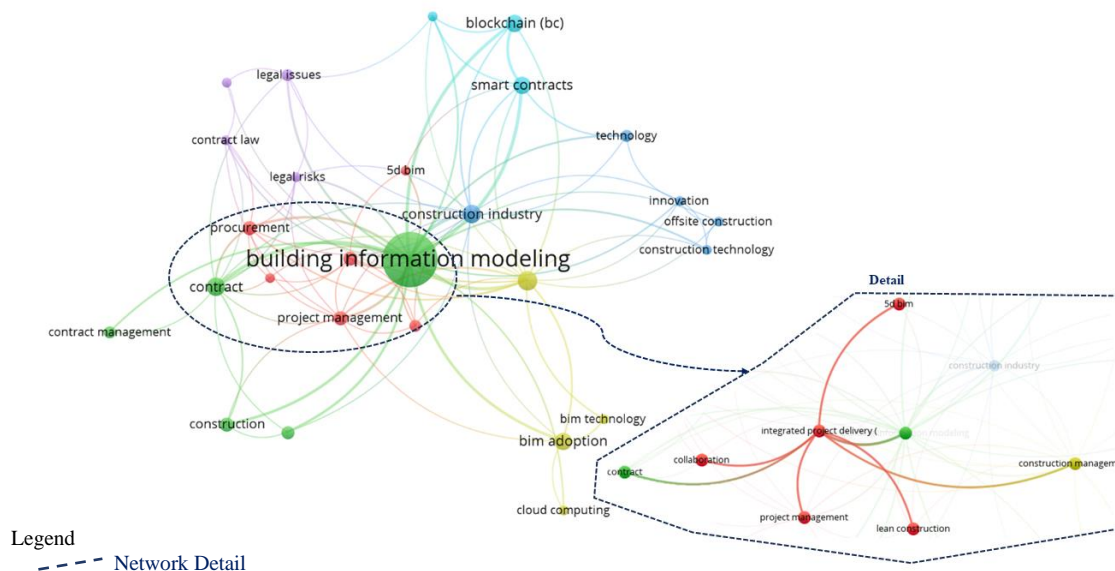

Figure 4. Keyword Co-occurrence Mapping

The co-occurrence analysis resulted in six clusters, represented by the color groupings. Red cluster focuses on the management area and introduces some terms related to agile management. Yasaman (2022) defines the agile project management in the construction field as a process which implements flexible and iterative strategies, leading to higher levels of innovation and value added for project owners. Green cluster has broader terms and indicates barriers to contract management in BIM

context. Blue cluster includes broader innovation and technologies topics while yellow and aqua clusters introduce technology in BIM adoption and contracts context. Finally, the lilac cluster focuses on BIM contract management from the legal perspective. The cluster analysis reveals the lack of integration between contract management of BIM-based projects and overall project management practices as well as the need for development of new processes and tools in this context. The keywords analysis indicates that the relationship between BIM-based projects and contract management is highly explored from the legal perspective. Legal issues are often pointed out as a barrier to BIM implementation, which is in line with the findings of Ku and Taiebat (2011). This finding also indicates the need for further research on contract management of BIM-based projects and the impact that the BIM use on projects has on the contract management.

As expected, "building information modeling (BIM)" was the most used keyword and had the most intense connections. However, considering that contract management was one of the main focuses of this review paper, the "contract" keyword appearing in the third place with only 10 occurrences indicates a gap in the literature on the connection between contract management and BIM-based projects. Figure 4 shows that contracts were directly explored in connection to "legal issues" and "contract law" as well as pointed as a barrier to full BIM implementation; thus, confirming the findings of our descriptive statistical analysis. On the other hand, the second most used keyword, "construction management," is connected to the integration of BIM with other technologies, adoption process, and management of new practices. The connection of "construction management" and "contracts" with practices such as "integrated project delivery" and "lean construction" (see details represented by dashed lines in Figure 4) in a context of contracts of BIM-based projects indicates the potential and beneficial relationship between the introduction of agile practices into the management models for BIM-based projects. This connection also indicates that the agile management approaches are yet to achieve their full potential in the construction management field, which confirms findings of Ku and Taiebat (2011), Gless, Halin and Hanser (2019), Leicht et al. (2020), and Boton et al. (2021).

Future Directions for Research on Contract Management of BIM-based Projects

A limited number of papers have comprehensively addressed the direct relationship between contract management and BIM-based projects (BIM-Contracts). As demonstrated by the paper focus analysis, most of the selected studies focused solely on specific facets of contract management. They identified the necessity to delve into contracts during BIM implementation, categorize these contrasts as challenges, and explore integration of BIM with other technologies. The findings of this bibliometric review suggest that future research should focus on:

- Identifying the drivers of and barriers to BIM-Contracts. There is a need to enhance our understanding of the BIM-Contracts aspects from a holistic perspective. The research on BIM-Contracts tends to focus on specific subjects of the contract management such as legal issues and payment processes; therefore, studies that explore the impact of BIM adoption on contract management are needed to ensure successful BIM adoption.
- Identifying aspects of contract management of BIM-based projects that can be standardized and aspects that need to be customized for the use in specific country. Given that contract-related subjects can vary among different countries, aspects that remain consistent across all construction contracts and those that do not should be identified. Consequently, it is crucial to explore how such aspects can be effectively translated for application within different countries.
- Development of practices, processes, and tools addressing contract management of BIM-based projects. The literature review revealed that contract management is an important

factor that influences the BIM adoption; however, the analysis of the main research topics indicated that only solutions for specific issues were found. Thus, there is a need for new contract management models (i.e., practices, processes, and tools) that integrate the contract management lifecycle synergistically.

- Exploring integration of BIM, contract management, and agile practices. The review results showed a clear connection between agile practices and the construction contract management. In addition to the already known synergy between BIM and agile practices, further research on integration of agile practices and BIM-Contracts is needed.

Considering the construction industry's need for guidance and support in overcoming challenges related to BIM-Contracts, there is a clear need to develop a benchmarking model for the adoption and operationalization of BIM-related contracts at both the organizational and project levels. The analysis of research focus has highlighted the emergence of new technologies and the importance of their integration with BIM. Future research efforts can investigate the drivers of and barriers to integrating technologies within the context of contracts.

Conclusions

This review paper extensively investigated the literature contribution to the research on contract management of BIM-based projects. The systematic review conducted by a bibliometric analysis of 107 articles extracted from six different databases explored the papers published in the past 15 years using a descriptive statistical analysis and keyword mapping. The data obtained by the initial literature search confirmed that BIM is a trending subject, with intense growth in the past five years. However, later, search and screening process indicated that the main research focus was on a holistic view of BIM while contract management of BIM-based projects has not been widely explored yet. Several limitations were encountered during this review since multiple databases were not standardized in terms of the bibliometric data provided by each database or the file formats that could be exported. This limitation constrained some of the analyses and required manual data treatment, exposing it to human error. Another limitation was the high number of papers in low-impact journals, affecting the generalizability of our findings. The practical implications of this research include the identification of the gap in literature on exploring the impact of BIM use on contract management in a holistic manner, considering real-world challenges and industry-utilizable solutions. Furthermore, this review paper suggested future research directions based on the state of art presented in the paper findings.

Acknowledgements

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