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Adopting BIM to Facilitate Dispute Management in the Construction Industry: A Conceptual Framework Development

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Abstract: Previous studies revealed that Building Information Modeling (BIM) has the potential to reduce project uncertainties, design errors, change orders, and delays, which might facilitate achieving effective dispute management in the construction industry. However, research into the adoption of BIM to holistically enhance effective dispute management is limited compared with the plentiful BIM research in the construction management field. This study explored whether and how BIM adoption can help minimize the chronic problem of dispute in the industry. A structured critical literature review method was employed in this study which involved 102 papers in the fields of BIM and construction disputes. Nine main common causes of disputes (e.g., change order, design error, site problem, contractual problem, payment problem, and delay) and eight primary benefits of BIM application (e.g., improved visual management, design optimization, improved information management, and enhanced collaboration) were identified. A conceptual framework was developed illustrating the mechanism of adopting BIM to facilitate dispute management in the overall life cycle of construction projects. The framework indicates that design error, delay, and change order can be reduced most significantly by most of the BIM benefits, whereas improved visual management, improved information management, and enhanced collaboration are three of the most frequently adopted BIM benefits that can settle the majority of dispute causes. This study contributes to dispute management with a more holistic view of adopting BIM in the life cycle of construction projects, as illustrated in the conceptual framework. In addition, the identified common causes of disputes and primary benefits of BIM application are valuable for on future research in these two areas. **DOI: 10.1061/(ASCE)CO.1943-7862.0002419.** *© 2022 American Society of Civil Engineers.*

Practical Applications: The research findings are valuable for practitioners to obtain a holistic understanding of the two topics of dispute causes and BIM benefits, both independently and integrally. First, the identified common causes of disputes can be used by project managers to develop more-targeted strategies for reducing potential disputes in their projects. Second, the identified BIM benefits provide a comprehensive view of the advantages of BIM application for the clients, which will enable them to use BIM in their projects more proactively. Finally, and more importantly, the research findings indicated that BIM could be used to manage disputes in the global construction industry more effectively. The identified BIM features and other technologies or tools in dispute management present comprehensive results illustrating how to use BIM directly or indirectly for dispute management. In addition, the proposed framework is valuable for practitioners to find better solutions to prevent and control construction disputes via the application of BIM throughout the project life cycle.

Author keywords: Building Information Modeling (BIM); Dispute causes; BIM benefits; Literature review; Conceptual framework.

Introduction

Despite the continued rapid development of the global construction market, the construction industry has been lagging behind other industries (e.g., aviation and military industries) in terms of automated production and digitization (Craveiro et al. 2019). As a result, the construction industry faces the challenges of low-level productivity, revenue losses, and poor collaboration among the stakeholders (Sanni-Anibire et al. 2022). In addition, because the construction process is inherently risky, technically complex, and highly fragmented, adversarial relationships among the parties are normal, and disputes frequently impede the successful delivery of construction projects. Over the last several decades, the number of claims and disputes has increased due to these chronic problems in the industry (Haugen and Singh 2015). The frequent disputes have resulted in significant cost overruns and delays, and undermined working relationships among the project participants, which have negatively impacted the success of construction projects (Assaf et al. 2019; Mehany and Grigg 2015). For example, a recent survey indicated that global construction disputes cost US$30.7 million and last 15 months/dispute case on average (Arcadis 2020).

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To address the problems of construction disputes, it is critical to identify the causes of disputes and explore new solutions with modern technologies (Hamledari and Fischer 2021; Marzouk et al. 2018; Noruwa et al. 2022). Among these solutions, Building Information Modeling (BIM), as a virtual design and construction environment, a communication vehicle for the stakeholders, a digital representation, or an education platform (Lu et al. 2013), has received extensive attention in various fields. Hence, in recent decade, a number of studies (e.g., Ali et al. 2020; Marzouk et al. 2018; Shahhosseini and Hajarolasvadi 2021) have investigated whether BIM is an effective strategy to facilitate dispute management, such as dispute prevention and settlement. Results indicated that BIM has the potential to reduce uncertainties and construction errors (Ashcraft 2008; Eastman et al. 2018), minimize claims for extension of time (Ali et al. 2020), and visualize delay analysis for fast settlement of construction disputes (Guevremont and Hammand 2018). However, compared with the extensive applications of BIM in other fields, existing studies (e.g., Guevremont and Hammand 2018; Handayani et al. 2019; Noruwa et al. 2022) generally focused on one aspect use of BIM [e.g., four-dimensional (4D) simulations] in reducing a particular type of dispute cause (e.g., delay and change order). A comprehensive review of whether and how BIM adoption can help reduce the common dispute causes in the construction industry still is lacking. The common dispute causes are the major categories of causes (e.g., design error and contractual problem) that key project stakeholders frequently encounter (e.g., client, contractor, and designer) globally. To fill this knowledge gap, by undertaking a critical literature review, this paper answers three main questions from a multistakeholder perspective (client, contractor, and designer):

1. What are the most commonly referred causes of disputes in the construction industry?
2. What are the most frequently cited benefits of BIM adoption in construction projects?
3. Whether and how the benefits of BIM adoption can facilitate effective dispute management?

Methodology

To answer these questions, the authors conducted a structured review and analysis of the extant papers in first-tier (adopted from Yi and Chan 2014) construction management English journals (section "Stage 1: Initial Journal Selection" presents the initial journal selection details). The common categories of dispute causes and benefits of BIM adoption were identified comprehensively, then a conceptual framework illustrating the relationship between construction disputes and BIM benefits was developed. Literature reviews aim to summarize and interpret the results from previous studies to identify the conceptual content of the research topic (Seuring and Muller 2008). An effective critical review goes beyond the mere description of existing studies, and encompasses a deeper material analysis and conceptual innovation, which stimulates knowledge synthesis and provides a basis for further theory development and testing (Grant and Booth 2009). Hence, a critical literature review method together with inductive reasoning was selected for this study to evaluate existing research outcomes and build new knowledge on the two topics of BIM and dispute management. This approach has been employed frequently in the construction management field in recent years (e.g., Hassan et al. 2021; Xue et al. 2020; Zhang et al. 2016). Because BIM has become a very popular topic in recent years, many publications have been produced annually. However, most of those publications do not relate to BIM benefits and dispute management. Hence, the following three criteria were adopted when searching and selecting the papers:

1. The topics of publications needed to focus on construction dispute management and BIM benefits.
2. Peer-reviewed papers published in first-tier English journals were selected for review and analysis. The CiteScore of the selected journals was over 1.5, which is significantly higher than the CiteScore of 0.70 used by Siraj and Fayek (2019).
3. BIM-related papers published in the last 10 years were preferred because these studies revealed the latest development of its application in the construction industry (Chen et al. 2015). However, first-tier papers published more than 10 years ago which were identified in the snowball referencing process also were included for review and analysis.

Based on the preceding criteria, a research flowchart (Fig. 1) was developed, which comprised four stages.

Stage 1: Initial Journal Selection

To ensure the comprehensiveness and high quality of selected journals, seven top journals in the field of construction management were selected first, namely the *Journal of Construction Engineering and Management*; *Automation in Construction*; *Journal of Management in Engineering*; *Engineering, Construction and Architectural Management*; *International Journal of Project Management*; *Construction Management and Economics*; and *Building Research and Information*. The selection of these journals was based on the journal rankings of Wing (1997) and SCImago Institutions Rankings, which has been adopted widely in various studies (e.g., Lin and Shen 2007; Zhou et al. 2015; Oswald and Dainty 2020). In addition, the *Journal of Legal Affairs and Dispute Resolution in Engineering and Construction* and the *Journal of Computing in Civil Engineering* also were selected because they are first-tier journals publishing considerable dispute-related and BIM-related articles (Hassan et al. 2021; Pan and Zhang 2021), respectively. Other journals, such as the *Journal of Civil Engineering and Management*, *International Journal of Construction Management*, and *Built Environment Project and Asset Management* were selected because they are recommended journals by the International Council for Research and Innovation in Building and Construction (CIB 2019). As a result, a total of 12 journals were selected as the target journals for literature searching.

Stage 2: Keyword Searching and Paper Selection

In Stage 2, a comprehensive visual search within the above 12 journals was conducted using keyword searching and a brief content review. A title–abstract–keyword (TAK) searching approach was employed. The content analysis method was employed initially to identify the keywords for searching and selecting papers. Similar to Siraj and Fayek (2019), in the preliminary literature review process, BIM and dispute related papers were reviewed, and the keywords used in the papers, especially literature review papers (e.g., Chen et al. 2015; Charefa et al. 2018), were identified extensively to include all the potentially relevant keywords. The frequently used keywords that were relevant to this research were employed to search for all the potential papers.

In the field of dispute management, relevant keywords such as "claim" and "dispute" were combined with "cause" for keyword searching, because these words were frequently used in the extant literature (Assaf et al. 2019; Love et al. 2010; Awwad et al. 2016; Ali et al. 2020). In the field of BIM benefits, relevant terms such as "BIM," "Building information modeling," "function," and "benefit" employed by Bryde et al. (2013), Chen et al. (2015),

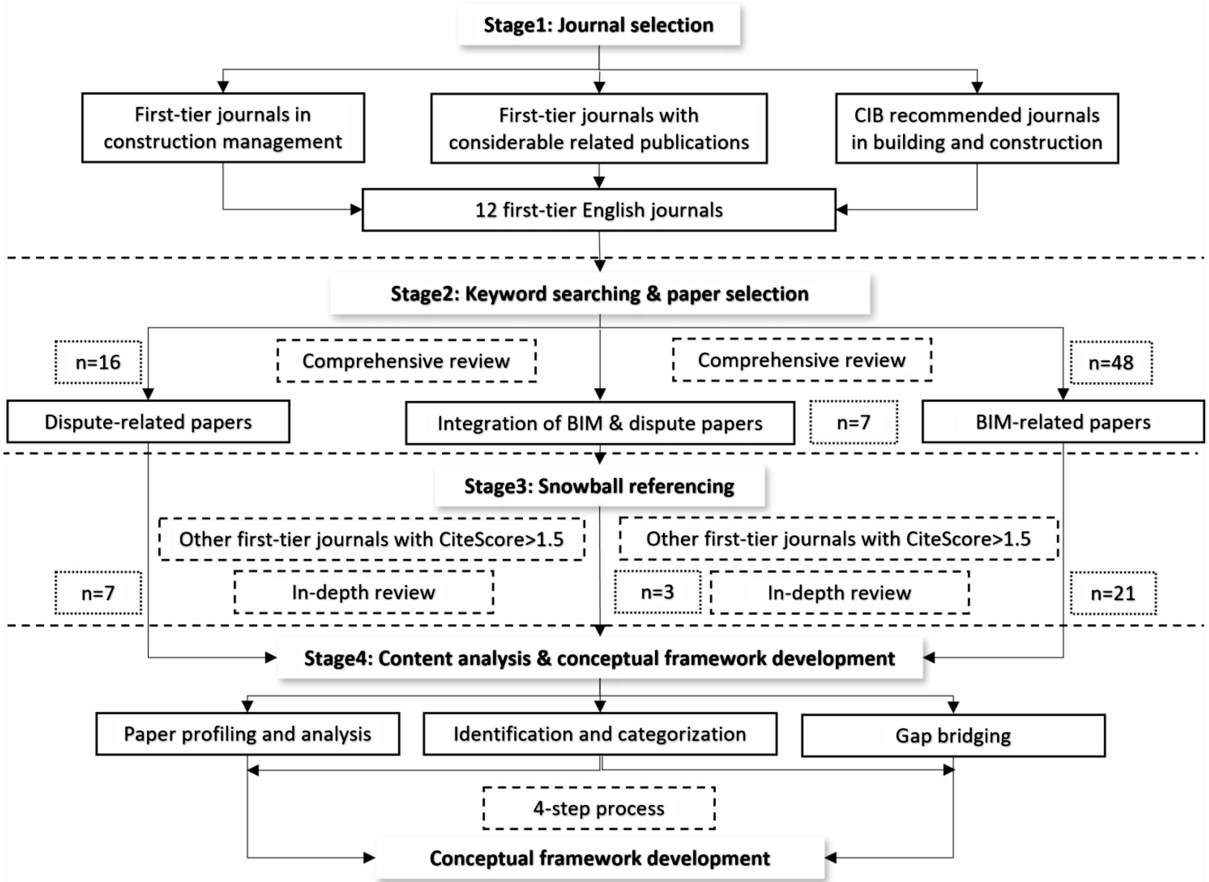


Fig. 1. Proposed research flowchart.

Charefa et al. (2018), Chan et al. (2019), and Ding et al. (2014) were used to search relevant literature. Furthermore, keywords including "construction project" and "construction management" were used to ensure that the research areas were related to this study. Therefore, the keywords used for searching the publications in the above journals were: ("claim" OR "dispute cause" AND "construction project" OR "construction management"); ("BIM" OR "building information modeling" AND "function" OR "benefit"); ("BIM" AND "construction dispute" OR "claim"). Other specific keywords relating to this research also were used to include all potential related papers, including "3D" OR "4D" and "change order" OR "variation" (e.g., Alnuaimi et al. 2010; Deng et al. 2019; Hosseini et al. 2018). Then the abstract or content of each paper was reviewed briefly to identify target papers in each journal. The preliminary searching resulted in a total of 71 papers. Among them, 16 papers were dispute-related, 48 were BIM-related, and 7 focused on the integration of BIM and dispute management.

Stage 3: Snowball Referencing

The snowball referencing approach aims to identify relevant and eligible studies by reviewing the papers in the references (Fatima et al. 2019). The primary advantage of adopting this approach is that it is time-saving to identify first-tier papers on particular less-popular topics among a huge number of publications on a broad research theme (Wnuk and Garrepalli 2018). The snowball referencing method adopted by Fatima et al. (2019) and Wnuk and Garrepalli (2018) was used in this paper. By critically reviewing the references of the 71 papers retrieved in Stage 2, first-tier papers in other top construction management journals (e.g., *Journal of Cleaner Production*) with a high number of citations (CiteScore > 1.5) also were reviewed, identifying more target papers. Using this method, additional 31 papers were identified, of which 7, 21, and 3 papers were dispute-related, BIM-related, and related to the integration of BIM and dispute management, respectively. Therefore, following the two aforementioned searching procedures, 102 papers were selected for further content analysis and critical review.

Stage 4: Content Analysis and Conceptual Framework Development

Content analysis is an observational method that does not merely count words, but examines materials intensively to determine major facets and valid inferences (Ragab and Marzouk 2021). In this stage, a detailed content analysis adopted from Siraj and Fayek (2019) and Ragab and Marzouk (2021) was carried out to (1) categorize the selected papers based on journals, years of publication, global demographics of the selected papers, and perspectives of the stakeholder reported by the paper; (2) systematically identify, categorize, and rank the main causes of construction disputes and the primary benefits of BIM adoption in the delivery of construction projects based on the categorizing approach used in previous studies (e.g., Chan et al. 2019; Love et al. 2010); and (3) bridge the gap between major categories of dispute causes and BIM benefits based on the practical and theoretical results presented in the selected papers. The analysis in this stage enables

Table 1. Selected journals and number of publications

Journal	Number of papers	Percentage of papers (%)
Journal of Construction Engineering and Management	18	17.6
Automation in Construction	17	16.7
International Journal of Construction Management	13	12.7
Journal of Management in Engineering	9	8.8
Journal of Legal Affairs and Dispute Resolution in Engineering and Construction	7	6.9
Journal of Civil Engineering and Management	6	5.9
Journal of Computing in Civil Engineering	5	4.9
International Journal of Project Management	4	3.9
Engineering, Construction and Architectural Management	4	3.9
Building Research and Information	3	2.9
Construction Management and Economics	2	2.0
Journal of Cleaner Production	2	2.0
Others, (e.g., *Built Environment Project and Asset Management*, *Building and Environment*, *Buildings*, *Construction Innovation*) (each journal contains one article)	12	11.8

Table 2. Global demographics of selected papers

Country or context	Number of papers	Percentage of papers (%)
General (not specific)	21	20.59
China	17	16.67
US	15	14.71
UK	7	6.86
South Korea	7	6.86
Canada	5	4.90
Australia	3	2.94
Saudi Arabia, United Arab Emirates, Brazil, Iran, and Netherlands (two papers each)	10	9.80
Middle East, Oman, Zambia, Sri Lanka, Turkey, Norway, Spain, Germany, Estonia, Pakistan, Thailand, Egypt, Colombia, Italy, Chile, India, and Singapore (one paper each)	17	16.67

researchers to examine large quantities of documents structurally, identify the meaning of the subject, and obtain emerging trends in the literature in both quantitative and qualitative ways (Zhang et al. 2016). By critically reviewing the literature, nine categories of dispute causes and eight categories of BIM adoption benefits were identified. The connection between major dispute causes and BIM benefits (including other supporting technologies or tools) was examined, consolidating a robust theoretical basis for the subsequent conceptual framework development.

Literature Review Results

Descriptive Results

Table 1 presents the number of papers published in the journals among the identified 102 papers. The first 5 of the 12 journals produced the majority (63%) of the papers. The analysis results for the year of publication revealed that more than half of the dispute-related papers (57%) were published between 2011 and 2021, and the majority of selected papers concerning BIM benefits (61%) and the integration of BIM and dispute management (65%) were published from 2017 to 2021.

The region of focus of the selected papers also was identified to indicate the global demographics of the selected papers (Table 2). Over 30% of the selected papers investigated the topics in China and the US (Table 2).

The perspectives of the stakeholders also were drawn from the selected papers (Table 3). The results indicate that various stakeholders were researched by the selected papers. However, the majority of studies derived their findings from the perspectives of the client and contractor.

Causes of Disputes

According to the 23 dispute-related studies in the context of 13 different countries and regions, major causes of disputes were categorized and ranked based on their frequencies, which were accumulated in the content analysis process identified from the publications (Table 4).

Change Order

Change order was the most frequently mentioned dispute cause category (96%) in the selected studies (Table 4). Change orders usually are issued by the engineer to contractors to deal with the variations in quantities, scope of work, and material prices, and usually result in extra work and time, claims, and disruptions, and these in turn frequently lead to disputes among the parties (Noruwa et al. 2022; Zhao et al. 2013). Alnuaimi et al. (2010) found that clients' modifications to design and the lack of site

Table 3. Perspectives drawn from selected papers

Perspective of study	Number of papers	Percentage of papers (%)
Not available	38	37.3
General	33	32.4
Contractor	11	10.8
Client	9	8.8
Client and contractor	6	5.9
Designer	5	4.9

Table 4. Identified major causes of construction disputes

Major categories of dispute causes	Literature sources	Number of papers
Change order	Diekmann and Nelson (1985), Jahren and Dammeier (1990), Jergeas and Hartman (1994), Semple et al. (1994), Kumaraswamy (1997), Mitropoulos and Howell (2001), Chan and Suen (2005), Acharya et al. (2006), Alnuaimi et al. (2010), Love et al. (2010), Sibanyama et al. (2012), Cheung and Pang (2013), Mehany and Grigg (2015), Awwad et al. (2016), Cakmak (2016), Assaf et al. (2019), Illankoon et al. (2019), Sanni-Anibire et al. (2022), Viswanathan et al. (2020), Zaneldin (2020), El-Sayegh et al. (2020), and Noruwa et al. (2022)	22
Design error	Diekmann and Nelson (1985), Jahren and Dammeier (1990), Jergeas and Hartman (1994), Semple et al. (1994), Kumaraswamy (1997), Mitropoulos and Howell (2001), Chan and Suen (2005), Acharya et al. (2006), Alnuaimi et al. (2010), Love et al. (2010), Sibanyama et al. (2012), Cheung and Pang (2013), Mehany and Grigg (2015), Awwad et al. (2016), Cakmak (2016), Assaf et al. (2019), Illankoon et al. (2019), Sanni-Anibire et al. (2022), Zaneldin (2020), El-Sayegh et al. (2020), Noruwa et al. (2022), and Hassan et al. (2021)	20
Payment problem	Jahren and Dammeier (1990), Mitropoulos and Howell (2001), Chan and Suen (2005), Acharya et al. (2006), Love et al. (2010), Sibanyama et al. (2012), Cheung and Pang (2013), Mehany and Grigg (2015), Awwad et al. (2016), Cakmak (2016), Assaf et al. (2019), Viswanathan et al. (2020), Zaneldin (2020), El-Sayegh et al. (2020), Noruwa et al. (2022), and Hassan et al. (2021)	16
Site problem	Diekmann and Nelson (1985), Jahren and Dammeier (1990), Jergeas and Hartman (1994), Semple et al. (1994), Kumaraswamy (1997), Mitropoulos and Howell (2001), Acharya et al. (2006), Love et al. (2010), Sibanyama et al. (2012), Cheung and Pang (2013), Mehany and Grigg (2015), Illankoon et al. (2019), Sanni-Anibire et al. (2022), Zaneldin (2020), El-Sayegh et al. (2020), and Hassan et al. (2021)	16
Delay	Jahren and Dammeier (1990), Jergeas and Hartman (1994), Semple et al. (1994), Kumaraswamy (1997), Mitropoulos and Howell (2001), Alnuaimi et al. (2010), Sibanyama et al. (2012), Cheung and Pang (2013), Mehany and Grigg (2015), Cakmak (2016), Assaf et al. (2019), Sanni-Anibire et al. (2022), Viswanathan et al. (2020), Zaneldin (2020), El-Sayegh et al. (2020), and Noruwa et al. (2022)	16
Contractual problem	Kumaraswamy (1997), Mitropoulos and Howell (2001), Chan and Suen (2005), Love et al. (2010), Sibanyama et al. (2012), Cheung and Pang (2013), Assaf et al. (2019), Awwad et al. (2016), Cakmak (2016), Illankoon et al. (2019), Viswanathan et al. (2020), Zaneldin (2020), El-Sayegh et al. (2020), Noruwa et al. (2022), and Hassan et al. (2021)	15
Lack of communication	Jahren and Dammeier (1990), Kumaraswamy (1997), Chan and Suen (2005), Alnuaimi et al. (2010), Assaf et al. (2019), Illankoon et al. (2019), Sanni-Anibire et al. (2022), Viswanathan et al. (2020), and Zaneldin (2020), El-Sayegh et al. (2020)	10
Errors in bid	Jahren and Dammeier (1990), Jergeas and Hartman (1994), Kumaraswamy (1997), Love et al. (2010), Mehany and Grigg (2015), Awwad et al. (2016), and Zaneldin (2020)	7
Opportunistic behavior	Mitropoulos and Howell (2001), Love et al. (2010), Sibanyama et al. (2012), Cheung and Pang (2013), Illankoon et al. (2019), and Viswanathan et al. (2020)	6

investigation ware reported as two major factors contributing to change orders. During the settlement of these two types of variations, the contractor can maximize their benefit due to the low level of risk and guaranteed payment. Awwad et al. (2016) also highlighted that the contractor would obtain the most benefit from change orders because they can improve their profit margin and transfer their risks with the changed scope of work without competing with other contractors. In addition, Zaneldin (2020) found that change orders are the top-ranked cause of claims in the United Arab Emirates.

Design Error

A variety of terms, such as poorly written design specifications, design defects, and inconsistencies in design documents, in the existing literature were categorized as design errors in this study; these were claimed in 20 studies to be the primary causes of dispute. The sources of design errors include unfamiliarity with site conditions, the inexperience of designers, and defective drawings (Acharya et al. 2006). Assaf et al. (2019) reported that "design errors and omissions" and "inconsistencies in the drawings and specifications" were perceived to be the most significant causes of disputes by the surveyed contractors and consultants. Acharya et al. (2006) explained that drawings and specifications should complement each other. However, these two files usually are not synchronized during the design process. In summary, design errors have become a chronic problem in the construction industry, specifically in large and complex projects which have lengthy and complicated design processes.

Payment Problem

Sixteen studies (73%) mentioned that payment problems, including late payment and failure to make a payment, are among the most common dispute causes in different contexts. They often are associated with failure to understand or comply with contractual obligations, such as the late settlement of interim or final payments between the client and contractors. The most significant risk to the contractor is that their payment rights cannot be protected. In this case, a payment problem may lead to a serious dispute in construction projects. Awwad et al. (2016) found that "failure to make interim awards on extensions of time and compensation by the owner" is perceived to be the second most common cause of disputes in the Middle East. Similarly, Zaneldin (2020) indicated that "delay in payments by the owner" is ranked as the fifth most severe claim in the United Arab Emirates construction sector.

Site Problem

Site problems are related to inadequate site investigations, differing physical site conditions, and poor site safety conditions. Inadequate site investigation could lead to change orders, design errors, suspension costs, and various other problems impeding project success (Love et al. 2010; Mitropoulos and Howell 2001). Different site conditions are considered to be a primary source of contractual dispute when the contractor encounters unpredictable site conditions that significantly differ from what is specified or required at work (El-Sayegh et al. 2020). Site safety is another important issue associated with site conditions, which also could lead to disputes (Assaf et al. 2019).

Delay

Project delays can result from delay in handing over the construction site to the contractor, late approval and permission, delay in working progress, late payment by the client, delay in delivery of material and equipment, and late decision-making by the client (Love et al. 2010; Tetteh et al. 2020; Zaneldin 2020). Delays have been identified as a significant cause of dispute in many studies. Mehany and Grigg (2015) found that delays were the most cited causes of disputes in 106 claim cases in road and bridge projects. Moreover, a recent international construction dispute resolution survey revealed that delays (73%) topped the list of dispute causes in major construction projects in China's One Belt One Road Initiatives, followed by change orders (58.46%) and unforeseeable risks (45.96%) (BCT 2021). Factors related to different parties that can cause delays in construction projects include inadequate design information, excessive contractual changes, clients' late decision-making, and suppliers' late transportation and delivery (Awwad et al. 2016; El-Sayegh et al. 2020). As a result, delays may cause time and cost overruns, loss of productivity and revenue, mistrust, and project disruption, resulting in court lawsuits (Sanni-Anibire et al. 2022).

Contractual Problem

Contractual problems encompass ambiguities in contractual documents, misunderstandings of contractual terms and conditions among the parties, and poor contract management. A poorly written contract will lead to diverse interpretations of the same issue, which may develop further into conflicts and disputes (El-Sayegh et al. 2020). Cheung and Pang (2013) proposed a classification of construction disputes, in which the root causes of disputes include "ambiguity," "deficiency," "inconsistency," and "defectiveness," which are grouped under the heading of "contract incompleteness." Awwad et al. (2016) also found that contradictory information in contract documents is the most significant cause of disputes in the Middle East.

Other Causes of Disputes

Other causes include lack of communication, opportunistic behavior, and errors in bids. Effective and transparent communication among the parties is crucial throughout the implementation of construction projects. However, communication-related problems have been identified as the major causes of disputes by many studies (e.g., Assaf et al. 2019; Mitropoulos and Howell 2001). In addition, opportunistic behavior is another frequently cited dispute cause that is interrelated to communications and payment problems. Cheung and Pang (2013) claimed that contractors often behave opportunistically after being awarded the lowest bid in an attempt to secure their profits, which results in intentional late or unfair payment from clients regardless of contract obligations. Consequently, mistrust and irrational decisions will occur. "Unbalanced bidding" and "insufficient time for bid preparation" also were identified in many studies as important causes triggering construction disputes (e.g., Awwad et al. 2016; Zaneldin 2020).

Table 5. BIM benefits identified and number of related papers

Category of BIM benefits	Number of papers
Improved visual management	54
3D visualization	47
Point cloud and laser scanning	7
Improved information management	37
Improved information accuracy	13
Information tracking	12
Better informed decisions	12
Design optimization	37
Reduced design errors	18
Design efficiency and consistency	11
Design alternatives	8
Enhanced collaboration	36
Improved stakeholder collaboration	22
Improved communication	14
Enhanced planning and scheduling	35
4D scheduling and simulations	29
Site logistic management	6
Cost estimation and control	20
Improved prefabrication	9
Integrated procurement process	7

Benefits of BIM Adoption

The benefits of BIM have been studied extensively in the extant literature. For example, Barlish and Sullivan (2012) claimed that adopting BIM not only reduces change orders and subsequent costs, but also decreases requests for information and optimizes project scheduling. Gholizadeh et al. (2018) revealed that three-dimensional (3D) visualization, clash detection, and constructability analysis are the three most widely adopted functions in the US construction industry. Georgiadou (2019) noted that BIM could help to achieve overall life-cycle management in residential projects in the United Kingdom (UK). Chan et al. (2019) found that improved cost estimation and control, efficient construction planning, and better design and quality are the top-ranked BIM benefits in the Hong Kong construction industry. By reviewing 79 BIM-related papers and papers on the integration of BIM and dispute, the categories and subcategories for BIM adoption benefits (BIM direct benefits) were identified (Table 5).

Improved Visual Management

Improved visual management is the most frequently mentioned BIM benefit (addressed in 54 studies) (Table 5). BIM enables stakeholders to have a comprehensive and accurate vision of what will be built in a simulated environment. This greatly reduces the risks of decision-making mistakes and eliminates waste and reworks with more-effectively integrated and coordinated 3D documents (Georgiadou 2019). For example, the decoration project of Shenzhen Metro Line 9 adopted BIM visualization and collaboration tools, resulting in a reduction of sheet changes by 40% and of rework by 3% (Li et al. 2018). Providakis et al. (2019) presented a 3D-BIM-based model to visualize and predict tunnel-induced settlement damage susceptibility of buildings. By integrating MATLAB tools, 3D visualization capabilities, and conversion of BIM data, the case results were proven to improve the building risk assessment performance significantly.

Improved Information Management

A total of 37 studies illustrated that improved information management is one of the most significant benefits of BIM adoption. BIM serves as an information repository for buildings, enhancing information exchange among the parties throughout the project life cycle with a higher level of accuracy. Hence, errors in the process of data entry, transformation, and versioning can be greatly reduced (Ashcraft 2008). In addition, BIM also enables the close linkage between relevant building information and virtual models. These information structures are embedded in models as objects (e.g., walls) with multiple attributes and relationships between the building elements (Sacks et al. 2010). As a project progresses, the project information from one phase can be transformed effectively to the subsequent phases, and the information created in previous projects can be searched more easily and referred to for future projects.

Design Optimization

A total of 37 papers were related to design optimization, including early involvement of stakeholders, reduced design errors, and analysis of multiple design alternatives (Saka and Chan 2020). For example, Lee et al. (2012) developed a BIM-based structural design procedure to obtain optimal design solutions, which improve the constructability, structural safety, and economic feasibility of buildings. Siahboomy et al. (2022) used a BIM-GIS integrated model to select the best alternative plan for positioning warehouses in Iran. The proposed model can assist stakeholders in making better-informed decisions based on local data. In addition, BIM facilitates the elimination of design errors and omissions through clash detection. Hanna et al. (2013) reported that clash detection and visualization of facility design are the two top-ranked BIM values perceived by mechanical and electrical construction firms in North America.

Enhanced Collaboration

BIM transforms the traditional linear and fractured construction activities into a collaborative effort, enabling early involvement of stakeholders and timely sharing of professionals' expertise and knowledge.

As a result, the efficiency of technological coordination and resource allocation can be enhanced. In addition, BIM can facilitate remote collaboration. For example, Merschbrock and Munkvold (2015) found that communication and collaboration can be transformed from physically colocated working into web-based distance working as the design progresses and more professionals become involved. These professionals can access and modify the same model via the web server. In this regard, collaborative design and construction in a BIM environment can be interpreted in two ways: internally, in which multiple users within a single discipline modify the same model simultaneously; and externally, in which multiple modelers from different disciplines simultaneously develop independent multidisciplinary models for design coordination (Sacks et al. 2010).

Enhanced Planning and Scheduling

Traditional bar charts and critical path methods have been criticized for their complicated nature and the lack of visual and spatial components of activities (Hardin and McCool 2015). By integrating scheduling into 3D models, 4D BIM provides accurate real-time planning and sequencing of activities which effectively can support on-time delivery and reduce project delays (Crowther and Ajayi 2021; Georgiadou 2019; Martins et al. 2020). For example, Barlish and Sullivan (2012) reported that schedule performance is 15% over the target without BIM application, whereas the discrepancy can be reduced to only 5% with BIM implementation. Son et al. (2017) developed a BIM-integrated schedule updating system, which enables the prompt assessment of project status and critical schedule information updates, resulting in improved project management efficiency and reduced human errors and subjective behaviors.

Improved Prefabrication

BIM models provide precise geometry and relevant data needed for design and construction, through which digital fabrication drawings can be created automatically, saving production time. With the computer-controlled fabrication and multidisciplinary review of designs, design clashes and human errors in transcribing information can be eliminated, and reworks can be reduced (Ashcraft 2008; Sacks et al. 2010). For example, Farnsworth et al. (2015) highlighted that the increased application of prefabrication is one of the key reasons for BIM adoption in most projects, and the companies interviewed had experienced a great decrease in construction time and rework. Mostafa et al. (2020) found that the most vital benefits of integrating BIM and prefabrication in Australia are the reduced inconsistency in final models between designers and fabricators, and the reduction of procurement time due to seamless information exchange and practical collaboration. The early involvement of stakeholders improves design and fabrication processes so that more-reliable and faster decisions about design changes and fabrication components can be made (Eastman et al. 2018; Mostafa et al. 2020).

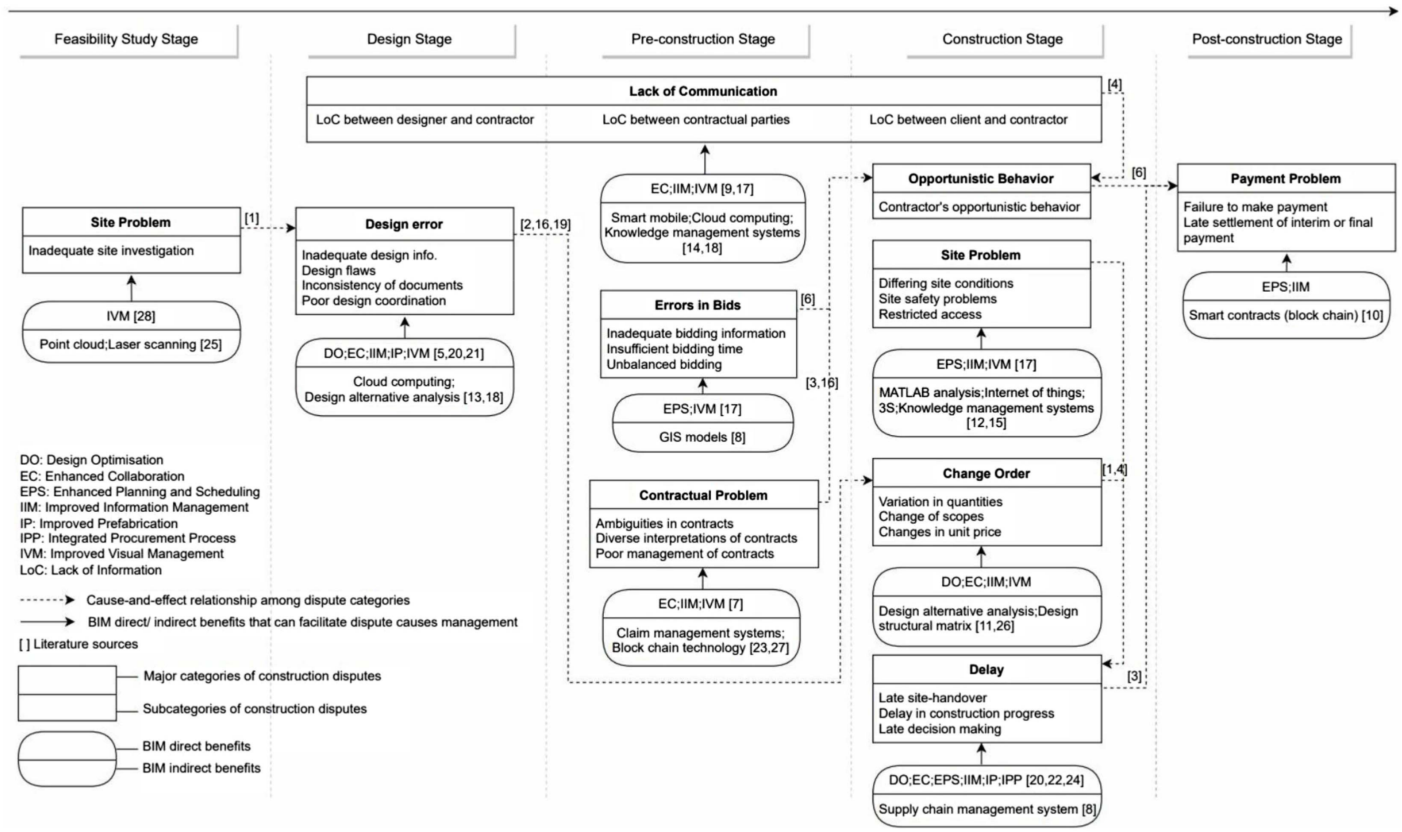
Other BIM Benefits

Other benefits of BIM adoption include enhanced cost estimation and control and the facilitation of an integrated procurement process. Lu et al. (2014) pioneered the use of time–effort distribution curves to measure the cost/benefit of BIM adoption. They found that the cost per square meter of the gross floor area of the sample BIM project was reduced by 8.61% compared with that of the non-BIM project in the construction stage. Farnsworth et al. (2015) identified scheduling, cost estimation, and quantity take-offs as three of the most obvious advantages among commercial contractors in the US. However, these techniques still are not utilized commonly in practice. In addition, BIM can facilitate the application of integrated project delivery (IPD), a novel delivery method promoting the concept of "sharing the risk and reward of a project through target project goals" (Hardin and McCool 2015).

Framework Development

Digital technologies have been driving the changes in the construction industry globally to provide more-efficient and -innovative solutions in construction project management, such as reducing claims and disputes. However, the literature review results of this study indicate that there are some limitations in existing research on the integration of BIM and dispute. First, extant studies primarily focused on the application of different BIM techniques in settling one type of dispute cause (e.g., delay and change order), and the causal relationships among the interconnected dispute causes have been overlooked. As Assaf et al. (2019) noted, disputes are the consequence of the complex and fragmented nature of construction projects. Therefore, an integrated perspective is required for this research, in which the interconnectedness of dispute causes needs to be considered holistically. Second, a comprehensive integrated framework that links dispute causes and BIM benefits is lacking. Both BIM and dispute have been commonly researched topics in the construction management field in recent years, but they generally are examined independently. Studies have demonstrated that BIM-integrated systems can manage disputes effectively, but existing research in this area has been limited to specific BIM systems or project settings (e.g., Ali et al. 2020; Shahhosseini and Hajarolasvadi 2021). Integrated thinking might be more effective in finding better and holistic solutions using BIM direct and indirect benefits in facilitating dispute management.

In responding to the aforementioned research limitations, a conceptual framework (Fig. 2) was developed to illustrate the



Note: 1=Acharya et al. (2006); 2=Alnuaimi et al. (2010); 3=Assaf et al. (2019); 4=Awwad et al. (2016); 5=Chahrour et al. (2021); 6=Cheung and Pang (2013); 7=Crowther and Ajayi (2021); 8=Deng et al. (2019); 9=Du et al. (2020); 10=Hamledari and Fischer (2021); 11=Handayani et al. (2019); 12=Kim et al. (2015); 13=Lee et al. (2012); 14=Lin (2014); 15=Lin et al. (2021); 16=Love et al. (2010); 17=Martins et al. (2020); 18=Merschbrock and Munkvold (2015); 19=Mitropoulos and Howell (2001); 20=Mostafa et al. (2020); 21=Paik et al. (2020); 22=Park and Lee (2017); 23=Pradeep et al. (2021); 24=Rehman et al. (2020); 25=Romero-Jaren and Arranz (2021); 26=Saoud et al. (2017); 27=Shahhosseini and Hajarolasvadi (2021); 28=Siahboomy et al. (2021).

Fig. 2. Proposed conceptual framework for effective dispute management through BIM.

mechanism of BIM benefits in facilitating dispute management throughout the overall life cycle of construction projects. The development process includes the following four steps:

1. By conducting a critical review and content analysis of the 79 papers concerning BIM benefits and the integration of BIM and dispute management, BIM direct benefits that can facilitate dispute management were examined first (e.g., 3D visualization and stakeholder collaboration). Then BIM indirect benefits, which refer to the use of BIM in managing dispute causes with the assistance of other technologies or tools (e.g., point cloud and GIS), were identified. During this step, empirical results and case studies from the existing literature were reviewed to examine how each direct or indirect benefit of BIM can facilitate managing different causes of disputes. Table 6 presents the content analysis results. The results revealed that 3D visualization, 4D simulation and schedule management, information repository centers, and stakeholder collaboration are the most frequently adopted features which can directly manage most of the dispute causes. These features are in the categories of improved visual management, enhanced planning and scheduling, improved information management, and enhanced collaboration, respectively. In addition, GIS models, cloud computing, and knowledge management systems are the most widely used technologies and tools that can assist BIM in achieving dispute management.
2. The construction project was divided into five stages: feasibility study, design, preconstruction, construction, and postconstruction. This division is similar to that used in the models of Ma et al. (2018) and Sibanyama et al. (2012) in demonstrating the BIM roadmap and causes of claims, respectively, in the life cycle of construction projects.
3. Based on the evidence from the 23 dispute-related papers showing the occurrence of each dispute cause at different stages, the identified nine major categories of dispute causes were allocated to the five stages mentioned previously of the life cycle of a typical construction project. For example, the lack of communication among various parties (e.g., client and contractor) would occur throughout the design and the construction stages (Awwad et al. 2016; Zou et al. 2007). In addition, change orders and delays are perceived to be the most prevalent causes during the construction stage, whereas payment problems occur frequently in the postconstruction stage (Sibanyama et al. 2012).
4. The main category of BIM direct benefits, and BIM indirect benefits, were matched further to particular causes to achieve effective dispute management. For example, "4D simulation" and "schedule management" were categorized under enhanced planning and scheduling, which, together with the supply chain management system, were directed to manage the "delay" cause.

A close examination of the relationship between the causes of construction disputes and BIM adoption benefits, as illustrated in the proposed framework, revealed the following important findings:

1. The identified major categories of dispute causes are interwoven. For example, delay, one of the most common causes of disputes, can result from various other causes in previous project stages (e.g., site problem, design error, and change order).

Table 6. Identified BIM features and other technologies and tools in dispute management

Categories of dispute causes	BIM features that can achieve dispute management directly	Literature sources	Other technologies and tools integrated with BIM to achieve dispute management (BIM indirect benefits)	Literature sources
Change order	• 3D visualization • Design validation • Stakeholder collaboration • Digital information	Bryde et al. (2013), Farnsworth et al. (2015), and Kalach et al. (2021)	• Design alternatives analysis • Parameter-based design structure matrix • Dynamo and visual basic for applications (VBA)	Ali et al. (2020), Fanning et al. (2015), Handayani et al. (2019), Noruwa et al. (2022), and Saoud et al. (2017)
Design error	• 3D visualization • Design coordination • Clash detection • Design information flow tracking • Design validation • Prefabrication production	Chahrour et al. (2021), Ham et al. (2018), Mostafa et al. (2020), and Paik et al. (2022)	• Cloud computing • Design alternatives analysis	Lee et al. (2012) and Merschbrock and Munkvold (2015)
Payment problem	• Progress tracking • Information repository center	Hamledari and Fischer (2021)	• Smart contracts (blockchain technology)	Hamledari and Fischer (2021)
Site problem	• 3D visualization • 4D simulation • Information repository center	Martins et al. (2020) and Tak et al. (2021)	• GIS, GPS, and remote sensing (RS) • Point cloud and laser scanning • MATLAB tools • Internet of things • Knowledge management system	Craveiro et al. (2019), Kim et al. (2015), Lin et al. (2021), Providakis et al. (2019), Romero-Jaren and Arranz (2021), and Siahboomy et al. (2022)
Delay	• Prefabrication production • Site logistics planning • Design coordination • Schedule management • Collaborative 4D tools • Fast track IPD	Bortolini et al. (2019), Martins et al. (2020), Park and Lee (2017), Sami Ur Rehman et al. (2022), and Sloot et al. (2019)	• Supply chain management system • Production management systems	Deng et al. (2019) and Lin and Golparvar-Fard (2021)
Contractual problem	• Information flow tracking • Record keeping • 3D visualization	Ali et al. (2020) and Crowther and Ajayi (2021)	• Claim management systems • Blockchain technology	Pradeep et al. (2021) and Shahhosseini and Hajarolasvadi (2021)
Lack of communication	• 3D visualization • Information repository center • Stakeholder collaboration	Bortolini et al. (2019), Du et al. (2020), and Martins et al. (2020)	• Smart mobile devices • Knowledge management systems • Cloud computing • Augmented reality (AR) applications	Garbett et al. (2021), Lin (2014), Merschbrock and Munkvold (2015), and Noruwa et al. (2022)
Errors in bid	• 3D visualization • 4D planning	Martins et al. (2020)	• GIS	Deng et al. (2019)

Lack of communication, errors in bids, and contractual problems are likely to cause contractors' opportunistic behavior, further leading to payment problems (Cheung and Pang 2013). Dotted arrows in Fig. 2 represent the cause-and-effect relationship among dispute causes. This highlights that in addition to traditional dispute management methods, a proactive dispute management strategy, with the facilitation of modern technologies or tools (e.g., BIM), is critical to prevent disputes and settle them more effectively.

2. The results demonstrate theoretically that BIM adoption can manage effectively the majority of disputes in construction projects. However, different features of BIM have different levels of effectiveness in achieving the benefits. For example, as illustrated in the framework, design error, delay, and change order can be reduced effectively by adopting most of the BIM benefits, including enhanced planning and scheduling, enhanced collaboration, improved visual management, improved information management, and improved prefabrication (Handayani et al. 2019; Mirzaei et al. 2018; Sami Ur Rehman et al. 2022). In addition, improved visual management, improved information management, and enhanced collaboration are the three most frequently appearing BIM direct benefits which can address the majority of different dispute causes throughout the project life cycle, including contractual problems, change order, errors in bids, and lack of communication (Du et al. 2020; Paik et al. 2022). Furthermore, other direct benefits, such as design optimization and enhanced planning and scheduling, can be adopted to manage design error, delay, and change order (e.g., Ham et al. 2018; Martins et al. 2020).
3. In terms of BIM indirect benefits, many other technologies or tools, such as GIS models, cloud computing, and design alternative analysis tools, can be integrated effectively with BIM to assist in managing disputes more effectively. This indicates that novel technologies (e.g., digital and automatic technologies, and additive manufacturing) can be aligned with BIM technologies (e.g., 4D simulations and common data environment) for effective dispute management. This aligns with the notion of Construction 4.0 or digital transformation to improve productivity, enhance safety and resource efficiency, and reduce delay and waste in construction projects (Craveiro et al. 2019).

4. For each stage of the construction project, various BIM benefits can be adopted to reduce the causes of disputes. However, the preconstruction and construction stages are critical periods, in which most of the causes (e.g., lack of communication and change order) arise and multiply, resulting in serious cascading effects (Sibanyama et al. 2012). This implies that the project management team should pay special attention to the two periods when fully using BIM direct and indirect benefits to reduce dispute causes. Furthermore, they should be equipped with thorough BIM knowledge and skills to use BIM effectively to manage disputes in the overall life cycle of construction projects.
5. Sufficient research focusing on identifying and resolving of BIM-related disputes (e.g., obligations, rights, and data security) remains lacking. Although a small number of studies have been conducted in the contexts of the UK and the US (e.g., Assaad et al. 2020), more studies in other territories are advocated to explore better solutions for the settlement of BIM-related disputes. In addition, the evidence for BIM's direct and indirect benefits in managing opportunistic behavior is a considerable knowledge gap, and needs to be explored further.

The following sections analyze in detail the mechanism of applying BIM to facilitate effective dispute management in construction projects (Fig. 2).

BIM Adoption Can Facilitate Preventing Site Problems

This is achieved mainly through improved visual management, improved information management, and enhanced planning and scheduling. Existing literature (e.g., Lu et al. 2021; Zhang et al. 2019) indicated that BIM, together with other technologies and tools, can enhance the effectiveness of site investigation and reduce site safety problems. For example, GIS technologies can be embedded into BIM models to provide integrated data with both site information and detailed 3D models of the construction project, which facilitates better-informed and more-scientific decisions on site selection and on-site material layout arrangement (Wang et al. 2019). Additionally, through BIM, professionals on construction sites can use 3D renderings and walk-through animations to identify safety hazards and communicate site plans to project staff. Lin et al. (2021) demonstrated that 3S techniques (remote sensing, GIS, and global position system) and sensors could be integrated into BIM systems to realize the manipulation of dynamic safety risk monitoring and control for excavation activities. Moreover, Kim et al. (2015) proposed a BIM-based knowledge management system which can prevent site accidents by connecting similar past accident cases with current site situations. A case study of a ferry berth presented by Mahdi et al. (2019) also demonstrated multiple BIM use in avoiding construction site disputes. BIM with visualized site logistic planning and resource allocation helped contractors to illustrate the specific details of site layout and required equipment for each activity at different stages, which not only facilitated the optimal solution for construction but also significantly reduced site injuries and disputes arising from site problems.

BIM Can Facilitate Enhancing Design Coordination and Reducing Errors

This is achieved mainly through improved visual management, enhanced collaboration, design optimization, improved information management, and improved prefabrication. BIM can reduce design errors and inconsistencies between design documents through improved coordination. According to Zaneldin (2020), multiple levels of design review and document checking are considered to be key strategies to eliminate design errors. BIM-based collaboration and information environments enable interdisciplinary drawings and documents to be timely modified and exchanged by different designers in design phases (Paik et al. 2022). This further improves prefabrication processes by facilitating early collaboration of stakeholders, which minimizes design errors and discrepancies in product models. In addition, BIM clash-detection tools allow technical conflicts and discrepancies to be identified and resolved effectively, minimizing design error–related rework at the construction stage (Jin et al. 2017; Paik et al. 2022). Park and Lee (2017) conducted a comparative case study and concluded that the BIM-led coordination process was 228% faster than the BIM-assisted coordination process, with a far lower frequency of design changes (0.42 times/drawing) than those of BIM-assisted coordination (2.13 times/drawing). Ham et al. (2018) reported that BIM-assisted design validation could reduce design error costs from 0.736% (non-BIM-assisted project) to 0.454% (BIM-assisted project) of the total construction amount. Chahrour et al. (2021) reported that BIM-based clash detection could achieve tangible savings of 20% of the contract value through enhanced 3D coordination and reduced design errors. The constructability analysis and clash detection tools implemented in the New Jaharr Hospital project in Kuwait resulted in strengthened design coordination and communication among various participants (e.g., structural engineer, architect, and mechanical engineer), which significantly eliminated design errors and contributed to the successful delivery of the project with zero claims among the parties (El-Hawary and Nassar 2016).

BIM Adoption Can Facilitate Enhancing Communication among Multiple Stakeholders

This is achieved mainly through improved visual management, enhanced collaboration, and improved information management. In the design and preconstruction stages, virtual design and construction allow deep interaction and coordination between design teams. Through collaborative 3D viewing sessions and workshops, BIM brings enhanced communication and trust among contractual parties, enabling the clients to make quick and informed decisions that best fit their requirements. During construction, the BIM-based common data environment can provide more-accurate and -reliable information exchanges between prefabrication and on-site construction activities, fostering more-collaborative relationships among the stakeholders than traditional communication methods (Ahankoob et al. 2019). Du et al. (2020) found that interpersonal information exchange is more direct and faster in BIM-adopting projects. Their results also indicated that team members in projects utilizing BIM tend to form tightly knit and well-structured subgroups featuring a high density of ties, resulting in a flatter organizational structure that encourages more-effective internal collaboration and information exchange.

BIM Adoption Can Facilitate Reducing Change Orders

This is achieved mainly through improved visual management, improved information management, enhanced collaboration, and design optimization. BIM visual management enables clients to become involved throughout the design stage to make necessary changes before actual construction. Real-time collaboration and integration of stakeholders can reduce uncertainties and facilitate the project to develop more-accurate information and documentation, which proactively will minimize the frequency of variations and reworks. For example, the use of a web server–based network system facilitates live collaboration in a remote workplace setting, in which the key stakeholders timely assess design changes and synchronize models on a daily basis (Merschbrock and Munkvold 2015). In addition, the adoption of a shared set of standards and a common data environment facilitates closer collaboration and more-effective communication (Georgiadou 2019). As a result, various stakeholders (e.g., client, designer, contractor, and supplier) can communicate specific characteristics of the project in a virtual environment, which enhances the efficiency of communication and accuracy of information exchanged. A comparative study undertaken by Fanning et al. (2015) revealed that BIM implementation could reduce by as much as 89% of change orders related to the superstructure, cost, schedule, and daily traffic. Moreover, the effects of change orders can be visualized and analyzed reactively via BIM models. For example, Handayani et al. (2019) reported the successful use of a BIM-based change impact assessment system in an actual 18-story building project to support design and construction. By detecting and quantifying the impacts of design changes (e.g., cost and schedule) through color-coded visualization and automated quantity take-off tools, the evaluation of change impacts and the claim process are improved significantly, which in turn greatly reduces disputes arising from change orders. Furthermore, the propagation of changes can be monitored and prevented through a BIM-based framework in design–build projects (Kalach et al. 2021).

BIM Adoption Can Facilitate Reducing Contractual Conflicts and Supporting Effective Resolution Processes

This is achieved mainly through improved information management, enhanced collaboration, and improved visual management. Shahhosseini and Hajarolasvadi (2021) proposed a conceptual framework for developing a BIM-based claim management system that can manage effectively contractual terms and conditions automatically during the overall life cycle of projects. The proposed system can prevent claims by providing timely notifications to the responsible parties. In terms of dispute resolution, researchers emphasized the importance of proper record keeping to help the claimant establish legal and factual justification for claim application and accelerate the resolving processes (Sibanyama et al. 2012; Zaneldin 2020). In this regard, Ali et al. (2020) indicated that the BIM-based claim management system can keep contemporary records and digital documentation by providing a centralized information repository. The timely provision of digital documentation and visualized claim reports could accelerate the dispute resolution process. Guevremont and Hammand (2021) presented a case study of replacing valves, cuffs, and servomotors in a powerhouse to demonstrate the use of a visualized and time-stamped simulation tool for visual analytics of delay claims. Their study indicated that by simulating and color-coding the delayed events, the tool grasps the liability of the stakeholder and captures the time stamp of the delay, which further ascertains the associated causality for the postponement of other related events. It provides a fairer and more efficient settlement of delay claims in terms of facilitating hearing procedures and pretrial negotiations. In addition, Pradeep et al. (2021) evaluated the capability of blockchain-aided BIM systems. They found that blockchain technologies enhance the recording of individual design inputs to the overall project design, which improves the design liability control and the auditability of information exchange records. In addition, Hamledari and Fischer (2021) revealed that robust information management and progress tracking provided by blockchain technology, with the assistance of BIM, have the potential to reduce contractual disputes caused by late payments and nonpayments.

BIM Adoption Can Facilitate Reducing Delays and Shortening Project Time

This is achieved mainly through enhanced collaboration, improved information management, design optimization, enhanced planning and scheduling, integrated procurement process, and improved prefabrication. The literature review results indicated that the majority of BIM direct benefits could address delay problems. First, BIM collaborative features and digital information-rich models allow contractors to understand clients' needs more effectively and make more-timely arrangements. Additionally, the creation of alternative design solutions and the visualization of the construction process through 4D models can help stakeholders choose optimal construction strategies to enhance supply chain management and bidding processes (Deng et al. 2019; Le et al. 2019; Martins et al. 2020). Hence, faster and more-accurate decisions can be made by the clients. Second, using the fast-track IPD method in a BIM environment creates close coordination of design and construction information, allowing design and construction to be commenced simultaneously. In this way, the construction permits could be released in phases, reducing the total design and construction duration. For example, Ibraheem and Mahjoob (2022) conducted a case study by adopting BIM in a three-story school project in Iraq. The results showed that 3D visualization and design coordination increased team collaboration in the design phase and reduced potential delays and change orders in the construction phase, reducing claims numbers by 55.2% and claim costs by 57.2%. Third, BIM can facilitate effective off-site manufacturing by avoiding overordering and longer lead-in time, and reducing construction waste and cost (Mostafa et al. 2020). Mirzaei et al. (2018) designed a 4D-BIM dynamic conflict detection and quantification system and found that BIM could mitigate labor congestion, achieve optimum scheduling, and improve project productivity. Bortolini et al. (2019) reported that BIM can facilitate site logistics planning for prefabricated buildings by reducing 60% of assembled trusses storage and 38% of worker-hours spent in transportation operations. Sami Ur Rehman et al. (2022) found that delays can be reduced significantly, and completion time can be reduced by 16.88% through BIM adoption.

Views from the Industry

Although many studies have indicated that BIM facilitates effective dispute management, researchers also argue that the complexity of successful BIM adoption and benefit realization should be properly understood and resolved (Oraee et al. 2019; Won et al. 2013). Because there is a gap between the appeal for BIM adoption from a governmental policy perspective and readily available strategies for wider implementation in practice, BIM adoption varies significantly among companies and industries (Georgiadou 2019). The critical barriers of adopting BIM and achieving benefits include operational expenditure; readiness of technologies, expertise, and training; interoperability among software; cyber security; and organizational culture (Georgiadou 2019; Won et al. 2013). As a result, many smaller companies with limited resources and lower levels of innovation are reluctant to adopt BIM. In addition, BIM implementation may cause misunderstandings and therefore disputes among parties (Assaad et al. 2020; Jamil and Fathi 2020; Ragab and Marzouk 2021), which was referred to as "BIM-related disputes" by Winfield and Rock (2018). That report, together with Assaad et al.'s (2020) study, revealed that a lack of sufficient clarity and consistency of BIM obligations, rights, and risk allocation tend to result in BIM-related disputes. Practitioners from the UK highlighted that BIM should be more actively incorporated into the standard forms of contracts such as the Joint Contracts Tribunal (JCT) and New Engineering Contract (NEC) to specify BIM terms and definitions, and the responsibilities and rights among the parties. In addition, BIM-related documents including client's information requirements, BIM execution plan (BEP), and BIM protocol should be more clearly defined and set out to calibrate with contract documents. Practitioners from the US also recommended that more specified information, such as naming rules, schedule of BIM deliverables, level of detail for the model, and establishment of a file-sharing platform, should be included in BEPs (Assaad et al. 2020). These recommendations from the industry are crucial to reducing BIM-related contractual disputes and facilitating more-effective dispute management.

Conclusions and Recommendations

The fast digital transformation in the construction industry has stimulated the broad research of BIM applications in the construction management field. Due to the limited integrated framework concerning whether and how BIM can be used to manage construction disputes more effectively, this paper bridged the gap between the major causes of construction disputes and BIM adoption benefits. By undertaking a structured critical literature review, this paper identified the major categories of dispute causes and the key benefits of adopting BIM in construction projects. The results indicate that the most frequently referred dispute causes by the selected journal papers are change order, design error, payment problem, site problem, contractual problem, and delay. The most widely realized BIM adoption benefits reported in these papers include improved visual management, improved information management, design optimization, enhanced collaboration, and enhanced planning and scheduling. Building on these results, a conceptual framework was developed, illustrating the mechanism of adopting BIM to facilitate the effective management of construction disputes. The framework demonstrates that although different BIM direct and indirect benefits can address various respective dispute causes, improved visual management, improved information management, and enhanced collaboration are the three most frequently appearing BIM direct benefits, and these can settle the majority of different dispute causes throughout the project life cycle. In addition, special attention should be paid to the preconstruction and construction stages in BIM adoption because most of the dispute causes arise during these two periods. Finally, the complexity of BIM adoption and barriers to achieving BIM benefits should be taken into full consideration when various organizations aim to achieve successful BIM implementation. The potential BIM-related disputes might further deteriorate the serious dispute problems in construction projects.

The developed conceptual framework in this study provides a theoretical basis for construction dispute reduction and effective resolution from the perspective of BIM utilization. Considering the substantial negative impacts of disputes in the construction industry globally, this study makes the following contributions. First, it contributes to the existing dispute research by identifying the sources and impacts of major dispute causes and constructing their interrelationships, which provides a comprehensive understanding of how disputes arise and how they can be managed effectively. Compared with the existing literature on the identification of dispute causes, the findings of this study enriched the related body of knowledge by portraying the casual interactions among the key categories of dispute causes. Second, it contributes to the BIM research by reporting the major BIM adoption benefits (including direct and indirect benefits) and analyzing in detail how these benefits are realized to address different dispute causes. Compared with the existing literature on the identification of BIM benefits, this study expands this body of knowledge by identifying and analyzing the applications of BIM derivate technologies (e.g., design alternative analysis) and BIM-integrated systems (e.g., the integration of BIM and GIS models), which provides strong evidence of the benefits of novel technologies and the current research trends in intelligent solutions for managing construction disputes. Third, the research bridges the knowledge gap between various BIM benefits and common dispute causes, facilitating proactive construction dispute management, which rarely is addressed in the existing literature. The conceptual framework consolidates a strong theoretical basis for future empirical research on this topic to demystify the complicated interrelationship between the causes of construction disputes and BIM adoption benefits. Hence, the outcomes not only extend the sphere of BIM application but also provide a more effective solution to solve the dispute problems in the construction industry.

Limitations and Future Research Directions

The study's primary limitations lie in the number of publications identified for analysis, which suggests possible future research directions. As mentioned previously, this study was based on publications from first-tier English journals. Some valuable research might have been overlooked through keyword searching and snowball referencing techniques. Future studies are advocated to undertake literature reviews in other journals or other languages (e.g., Chinese) to identify BIM adoption benefits and their applications in dispute management. In addition, although the interrelationship between the identified main causes of dispute and primary benefits of BIM application was illustrated theoretically, future research employing triangulation research methods (e.g., case study, questionnaire survey, and interview) is necessary to verify and optimize the proposed conceptual framework through empirical investigation. Finally, a comparative study of different territories on this topic also is paramount to generalize the research findings more broadly.

Data Availability Statement

Some or all data, models, or code that support the findings of this study are available from the corresponding author upon reasonable request.

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