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Exploring the Legal and Contractual Impediments in BIM-based Application: A Systematic Literature Review

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Abstract

Building information modelling (BIM) has been theoretically proven to enhance the integration of design, construction, and operation processes, hence improving the holistic delivery of a construction project. Despite the many initiatives provided by the government across various countries to increase the uptake of BIM in project implementation, previous studies have discovered the many barriers to successfully applying BIM, among which are legal and contractual issues. Hence, the present study explores and reviews the current legal and contractual impediments that have restricted BIM-based applications in the construction industry. Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) were employed as a standard protocol for reviewing the current research in the existing literature. The overall search process resulted in a total of 44 articles, which were then thematically analysed to disclose the findings. The review derived eight key aspects, namely procurement method, contract documentation, time and cost, quality, coordination, liability, security and law and regulation and their respective subcomponents as the basis of legal and contractual impediments that could challenge the success of BIM application in construction projects. The study extends the existing knowledge of BIM application and the implications arising from its utilisation and offers some practical insights for design and construction practitioners to improve their roles, obligations, and compliance with BIM contractual requirements. Several recommendations are also made for future research on BIM functionalities for contract administration.

1. Introduction

The construction industry is one of the key sectors that involve various design services, manufacturing, and construction-related activities with a specific goal of achieving the required deliverables of a particular development. This sector is also widely regarded as complex and challenging [1]. Construction stakeholders

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must participate in dynamic processes to manage various works effectively and efficiently to avoid any uncertainties that could impede a project's success.

Some of the challenges and risks can be attributed to the disintegration of project execution and poor coordination when integrating design, construction, and operation processes, which may result in uneven collaboration among the project team [2][3][4][5]. With regard to overcoming this challenge, recent scholars have emphasised the importance of adopting technological advancements associated with industrialisation to support the dynamic ecosystem in various processes involved in the construction industry [2][6]. BIM is shown to be one of the most effective tools for supporting various integrations involving various disciplines. In BIM, all project stakeholders must collaborate on a single platform to design, construct, and operate various activities from the outset [6][7][8]. BIM also enhances visualisation, thus transforming traditional project management into a fully integrated digital practice. Many recent scholars claimed that using the BIM application could resolve unwanted conflicts as it supports the collaborative relationship between multi-party users [9]. Disintegration and fragmentation in the construction industry can be alleviated, and productivity can be increased by maximising BIM functionalities.

Nevertheless, the evolving criticisms on BIM-based applications need to be addressed at various levels in the supply chain. Some of the emerging challenges concern legal and contractual problems as the emerging risks in the construction industry [10][11]. This risk is attributed to the ambiguous roles and contractual obligations of the various parties involved in BIM-based collaboration [12][13]. For more than a decade, several scholars have emphasised that the existing regulatory and contractual frameworks for BIM application remain unclear to support of various contractual responsibilities in real project implementation [13][14][15][16][17][18]. This unpleasant scenario not only happened in developing countries but other well-developed countries from the Western context were also hampered by various legal and contractual challenges, such as in the U.S. [19][20][21] and the Australian construction industry [22][23]. The context from developing countries, such as Malaysia, demonstrated emerging barriers from the abovementioned aspects after a few studies conducted [24][25][26] exposed multifaceted BIM issues and challenges in real project implementation. Thus, diverse approaches have been introduced to improve BIM-based contractual guidelines [20][21][27][28]. However, research findings show that project BIM implementation activities benefit designers and general contractors differently. This difference is related to their distinct roles in BIM-enabled inter-organisational resource exchange processes, which is found lacking in the current construction contracts setting.

A theoretical foundation is required to outline the issues and their impacts on various BIM processes as part of a mitigation plan when managing BIM-based contract administration. Besides, the context of legal and contractual impediments arising from BIM-based applications must be learned from global perspectives to understand the existing gaps to lead future research direction. By contemplating the scenarios discussed previously, the current systematic literature review is grounded on the following main research question: what legal and contractual impediments to BIM-based application have impacted its use in the construction industry? To answer this question, this study outlines the theoretical and contextual dimensions learned from various countries associated with BIM-based applications, focusing on its legal and contractual aspects. The goal of this paper is critical; it aims to facilitate project employers or policymakers in defining the right contractual language for future BIM-based contractual guidelines in light of the emerging issues identified from the review. Contract management can be effectively managed only if the roles and responsibilities are clearly defined and drafted adequately in BIM contract guidelines.

2. Methodology

This study employed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) methodology introduced by Moher [29] to systematically review publications related to the legal and contractual issues in BIM-based applications. PRISMA has been adopted in various studies apart from construction-related studies for its capability to guide researchers in performing a review of high-quality and rigorous standards [30]. In this study, the terms and predefined keywords related to legal and contractual impediments must be searched extensively using a scientific process. Current scholars have agreed that PRISMA could enable the coding of information relevant to the context to be reviewed systematically [31]. In the initial stage, the research question for the systematic review must be defined concisely and logically to ensure that the methodology can be done accurately. The following parts of this paper describe the four key phases of the PRISMA process: (1) identification, (2) screening, (3) eligibility, and (4) analysis.

2.1 Identification

This study employed three main sources–Scopus, Web of Science (WoS), and Emerald databases–to search for articles related to BIM studies. The articles derived from each database were identified using search techniques such as boolean operators, phrases, truncation, and wildcards (Table 1). The search discovered 114, 69, and 126

records from Scopus, WoS, and Emerald databases, respectively. In this first stage of the systematic review process, 295 records from the combined sources were successfully retrieved.

Table 1 *Key search strings*

Database	Search string
• Scopus (publication year: 2010-2024)	TITLE-ABS-KEY (("building information model*" OR "BIM" OR "BIM implementation" OR "BIM technolog*" OR "BIM application" OR "BIM environment" OR "BIM implication") AND ("contract* impediment*" OR "contract* aspect*" OR "contract* challenge*" OR "contract* risk*" OR "contract* concern*" OR "contract* issue*" OR "contract* barrier*" OR "legal* impediment*" OR "legal* aspect*" OR "legal* challenge*" OR "legal* risk*" OR "legal* concern*" OR "legal* issue*" OR "legal* barrier*"))
• WoS (publication year: 2010-2024)	TS=(("building information model*" OR "BIM" OR "BIM implementation" OR "BIM technolog*" OR "BIM application" OR "BIM environment" OR "BIM implication") AND ("contract* impediment*" OR "contract* aspect*" OR "contract* challenge*" OR "contract* risk*" OR "contract* concern*" OR "contract* issue*" OR "contract* barrier*" OR "legal* impediment*" OR "legal* aspect*" OR "legal* challenge*" OR "legal* risk*" OR "legal* concern*" OR "legal* issue*" OR "legal* barrier*"))
• Emerald (publication year: 2010-2024)	"building information model*" OR "BIM" OR "BIM implementation" OR "BIM technolog*" OR "BIM application" OR "BIM environment" OR "BIM implication" AND "contract* impediment*" OR "contract* aspect*" OR "contract* challenge*" OR "contract* risk*" OR "contract* concern*" OR "contract* issue*" OR "contract* barrier*" OR "legal* impediment*" OR "legal* aspect*" OR "legal* challenge*" OR "legal* risk*" OR "legal* concern*" OR "legal* issue*" OR "legal* barrier*"

2.2 Screening

In this stage, the sorting of articles involved the removal of duplicate documents and a further screening process based on inclusion and exclusion criteria, as predetermined at the early stage of the study.

Table 2 *Inclusion and exclusion criteria*

Inclusion criteria	Exclusion criteria
• Publications from year 2010 until 2024 (January 2024) • All countries included • Limited to journal and selected conference proceedings only • Articles written in the English language	• Reports, books, theses and dissertations • Research other than the construction industry • Not BIM-based research • Not written in English

A total of 309 articles were screened based on (1) year of publication (period 2010–2024), (2) countries where the publications took place, (3) journals and conference proceedings (fulfilled the main context of study), and (4) those published in the English language. Hence, journal publications with a few conference proceedings were selected. Other documents were also included, such as reports, books, theses and dissertations. Hence, 79 articles were removed due to duplications, and another 148 were rejected due to not meeting the inclusion criteria (Table 2).

2.3 Eligibility

A total of 82 articles then qualified for the third stage: the quality assessment (Q.A.). The articles must be thoroughly evaluated based on specific questions that meet the needs and requirements concerning the study's context [32]. The Q.A. questions that were used in this stage comprised the following requirements: the objective relevance to the context of this study (QA1), the research methodology used (QA2), relevance of article to the construction industry (QA3), contextual relevance of article within BIM environment (QA4), and explanatory of the legal and contractual impediments in BIM application (QA5). A three-point scale consisting of yes (score=1), partial (score=0.5) and no (score=0) were used for the assessment (Table 3). Each article that passed this stage was selected based on an average score of at least 4/5 of the total score.

Table 3 *Overall results from the Quality Assessment (Q.A.)*

No	Author ID	Authors	Year	Quality Assessment					Score	Total (%)
				Q1	Q2	Q3	Q4	Q5		
				Obj.	RM	CI	BIM	Leg. & Ctt. Impediments		
1)	P1	Mohammadi et al.	2024	1	1	1	1	1	5	100
2)	P2	Jun et al.	2024	1	1	1	1	1	5	100
3)	P3	Alwee et al.	2023	0.5	1	1	1	1	4.5	90
4)	P4	Mahdian et al.	2023	1	1	1	1	1	5	100
5)	P5	Celoza et al.	2023	1	1	1	1	0.5	4.5	90
6)	P6	Nilchian et al.	2022	1	1	1	1	1	5	100
7)	P7	Faghihi et al.	2022	1	1	1	1	1	5	100
8)	P8	Malla et al.	2022	1	1	1	1	0.5	4.5	90
9)	P9	Mustaffa et al.	2021	1	0.5	1	1	0.5	4	80
10)	P10	Asare et al.	2021	1	1	1	1	1	5	100
11)	P11	Ragab & Marzouk	2021	0.5	1	1	1	1	4.5	90
12)	P12	Erpay and Sertyesilisik	2021	1	1	1	1	1	5	100
13)	P13	Ho	2021	1	1	1	1	1	5	100
14)	P14	Rodrigues & Lindhard	2021	0.5	1	1	1	0.5	4	80
15)	P15	Khawaja & Mustapha	2021	1	1	1	1	1	5	100
16)	P16	Alwee et al.	2021	1	0.5	1	1	0.5	4	80
17)	P17	Baharom at al.	2021	1	1	1	1	1	5	100
18)	P18	Jobidon et al.	2021	0.5	1	1	1	0.5	4	80
19)	P19	Assaad et al.	2020	0.5	1	1	1	1	4.5	90
20)	P20	Abd Jamil & Fathi	2020	1	1	1	1	1	5	100
21)	P21	Liao et al.	2020	1	1	1	1	0.5	4.5	90
22)	P22	Fan	2020	0.5	1	1	1	1	4.5	90
23)	P23	Almarri et al.	2020	0.5	1	1	1	0.5	4	80
24)	P24	Babatunde et al.	2020	0.5	1	1	1	0.5	4	80
25)	P25	Almarri et al.	2019	1	1	1	1	1	5	100
26)	P26	Abd Jamil & Fathi	2019	1	1	1	1	1	5	100
27)	P27	Dixit et al.	2019	1	1	1	1	1	5	100
28)	P28	Arshad et al.	2019	1	1	1	1	1	5	100
29)	P29	Jo et al.	2018	1	0.5	1	1	1	4.5	90
30)	P30	Abd Jamil & Fathi	2018	1	1	1	1	1	5	100
31)	P31	Fan et al.	2018	1	1	1	1	1	5	100
32)	P32	Barakeh & Almarri	2018	0.5	1	1	1	0.5	4	80
33)	P33	Sardroud et al.	2018	0.5	1	1	1	0.5	4	80
34)	P34	Chong et al.	2017	1	1	1	1	1	5	100
35)	P35	Ussing et al.	2016	1	1	1	1	1	5	100
36)	P36	Pandey et al.	2016	0.5	0.5	1	1	1	4	80
37)	P37	Manderson et al.	2015	1	1	1	1	0.5	4.5	90
38)	P38	Hsu et al.	2015	0.5	0.5	1	1	1	4	80
39)	P39	Olatunji & Akanmu	2015	1	1	1	1	1	5	100
40)	P40	Fan	2014	1	1	1	1	1	5	100
41)	P41	Kuiper & Holzer	2013	0.5	0.5	1	1	1	4	80
42)	P42	Arensman & Ozbek	2012	1	1	1	1	1	5	100
43)	P43	Olatunji	2011	1	1	1	1	1	5	100
44)	P44	Mcadam	2010	1	1	1	1	1	5	100

In total, 44 articles passed the eligibility stage, which means that 38 articles were excluded after the entire Q.A. phase was completed. The excluded articles do not sufficiently focus on BIM-related construction industry studies, and most of the articles do not address legal and contractual impediments in BIM application. Two of the studies discuss challenges that hampered the adoption of Construction 4.0 rather than specific legal and contractual challenges related to BIM adoption and strategies that must be considered for mitigating the risks of BIM for international construction projects, rather than the legal and contractual risks associated with BIM uses [33]. Thus, through the Q.A. process, only articles that mention legal and contractual impediments (including the associated issues, challenges, risks, barriers, and concerns) as the primary unit of analysis were selected for the final review.

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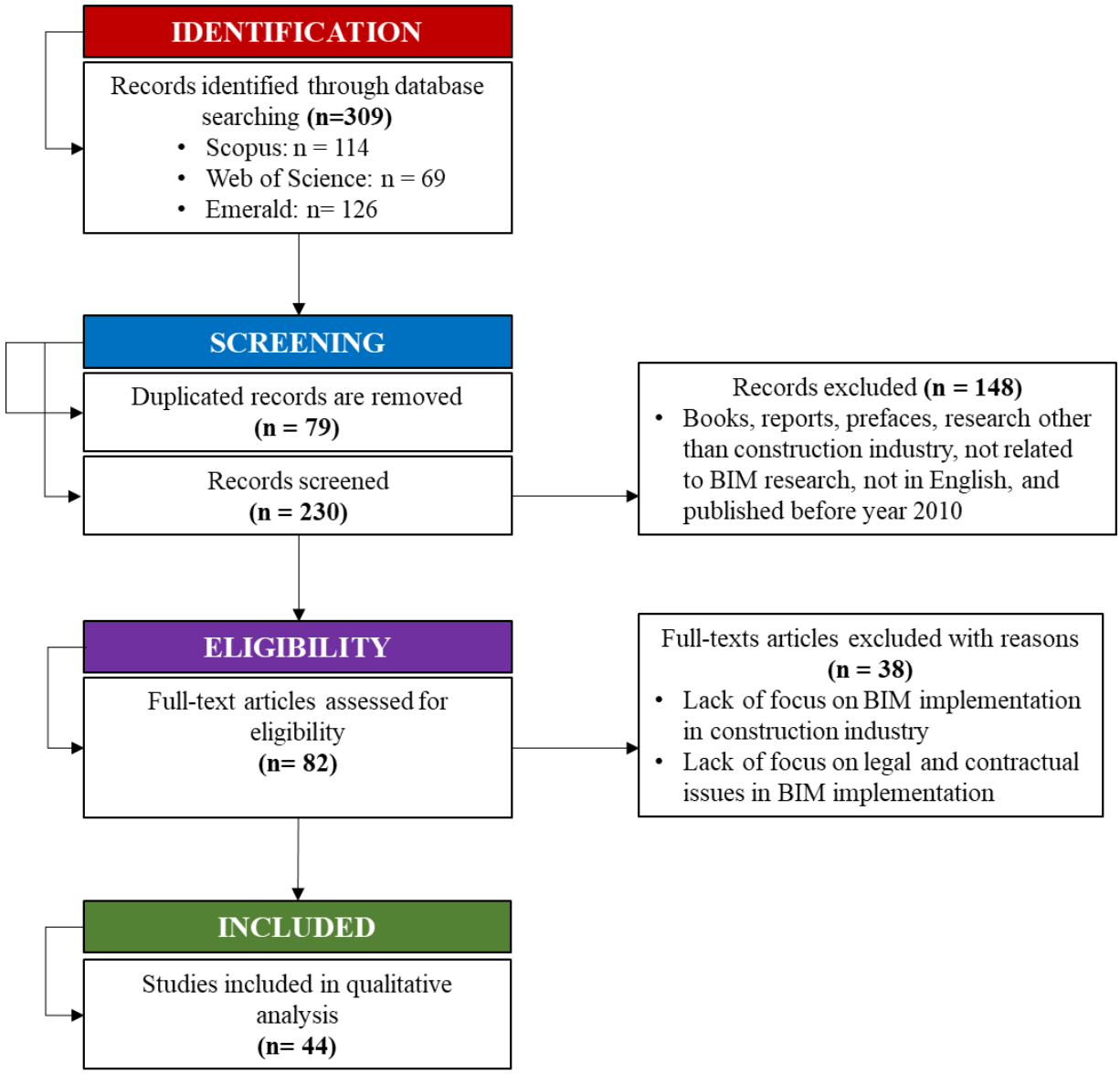

Fig. 1 *Flow diagram of the systematic review (adapted [29] Moher et al., 2009)*

2.4 Analysis

For data analysis, the thematic analysis steps proposed by Braun and Clarke [34] were employed. A qualitative data analysis software, ATLAS.ti 23, was utilised extensively when developing the initial codes related to the study 35]. The 44 articles were analysed thematically, and the code dimensions were then categorised into more meaningful code groups to represent the key aspects and subcomponents of legal and contractual impediments arising from BIM-based applications in the construction industry. Figure 1 summarises the overall systematic review process involved in the study.

3. Results and Discussion

The findings are presented in two subsections: quantitative and qualitative. From the analysis of the 44 articles, the word cloud (Figure 2) shows *BIM* to be the most frequent word appearing in most of the articles (8477 times). Other words, such as *contract* and *construction*, stand at the second and third highest in rank, appearing 1735 times and 1552 times, respectively. Since the study also contextually looks into the 'legal' aspects involving BIM-based applications, the word cloud analysis found that the word was mentioned 1036 times in the articles reviewed.

Fig. 2 *Word cloud on the word frequencies from the selected 44 articles*

3.1 Quantitative Results

As shown in Figure 3, seventeen studies were examined and reviewed by Eastern scholars [4][12][24][25][26][27][28][36][37][38][39][40][41][42][43][44][45]; six studies concentrated on the U.S. context [19][20][21][46][47][48]; five studies focused on the Australian context [13][14][22][23][49]; four studies focused on the Iranian construction industry [11][50][51][52]; two studies revolved around UAE[10][15]; and another two studies centred on Danish BIM-based application [53][54]. Other countries such as the UK, Canada, India, Egypt, Nigeria, Pakistan, and Turkey represent a single study, respectively, on legal and contractual contexts of BIM-based applications [16][17][18][55][56][57][58]. The findings of the studies indicate that there are several categories of challenges that affect the implementation of BIM, both within and between organisations.

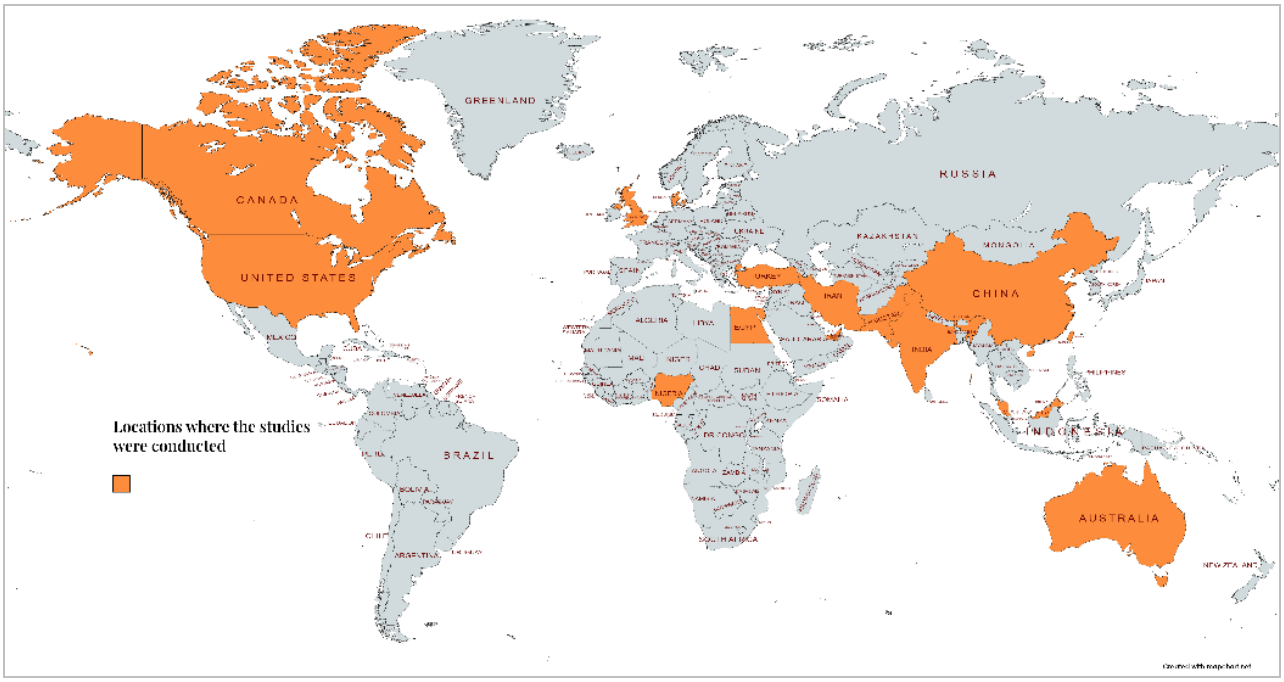

Fig. 3 *Locations where the studies were conducted (adapted from www.mapchart.net)*

The trend of publications has increased tremendously over the years due to the rising number of challenges hampering the real practice of BIM-based applications (Figure 4).

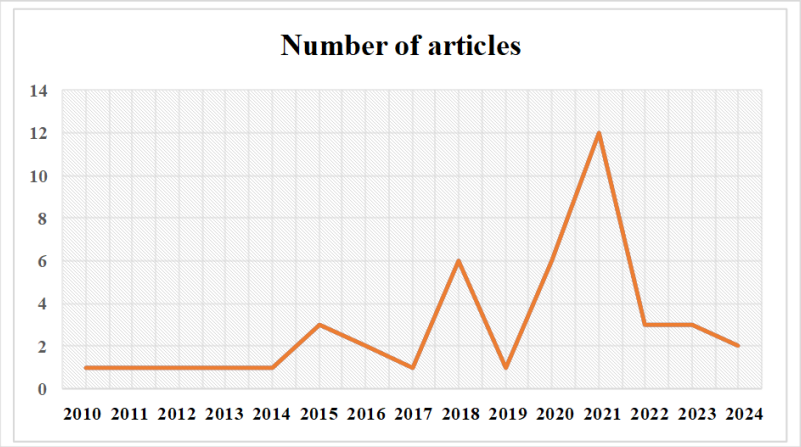

Fig. 4 *Articles published between 2010 and 2024*

Only one article was published annually between 2010 and 2014. The trend somehow increased as six articles were published in 2018 and 2020. The highest record was found in 2021, with 12 articles discussing the legal and contractual issues of BIM implementation in the construction industry. For the past decade, a few top-tier journals have received increased intentions from BIM researchers to highlight the importance of BIM implementation and its legal and contractual implications from academic perspectives.

As shown in Table 4, the Journal of Legal Affairs and Dispute Resolution in Engineering and Construction and the Journal of Construction Engineering and Management are the two top-ranking journal publications chosen by BIM scholars to discuss their empirical findings arising from BIM implementation. A few Scopus-indexed proceedings, such as the Construction Research Congress and Proceedings of the 3rd International Sustainable Buildings Symposium, were also considered in this study. These articles were chosen due to the high methodological quality presented and discussed [10][25][36][48][52][54].

Table 4 *Distribution of research publications*

Publication	Year															Total
	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	
Buildings														1		1
Built Environment Project and Asset Management						1			1							2
Construction Innovation												1				1
Engineering, Construction and Architectural Management											2					2
Facilities									1							1
Journal of Construction Engineering and Management					1			1		1	2	1				6
International Journal of Building Pathology and Adaptation												1				1
International Journal of Sustainable Construction Engineering and Technology												1				1
International Journal of Construction Education and Research			1													1
International Journal of Law in the Built Environment	1															1
International Conference on Construction Digitalisation for Sustainable Development												1				1
Journal of Legal Affairs and Dispute Resolution in Engineering and Construction												2	3	1	1	7
Journal of Information Technology in Construction		1										1				2
Journal of Advanced Research in Applied Sciences and Engineering Technology															1	1
Journal of Construction Economics and Building				1		1										2
Journal of Construction in Developing Countries												1				1
Journal of Facilities Management												1				1
Journal of the Chinese Institute of Engineers											1					1
Laws												1				1
Malaysian Construction Research Journal												1				1
New Design Ideas														1		1
Technological and Economic Development of Economy									1							1
Construction Research Congress (Proceeding)							2									2
Proceedings of 3rd International Sustainable Buildings Symposium (Proceeding)									1							1
10th Asia Pacific Structural Engineering and Construction Conference (Proceeding)											1					1
4th International Conference on Civil, Offshore & Environmental Engineering (Proceeding)									1							1
35th International Symposium on Automation and Robotics in Construction (Proceeding)									1							1
Proceedings of the Institution of Civil Engineers (Proceeding)						1										1
Total :	1	1	1	1	1	3	2	1	6	1	6	12	3	3	2	**44**

Overall, 91 % of the articles are related to indexed journal publications that focus on BIM-related legal and contractual contexts and have undergone the Q.A. process during the eligibility stage, as discussed earlier in the research methodology section of this paper. The patterns and relationships are formulated to address the research question, yielding eight key aspects of legal and contractual impediments in BIM-based applications. These aspects are discussed further in the following section.

3.2 Qualitative Results

In this section, eight legal and contractual aspects that emerged from the thematic reviewing process are discussed, namely:
(1) procurement method;
(2) contract documentation;
(3) time and cost;
(4) quality;
(5) coordination;
(6) liability;
(7) security; and
(8) law and regulation.

These results answer the research question, 'What legal and contractual impediments to BIM-based application have impacted its use in the construction industry?' The findings will be discussed in the following subsections.

3.2.1 Procurement Method

This part discusses the impediments to BIM legal and contractual practices involving the conventional procurement methods used in the construction industry. The subcomponents that emerged from the review include the collaborative procurement environment, scope of works, and F.M. provisions (see Table 5).

Table 5 *Legal and contractual impediments related to the 'Procurement Method'*

Aspect	Subcomponents	Authors	Number of articles
Procurement Method	Collaborative procurement method	[4][24][47][50][51]	5
	Scope of works	[11][18][19][27][38]	5
	F.M. provisions	[12][15][22][26][36][45][49]	7

Collaborative procurement environment. A few setbacks were debated among the BIM scholars, such as the fact that various existing procurement methods still cannot improve the interaction between the project stakeholders due to the fragmented nature of the industry. Many parties still face complexities and reluctance to use plugged-in software and cutting-edge technologies that supposedly could improve their collaborative works across different BIM functionalities [4][24][47][51]. The lack of contractual guidelines to support collaborative working processes could become the main reason why many parties are still unwilling to work collaboratively [5]. The findings indicate that the primary approach to getting stakeholders to implement BIM is by requiring its use in procuring all construction projects and thereby establishing BIM as a "Black Box." This Black Box is a closed network component that includes instructions for using BIM in projects conducted by the client. However, there have been difficulties in accepting this Black Box, resulting in a varied impact on the demand for BIM in procured construction projects.

Scope of works. The existing literature indicates that unclear relationships between the client, contractors, designers, and other project stakeholders happened due to poor working relationships and grey areas when engaging multiple disciplines via collaborative processes [27][38]. Some designers stressed that they must be liable for design contributions that are at times beyond the original scope of duty [43]. Thus, a clear guideline to define the structures and responsibilities could be considered a panacea to solving issues involving risk allocation and professional liability [11][18][19].

F.M. provisions. Issues on how BIM could support facilities management have been debated by past scholars in the Western and Eastern contextual since many uncertainties on the contractual provisions to support the handling process for F.M. use are not being resolved adequately [12][15][22][26][36][45][49]. Despite the many benefits that could be gained by the facility owner when using BIM, the final models still do not incorporate sufficient data and information that are crucial for operation and maintenance. Besides, some asset requirements were too vague [24]. Facility owners preferred to develop the information system for F.M. use during the operation stage. Thus, more priority must be included in the contract requirements to ensure the modelled information is adequately defined for F.M. purposes [19].

3.2.2 Contract Documentation

Several articles raise issues on legal and contractual matters related to BIM-based contract documentation, such as related BIM requirements in the contract, EIR, BIM protocol, and BEP as required in BIM-based contractual guidelines and the mechanism for dispute resolution. These subcomponents were grouped based on the topics disclosed in the thematic review analysis (see Table 6).

Table 6 *Legal and contractual impediments related to 'Contract Documentation'*

Aspect	Subcomponents	Authors	Number of articles
Contract Documentation	BIM requirements in the contract	[11][13][16][21][25][26][28][44]	8
	EIR, BIM protocol and BEP	[13][15][21][23][36][37][50][56]	8
	Mechanism for dispute resolution	[14][17[20][28][37][44]	6

BIM requirements in the contract. The existing contractual guidelines used in the contract for BIM-based projects are still not unified and standardised to solve contract-related issues, such as the priority of documents to be included in the contract, provisions that stipulate the parties' obligations related to BIM duties and responsibilities; and the remedies for any breach of contract arising from BIM implementation [13][16][21][26]. As proven in the empirical study [25], many construction players argued that the absence of a standard form of contract for BIM-based projects could hinder the delivery of design and construction processes. Current practice has at least two legal structures incorporating BIM requirements in construction contracts. First, some countries have incorporated a separate addendum [11] that includes BIM requirements and named the particular addendum as a co-contract, inferential, and accommodation document [44]. Other countries may provide their own BIM standard form that explicitly covers all related BIM contractual provisions, such as those practised in Hong Kong, the U.K., and the U.S. [28]. However, recent scholars mentioned that conflict between different provisions in the addendum and main contract could lead to disputes if no express provisions prioritising which document shall take precedent are clearly defined in the contract documents.

EIR, BIM protocol, and BEP. Having sufficient Employer's Information Requirements (EIR) is crucial to ensure all coverage related to BIM risk allocation is defined clearly to avoid any potential disputes arising in the parties' relationships [13][37][50]. Nonetheless, one study has argued that some existing BIM-based protocols undervalue the complexities of information in the models [15]. Besides, the BIM execution plan (BEP) that is supposed to be prepared in detail by contractors and other project members at the early stages should not be too theoretical and should serve as the main guide to maintaining BIM-based sequences [23][36][21][56]. The team members must ensure that any additional information introduced while collaborating via BIM-based processes is regularly updated, such as schedules, modelling sequences, and naming conventions.

Mechanism for dispute resolution. Because disputes and conflicts can arise in multi-party relationships, a mechanism for dispute resolution is still lacking in BIM-based contract clauses [37]. Some existing contracts, such as the New Engineering Contract (NEC) and the International Federation of Consulting Engineers (FIDIC), do not include an explicit provision to resolve conflicts involving data extracted from the BIM model [28]. Although not many court cases were reported a decade ago [14], the BIM contract requirements must be aligned with the current situation [17[20][44]. This is important to ensure that collaborative dispute resolution can be used to facilitate disputed parties' disagreement or any event related to the breach of contract.

3.2.3 Time and Cost

This part highlights the patterns in topics related to time and cost that impede BIM application in the construction industry. The following three subcomponents are discussed: fees and charges, cost estimation and timeline to complete deliverables. The breakdown of previous studies related to this theme is shown in Table 7.

Table 7 *Legal and contractual impediments related to 'Time and Cost'*

Aspect	Subcomponents	Authors	Number of articles
Time and Cost	Fees and charges	[4][12][14][16][37][43][46]	7

Cost estimation	[13][18][26][53][54]	5
Timeline to complete deliverables	[15][18][28][41]	4

Fees and charges. Several studies have highlighted improper financial strategies, including fees and rewards, which remain unclear when handling BIM-based processes. Many studies have criticised the reliance on existing scales of professional fees to cover expenses incurred by project stakeholders [4][12][14][16][37][43]. Moreover, it can be argued that extensive work is needed when developing BIM models compared to conventional workflows [46], especially for design works.

Cost estimation. Also mentioned in the literature is that the credibility of data that mixes information from 2D drawings and 3D models becomes the main barrier to verifying the accuracy of quantity extraction [13][26] for cost estimation [54]. Some parties have faced several contractual challenges in collaborating via 5D BIM due to the absence of detailed information provided in the BIM models [18]. Such would suggest that the lack of a standard method for measuring code objects in the BIM model is a risk that impedes BIM implementation. Measurement quality can be improved if all parties agree to their early involvement [53]. Various processes could be scrutinised concurrently to ensure that models are developed with high integrity and reliability for determining overall costs, particularly during the pre-contract stage.

Timeline to complete deliverables. Previous studies have observed that some pertinent issues involving time management had impacted the process of delivering BIM-based projects at the required stages defined in the contract. The risks of "holding data" could lead to delays in data transfer due to the huge amount of BIM data that must be taken care of while executing BIM systems [15]. Adequate timelines are required in the form of schedules to measure the success of BIM implementation [41]. The lack of emphasis on the completion of the detailed design stage should be improvised so that up-front efforts can be prioritised and many reworks during the construction phase can be overcome [18][28]. As time is of the essence in project completion, issues involving time management to complete the design and construction processes must be considered systematically.

3.2.4 Quality

The results for this part describe the patterns of quality-related legal and contractual issues that emerged from the thematic analysis (see Table 8). Three subcomponents revealed that the barriers related to model management, mistrust and plagiarism and integrity of data and model are the challenges faced by industry players while working in the BIM environment.

Table 8 *Legal and contractual impediments related to 'Quality'*

Aspect	Subcomponents	Authors	Number of articles
Quality	Model management	[4][24][41][47][51][54]	6
	Mistrust and plagiarism	[13][28][41]42][54]	5
	Integrity of data and model	[17][24][26][43]	4

Model management. Many studies have highlighted the association of model management with quality control when monitoring BIM workflow. Failure to update BIM information regularly could lead to quality issues that may impact the use of BIM by F.M. personnel [47]. More challenges could happen when the contract's language fails to describe the protocol for model exchange and how the data is protected against errors and corruption during BIM execution [13][24][41][51][54]. Hence, unclear contract requirements on model management could impact the parties' relationship while integrating with BIM-based processes.

Mistrust and plagiarism. Issues related to plagiarism could occur when the BIM information is shared among the project stakeholders or if some of the sensitive information is used by an unauthorised person while working on the digital platform [13][28][41]42]. In a different situation, some mistrust issues may emerge during the exchange of information from one model to another before all design is fully coordinated [54]. The issues are crucial to be addressed to assist professionals in comprehending the significance of sharing information and in determining whether the data they regard as "sensitive" and "confidential" is genuinely confidential or if it is non-sensitive data that helps in decision-making.

Integrity of data and model. BIM models must be audited regularly to check for the compliance of the BIM deliverables with the contract requirements. Nonetheless, several studies have found that some practices are exempted from this obligation due to a lack of details and procedures [26] inspecting model development [24][43]. BIM users should be held responsible for maintaining the model's integrity, although they also incurred other limitations to controlling other parties' works when collaborating on a single platform [17]. Further validation must also be done by higher authorities to improve the reliability of BIM data and information for future usage until the F.M. stage.

3.2.5 Coordination

Several articles have raised issues on legal and contractual matters related to BIM-based coordination, such as variations and modifications, data interoperability, subcontracting, and the site work approval process during BIM implementation. These subcomponents were grouped accordingly to the thematic review analysis (see Table 9).

Table 9 *Legal and contractual impediments related to 'Coordination'*

Aspect	Subcomponents	Authors	Number of articles
Coordination	Variations and modifications	[4][11][17][21][24][25][42][50][51]	9
	Data interoperability	[10][14][20][23][44][47][48][50][58]	9
	Subcontracting	[18][19][21][23][24][26][28][54][57]	9
	Site work approval process	[12][15][51]	3

Variations and modifications. As highlighted in the literature review, excessive changes could still occur when coordinating the design and construction processes via BIM cooperation. Due to alterations made by an unauthorised person, issues with data reliability could take place, and subsequent rectification that could impact the time and cost due to unnecessary work could jeopardise the whole coordination process [11][24][42][50]. Thus, it is difficult to solve problems associated with design changes and modifications without clear descriptions of the parties to solve clashes stated in the execution plan [4][17][21][51]. Although many studies found that BIM could solve 1many variations compared to the conventional process, human and technical errors are inevitable [25]. The emergence of coordination-related issues in BIM contracts results from the blurred understanding between the parties that cause modifications to the model details.

Data interoperability. Previous studies have sparked some debates about data interoperability issues, such as the unresolved compatibility of BIM software when exchanging data during collaboration. Several researchers have agreed that the lack of compatibility has led to many discrepancies due to different software formats that impair the allocation of liabilities among the project team [14][20][23][44][47]. Moreover, legal issues such as data loss and errors [10][50][51] could be claimed only by the aggrieved party limited to the purchasing cost from the manufacturer only [48][58]. Hence, the limitations associated with software interoperability must be resolved immediately to avoid the failure to coordinate BIM-based processes from the beginning.

Subcontracting. In subcontract activities, coordination errors could occur, particularly when complex interactions are involved between various subtrades. Many scholars agree that the lack of BIM skills and competencies has convoluted the coordination of various subtrades via BIM working processes [24][54][57]. Only limited BIM contractual guidelines include the requirements for managing digital data that involve subcontractors and suppliers in the industry, whereas these parties should also be involved in synchronising their design contributions [21][23][28]. Some implications during the construction phase can be seen when some modelling details were not coordinated properly during the design stage, leading to other risks such as reworks and claims on additional expenses incurred by the suffering party [18][19][26]. Thus, the direct involvement of subcontractors from the designing stage must be improvised to overcome contractual issues that could cause delays in project completion, and higher expenditure must be incurred to complete the BIM deliverables.

Site work approval process. 4D BIM simulation has also been minimally used by construction players, despite some BIM objectives necessitating the contractor to perform site work that integrates BIM models. Some contractors still encountered challenges while working in BIM process and discovered inconsistencies in managing data from the 3D to 4D model [15][51]. When a client checked and audited a BIM progress using the

model, some of the contractors were reported to have not persistently complied with the requirements [12]. This issue requires immediate attention so that the grey line between too-much or too-little details related to the BIM data required for construction scheduling can be identified correctly so that the site activities can be monitored interactively using the BIM model.

3.2.6 Liability

This part indicates the patterns of liability-related legal and contractual issues that emerged from the thematic review analysis (see Table 10). The four subcomponents revealed that the challenges industry players face when working in BIM-based processes are related to the ownership of the BIM model, standard of care, and ongoing protection and licenses.

Table 10 *Legal and contractual impediments related to 'Liability'*

Aspect	Subcomponents	Authors	Number of articles
Liability	Ownership of BIM model	[11][12][13][18][38][39][41][42][44][46][51][56]	12
	Standard of care	[4][11][12][38][45][49][50][58]	8
	Ongoing protection and licenses	[15][27][38][40][50][52]	6

Ownership of BIM model. The main problem with managing digital data is the ownership of the BIM deliverables, particularly the final BIM model. This matter raises many concerns [11][13], particularly from the project stakeholders concerned about violations, intricacies, and repurposing that could happen if the other party uses the data and information for wrongful functions [18][46][51][56]. It is crucial for the infringement on IPR to be crystallised between the parties, particularly by declaring the types of contributions owned by the authorised party so that others will be prudent in using or sharing the data for other purposes [39]. Past researchers have highlighted that the client would own the intellectual property because he/she is usually the paymaster who will operate the building after completion [38][41]. However, the fact that various parties jointly contribute to the final output of BIM processes raises other critical issues, particularly for designers who want to claim ownership of their design contribution [12][42][44]. Clearer terms and provisions must be included in BIM contracts to ensure that the uncertainties regarding BIM model ownership can provide fairness to all contributors who may challenge their rights if unsatisfactory consequences occur after project completion.

Standard of care. The issue of design liabilities arising from BIM implementation was raised more than a decade ago by scholars who were concerned about the impact of collaborative design on professional relationships [4][11][38][58]. The is still uncertainty about the right to claim any damage or losses for risks involving professional liability [49] when the deployment of BIM is conducted without authorisation [50]. A higher standard of care is expected due to the liability gap between the software used when collaborating via the BIM environment [12][45]. Therefore, it is advisable to use contracts that incorporate a strong resource management strategy in project, which is a fundamental aspect of BIM management. This can lead to advantages such as increased efficiency, enhanced coordination, and a reduction in errors and redundant tasks.

Ongoing protection and licenses. As implied from the literature, the liabilities concerning the copyright to reuse BIM data are still being criticised due to the lack of understanding about licensing agreements involving multiple users when producing models as part of BIM deliverables. Currently, some existing contractual guidelines still lack the proper procedures on how subcontractors and other contributors can use the licenses correctly [15][27][38][40][50][52]. A standardised guideline that provides the rights to use and reuse BIM data is urgently needed to improve the adoption of BIM technology in the current situation.

3.2.7 Security

The results and discussions for this theme denote the patterns of security-related legal and contractual impediments that emerged from the thematic review analysis (see Table 11). The three subcomponents derived indicate that the barriers related to data loss and corruption, access and sharing and risks of electronic files are the real challenges faced by industry players while working in the BIM environment.

Table 11 *Legal and contractual impediments related to 'Security'*

Aspect	Subcomponents	Authors	Number of articles

Security	Data loss and corruption	[4][15][43][44][48][56]	6
	Access and sharing	[13][21][28][38][48]	5
	Risks of electronic files	[26][42][47][52]	4

Data loss and corruption. Some researchers have argued that the issues of failure to comply with protocol, theft, errors in BIM software, and file corruption could cause economic loss when handling the uncertain process of managing BIM-based data [15][43][44][56]. The empirical evidence from the real projects also suggests that the difficulty of responding to events related to data loss is due to the lack of provisions to handle this kind of situation stipulated in the BIM contracts [4][48]. More advanced mechanisms, rather than the traditional approach, must be considered to improve the security aspects of BIM-based applications.

Access and sharing. Data confidentiality and sharing issues were discussed in one of the U.K.'s BIM court cases, *Trant Engineering Limited v. Mott MacDonald* (2017) EWHC 2061 (TCC), in which the client was denied access to the BIM platform due to non-payment of professional fees. This case demonstrates that limited accessibility via BIM collaboration can still be disputed in litigation due to dissatisfaction that arises while working in an integrative platform [28]. [48] further criticised that the current contracts are still unclear about who is granted access to review or contribute to the BIM platform. The sharing activities cannot be overlooked because BIM applications could lead to many data privacy issues [13][21][38]. Precautionary measures must be performed with due diligence to avoid potential disputes arising from the sharing and accessibility of data by the authorised or unauthorised party involved with the project.

Risks of electronic files. Other risks involving electronic files are also highlighted in the existing literature to disclose the legal barriers that emerged from BIM-based processes. Besides data manipulation, cybersecurity threats, such as hackers attacking sensitive information, become a major challenge to maintaining high-security levels when managing digital data [26][42][47]. It is not just the organisations and projects that could be affected by cyber threats. Various digital attacks are still possible in the government administration [52]. The migration toward e-communication has triggered concerned parties about the reliance on data security and protection, which is crucial when collaborating via BIM-based processes.

3.2.8 Law and Regulation

This section highlights the patterns in topics related to law and regulation that impact BIM-based applications in the construction industry. Two subcomponents are discussed: electronic-based evidence and BIM mandates and regulations. The breakdown of previous studies related to this theme is presented in Table 12.

Table 12 *Legal and contractual impediments related to 'Law and Regulation'*

Aspect	Subcomponents	Authors	Number of articles
Law and Regulation	Electronic-based evidence	[13][14][15][16][21][23][42][45]	8
	BIM mandates and regulations	[10][14][21][42][50][53][55][57]	8

Electronic-based evidence. The admissibility of digital representation for court administration is still one of the legal risks in BIM contract administration [13][14][15][16][21]. Furthermore, judges and litigation experts are still not familiar with BIM. However, more presence of BIM-based cases could help them reach a certain level of perfection in resolving disputes arising from BIM applications [42]. However, the terms or provisions in the contract must stipulate 'e-contracting' and 'e-communication' [23][45] to ensure that any jurisdiction involving a digital environment could safeguard all parties' interests. The notion of BIM as a single source of truth must be warranted in a legalised format to avoid future uncertainty.

BIM mandates and regulations. Numerous studies have highlighted the impacts when BIM is not mandated in construction contracts or regulated as government policies, which become the main reason for the difficulty of BIM in getting full support from industry players [10][42][53][55]. Due to various legal instruments, such as regulatory frameworks and industry standards that are fragmented, many parties are stuck in normative fog due to the complexities of integrating their works when using BIM in project administration [14][21][50][57]. The need for regulation is important to be mandated by the government to reduce conflicts arising from BIM implementation.

Summarily, it could be indicated that there is an inadequate connection between the credibility of digital models and the current contractual practices to support the various complexities and integration processes in BIM-based applications. As presented in Figure 5, a framework comprising the key aspects and their subcomponents that constitute the legal and contractual impediments in BIM-based applications was propositioned through the thematic review analysis of the selected review articles.

4. Future Research Directions

The preceding section highlighted various BIM challenges; this section identifies potential research directions that can be considered to enhance BIM-based applications from legal and contractual perspectives.

4.1 Process Protocol for BIM-based Contract Administration

At various stages of BIM deployment, it is necessary to clearly understand the legal and contractual considerations to support various design and construction tasks in project administration. A process protocol framework comprising high-level contractual roles and obligations undertaken by various BIM stakeholders should be considered during real project implementation. Following past research (Ah Ahbabi, 2014; Al-Adwani, 2021), the process protocol principles could add many values throughout the BIM supply chain that should be considered pivotal to achieve full collaboration. The process protocol incorporated BIM contract administration could be explored in a future study to transform the conventional process of managing construction contracts that are fragmented and prone to dispute.

4.2 Specific BIM Contract for Construction Projects

Future research should develop a holistic standard form of contract specifically for BIM projects to solve the issues of uneven contractual risk allocations when implementing BIM in construction projects. It is crucial to take into account the key aspects mentioned above and as the baseline to improvise contractual requirements specifically for BIM contracts. It is believed that definite roles and responsibilities at a functional level amongst various project stakeholders could guide them to fulfil their contractual obligations rightly from the outset [16][21][[27]. Thus, parties' compliance with the stipulated contract requirements is pivotal to minimise or prevent disputes involving professional liability, integrity, and security-associated issues from BIM applications.

4.3 Legal and Contractual Considerations Integrating BS EN ISO 19650 Requirements

Compliance with information standards such as BS EN ISO 19650 can also be considered a desirable solution to manage the abovementioned challenges. Integrating this standard when drafting BIM contractual requirements can be beneficial because it caters to BIM information management until the operation and maintenance [59]. The current BS EN ISO standard comprises Five Parts (i.e., concepts and principles, information requirements at various project stages, information management by asset owners, exchange information requirements, and security aspects and processes in BIM application), which aims to administer and facilitate the involved parties to work collaboratively. Hence, future research could consider this standardisation so that legal and contractual matters associated with BIM coordination can be further optimised when managing people, processes and integrated technology.

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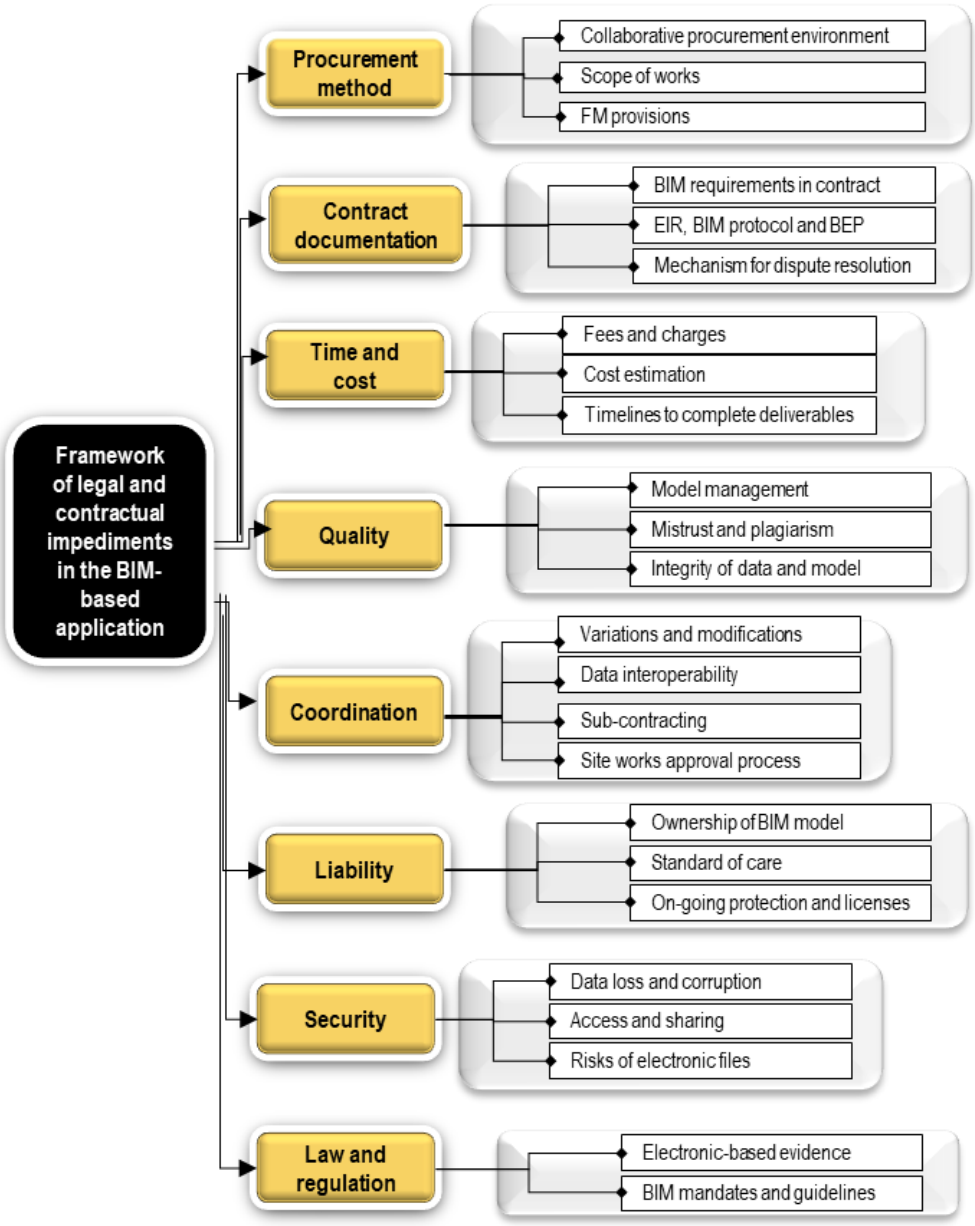

Fig. 5 *The framework of key aspects and their subcomponents of legal and contractual impediments in BIM-based applications*

4.4 Common Data Environment (CDE) incorporating BIM Contract Management

Another crucial area that future studies can focus on is the enhancement of BIM contract management by utilising CDE as a single source to collaborate and integrate project stakeholders via the digitalised platform. Past literature emphasises the need to work via a cloud-based system to accommodate BIM data and information, thus maintaining the risk of cyber-attacks and other associated security risks. As such, CDE can support the centralised data management system for contract administration [60] to improve project participants' accountability when managing the BIM process. The CDE integration with blockchain and smart contracts could also provide potential solutions for further consideration.

5. Conclusion

The implementation of BIM in construction projects has encountered numerous issues throughout the life cycle of construction developments. The first aspect highlights the challenges associated with traditional procurement methods, characterised by being fragmented and lacking support for a cooperative environment. The second aspect reveals the issues associated with contract documentation; some of the existing requirements in BIM contractual guidelines are unable to clarify the roles and obligations of the parties to fulfil BIM objectives and

deliverables at specific LOD stages. This situation could result in adversarial relationships among the BIM stakeholders. The third aspect refers to the time and cost challenges, such as contractual barriers related to the payment monitoring process, cost estimation, and fees for professional services that incorporate BIM-based processes. The fourth aspect discloses the impact of poor monitoring on quality control when managing the exchange of information by different authorships, which leads to integrity issues, mistrust, or plagiarism. The fifth aspect exposes coordination-related issues pertaining to BIM contract administration, such as the effect of modifications to subcontracts and site management works during the contract period. The sixth aspect highlights the emerging issues related to professional liabilities, particularly on the ownership of the BIM model, licenses, and standard of care that should be owned by parties involved in the BIM environment. The seventh aspect reveals security risks such as data loss and protection, while the final aspect is related to law and regulation that must be subjected to the policies governing the uses of BIM through mandates and legislation.

Overall, it is clear that the lack of identification for risk allocations in existing legal and contractual frameworks involving multi-party users would lead to various BIM challenges. From the various dimensions disclosed, there is a gap in the existing body of knowledge about the issues in actual BIM implementation as well as from the context of global applications of BIM learned from the thematic reviewing process. Based on the future directions proposed in the study, there is a need to consider the integration of people, governance and integrated technology to improve the contractual considerations on the uses of BIM for digital construction.

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Conflict of Interest

Authors declare that there is no conflict of interest regarding the publication of the paper.

Author Contribution

The authors confirm contribution to the paper as follows: study conception and design: S.N.S.A., N.A.I., U.K.Z., H.S. and A.H.A.J.; data collection: S.N.S.A. and U.K.Z.; analysis and interpretation of results: S.N.S.A., H.S. and A.H.A.J.; draft manuscript preparation: S.N.S.A. and N.A.I. All authors reviewed the results and approved the final version of the manuscript.

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