Association of BIM-Related Contract Language and BIM Use on Construction Projects

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1 Introduction

Building information modeling (BIM) in the architectural, engineering, and construction (AEC) industry is transforming how construction projects are delivered. BIM is a "digital representation of physical and functional characteristics of a facility" and is a shared information system [15]. BIM can provide benefit throughout a project's lifecycle by enabling uses such as design coordination, 4D scheduling, quantity take-offs, and facility management. Furthermore, BIM use has been linked to improved project performance with respect to delivery speed [11]. As BIM has the potential to improve project performance in the AEC industry, there is a need to understand how to improve BIM adoption among project stakeholders. BIM is a common information repository for all project stakeholders. Hence, the more participation and buy-in of stakeholders in this system could lead to a better information management and overall project performance. Traditionally, contracts have been used to define expectations and requirements for stakeholders. Current research in BIM and contracts focuses on identifying the potential areas of dispute and risk [5, 6] and there is little focus on how contracts can impact stakeholder use of this technology at the project level. To this end, researchers focused on the relationship between contract requirements and BIM use. The objective of this study was to evaluate the association between BIM-related

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contract requirements and BIM use on construction projects. Researchers specifically evaluated the use of BIM by key stakeholders (architect/engineer, contractor, subcontractor) and the use of a BIM execution plan (BEP).

2 Background

2.1 Literature Review

Researchers conducted a literature review focused on the implementation of BIM and BEPs, and the relationship between contracts and BIM. When reviewing literature related to BIM and BEPs, researchers focused on identifying benefits to stakeholders and the project as a whole to make the case for BIM adoption by project stakeholders. When reviewing previous research related to contracts, researchers wanted to understand the potential BIM-related contractual challenges and how contracts currently address BIM. Overall, researchers wanted to understand BIM's impact on construction projects and how contracts could impact BIM adoption and implementation on the project level.

2.1.1 BIM Implementation

BIM is a "shared knowledge resource for information about a facility" [15] and can be used as a collaborative tool throughout a project's lifecycle. One of the major benefits of BIM is that it can be used as a common source of information, decreasing the need to manually transfer or recreate information in stakeholders' respective systems. For this benefit to be achieved, relevant project information needs to be captured in a single repository, which requires participation of major stakeholders throughout the project's lifecycle. With BIM implemented on a project, there are numerous applications that stakeholders can take advantage of, including design coordination, photorealistic renderings to communicate with stakeholders, contractor coordination, and schedule management [14]. These applications can provide benefit for specific stakeholders in their specific project scope; for example, BIM can be used by contractors and subcontractors for coordination among construction trades to avoid conflicts during field installation and minimize trade stacking, or BIM can be used by designers to improve collaboration among a distributed design team. In addition to benefits for specific stakeholders or project phases, BIM can also improve a project's overall performance. Franz and Messner [11] evaluated BIM uses' effects on project performance. They analyzed over 200 projects and found a significant positive relationship between BIM use and speed of delivery when controlling for project complexity. Overall, BIM has the potential to improve construction projects at both the stakeholder level and the overall project level.

2.1.2 BEP Implementation

A BIM execution plan is used to define BIM goals and uses, develop project specific information exchanges, and define BIM processes [9]. This process is a result of a collaborative effort that represents stakeholders' specific goals and requirements for BIM use throughout a project's lifecycle. Having these procedures documented is critical; researchers have identified a documented BEP as a critical success factor in construction projects implementing BIM [7]. Furthermore, research into the relationship between BIM use and BEP creation indicates that participating in a BEP's creation was a predictor of BIM use [11]. When stakeholders have the opportunity to participate in BIM execution planning, they are given the opportunity to discuss their shared and organizational goals, as well as the processes that are required to achieve those goals, which can ultimately lead to project success. This suggests the importance of stakeholder buy-in to BIM, including its uses and the overall process required to implement it at the project level.

2.1.3 Contracts and BIM

Previous research on contracts and BIM address areas of legal and technical risk, as well as, project performance. Assaad et al. [6] evaluated standard agreements in the United States (US), such as American Institute of Architects (AIA) agreements and ConsensusDocs, with respect to how they address BIM risks and potential issues arising from the implementation of BIM. They identified data management and collaboration, management of information discrepancies, and indemnity as areas of contractual concern. Arshad et al. [5] identified risks related to BIM in design/bid/build projects and proposed mitigation strategies. These risks include intellectual property, professional liability, and challenges with model management. Many of the proposed strategies to mitigate these risks include the use of additional contract language addressing specific risks and defining a BIM process, often using a contractually obligated BEP [5, 6]. Another study, conducted by Hamdi and Leite [12], identified legal challenges when implementing BIM through the use of expert interviews. Their study identified numerous challenges, including the need for all stakeholders to be involved in BIM and that there are gaps in current contracting strategies with respect to BIM. Additionally, the importance of interfaces between design and construction, and construction and operations were highlighted, underscoring the need for consistent BIM requirements and expectations across a project's lifecycle. This focus on interfaces highlights the importance of key stakeholder participation in BIM throughout the project. Additionally, a study evaluated the relationship between contractual BIM requirements and project cost performance and found that contractually requiring the contractor and subcontractor to use BIM were factors related to project cost success [8]. This existing research develops an understanding of BIM risks and contractual remedies, as well as, the impact of BIM-related contractual language on project performance, however, there is a lack of understanding on how project contracts can impact BIM use by project stakeholders.

2.2 Motivating Case

With numerous challenges identified in literature, it's important to understand how these challenges occur in practice. Issues have arisen regarding inconsistent BIM requirements among stakeholders. One notable case is *North American Mechanical, Inc. v. Walsh Construction Company, LLC* [16]. North American Mechanical, Inc. (NAMI) was hired as the mechanical subcontractor by Walsh Construction, the general contractor. The project required certain subcontractors to participate in BIM, including NAMI. The project BIM was initially created using 2D drawings provided by the architect and supplemented with information from the contractor and subcontractors. NAMI developed their installation sequences using the project's BIM; however, when they started field installation, they encountered unforeseen field conditions. A subcontractor who had not been required to participate in BIM had installed their equipment in an area that NAMI was planning to install their respective equipment. This led to an overall project delay. This case highlights the importance of consistent stakeholder participation to fully realize BIM benefits, such as coordination and 4D scheduling.

2.3 Research Gaps and Study Objective

While previous research has found that BIM can provide benefits to overall project performance, there is little research focusing on how BIM-related contract language impacts the implementation of BIM and BEPs on projects. Specifically, there is a gap on how contract requirements impact specific stakeholder BIM use and the use of a BEP, as seen in Fig. 1. As illustrated in the *North American Mechanical, Inc. v. Walsh Construction* case, it is important to understand how to improve stakeholder BIM participation to enable BIM's full benefit on construction projects. Without participation of all stakeholders in the BIM process, there is the potential for disputes and claims. As an initial step to understanding how to improve project performance using BIM, researchers focused on the relationship between contracts requirements

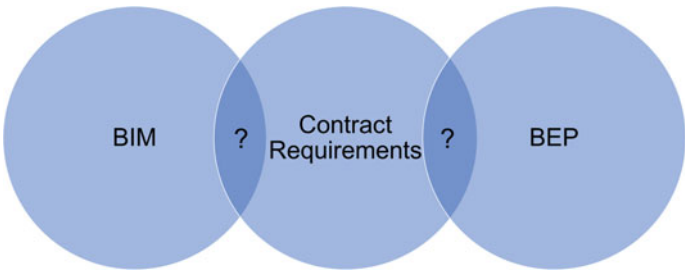

Fig. 1 Research gaps

and BIM and BEP use on the project level. The objective of this research was to evaluate the association of BIM- and BEP-related contractual requirements and BIM and BEP use on construction projects.

3 Research Approach

The research approach in this study included collecting construction project data and performing Fisher's Exact Test to identify significant associations between BIM-related contract requirements and BIM use on construction projects. This approach is illustrated in Fig. 2.

Researchers utilized a survey to capture project data from construction projects completed between 2015 and 2020. The survey captured project data using 44 multiple choice and open-ended questions, including BIM contract requirements for specific project stakeholders, the contractual requirement of a BEP, and the implementation of a BEP. Researchers utilized Qualtrics to host the online survey and it was distributed via email and LinkedIn. Data was collected between March 2020 and May 2020. Researchers then used Fisher's Exact Test to identify significant association between categorial attributes. Fisher's Exact Test relies on 2 × 2 table to measure the association between attributes as illustrated in Fig. 3. The 2 × 2 table is populated with frequencies that represent the projects within the sample that have the listed attributes.

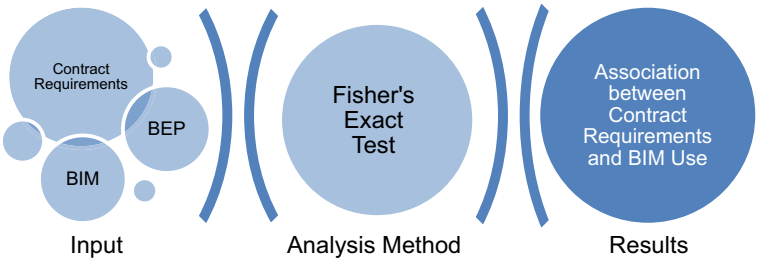

Fig. 2 Research approach

Fig. 3 Example of a 2 × 2 table for fisher's exact test

BIM is Used	BIM is Contractually Required: Yes	BIM is Contractually Required: No
Yes	a	b
No	c	d

The null hypothesis of Fisher's Exact Test is that there is no association between attributes. Researchers selected this test and determined it was appropriate for this study as it can be used on small sample sizes [13], similar to those collected in this study. In this study, researchers wanted to test the association between the BIM contractual requirement of a stakeholder and their respective BIM use on a project, and the association between contractually requiring the use of a BEP and the implementation of a BEP on the project.

4 Results

4.1 Survey Results

The survey was opened 97 times and 71 responses were recorded with at least one survey question answered. The recorded responses were not all complete surveys and did not necessarily include all project information relevant to this study. Researchers identified 28 projects that met the criteria for this study. To be included in this study, the survey response had to include data related to BIM use of key stakeholders (architect/engineer, contractor, and subcontractor), their respective BIM contract requirements, BEP use, and BEP contract requirements. Of the 28 projects submitted, 23 projects were located in the US and five were outside of the US. Three primary project types were submitted, buildings, infrastructure, and light industrial. Table 1 breaks down the project type.

Table 2 shows the breakdown of projects by delivery method. The primary delivery method of the projects analyzed in this study are construction manager at risk. Overall, the dataset contains more projects delivered with a less collaborative delivery

Table 1 Project type

Project type	Count
Buildings	22
Infrastructure	5
Light industrial	1

Table 2 Delivery method

Delivery method	Count
Construction manager at risk	14
Design/Build	5
Design/Bid/Build	4
Not reported	4
Design assist	1

Table 3 Results from fisher's exact test

Factor 1	Factor 2	*p*-value
Architect/Engineer BIM use	Architect/Engineer's contractual BIM requirement	0.0581
Contractor BIM use	Contractor's contractual BIM requirement	**0.0148**
Subcontractor BIM use	Subcontractor's contractual BIM requirement	**0.0002**
BEP use	BEP contractual requirement	0.0978

Bold indicates significance at $p < 0.05$

method (e.g. construction manager at risk or design/bid/build) rather than a more collaborative method, such as design/build or integrated project delivery.

4.2 Results of Fisher's Exact Test

Researchers implemented Fisher's Exact Test to evaluate the association between BIM use and contractual BIM requirement. Table 3 summarizes the results of Fisher's Exact Test. These results indicate a significant association between contractor BIM use and contractual BIM requirement for contractor, and the use of BIM by subcontractors and their respective contractual BIM requirement.

5 Discussion

These findings identify a significant association of BIM contract requirements and BIM use on projects with respect to the contractor and subcontractor. This finding could be due to the increased awareness of owners with respect to BIM benefits during the construction phase and the resulting motivation to implement BIM during the construction phase of projects. The requirement of a contractor to use BIM could also influence the BIM requirements of the contractor's subcontractors, either through contractual requirement from the owner for the contractor's agreements with their subcontractors to require BIM or the contractor's understanding that BIM is most useful when all subcontractors are involved in developing and using the BIM. Some examples of BIM benefits during construction include 4D scheduling and coordination among trades. Considering the case of *North American Mechanical, Inc. v. Walsh Construction* [16] previously presented, if all subcontractors had been required to use BIM, increased participation in trade coordination could have resulted in less conflict in the field during equipment installation. Furthermore, it is important to leverage BIM during construction as it can positively impact project performance in terms of cost and schedule. Comparing the design and construction phases of a project, the construction cost is typically the largest cost prior to operations. The use of BIM with contractors and subcontracts could positively impact the construction

phase's cost and schedule, which in turn could positively impact a project's overall performance.

Another factor that could impact the association between contractual BIM requirements and BIM use could be the result of contract templates in the US adding BIM-related language and documents. These contract documents include ConsensusDocs 301 BIM addendum [10] and the American Institute of Architect's suite of BIM documents, including C106 Digital Data Licensing Agreement, E203 BIM and Digital Data Exhibit, G202 Project Digital Data Protocol, and G203 Project BIM Protocol [1–4]. These contract templates could provide owners guidance on how to incorporate BIM language into contract documents and this guidance could lower the barrier to entry with respect to adding BIM to contract requirements. As BIM project data, including performance and contract requirements, becomes available, it will be interesting to understand the impact of these BIM documents on specific BIM uses and overall project performance.

With respect to architect/engineer (A/E) BIM use, the lack of significant association with the contract requirement could be due to the evolving standard of practice. As the industry transforms from 2D project delivery to digital project delivery, A/Es could have already adopted BIM as standard practice within their workflows. That being said, there are instances where A/Es use BIM solely to create 2D deliverables, which include 2D PDFs or 2D CAD drawings and traditional paper drawings, and the BIM is not required for handover to construction. While it is not apparent whether the lack of significant association between BIM use and contractual requirements for the A/E is due to BIM being a part of standard A/E practice or if owners simply do not require BIM due to requiring only 2D deliverables from the A/E, this represents a missed opportunity to improve information management throughout the project. This can be illustrated in the *North American Mechanical, Inc. v. Walsh Construction* [16] case, where the BIM utilized by the contractor and subcontractors was developed from 2D drawings provided by A/E. With the information being transferred from one phase to another using traditional 2D deliverables, there was opportunity for information to be lost. One way for information to be lost was during the manual recreation of information from the 2D format to BIM, which represents the information in 3D and has the capability of storing other information about objects, such as start-up information for equipment or rules that describe the object's relationship to other objects in the model [18].

The lack of significant association between BEP use and its contractual requirement highlights a possible opportunity for improvement. As BEPs can be a contract document, it is important that it is aligned with the overall contract. Often, A/Es and/or contractors are asked to develop the project's BEP after the base terms and conditions are agreed upon with the owner with the expectation that these parties will signoff on the BEP document and it will be incorporated into the contract. While the intent is to improve BIM implementation throughout the project, this is not always the case. Researchers interviewed a construction manager's (CM's) BIM manager of a large university campus project and learned about the interface challenges between design and construction when there is no contractual relationship between the parties. The CM and the designer on the project were negotiating the deliverables outlined in

the BEP. At issue was the handover of the designer's BIM to the CM for construction phase use for tasks such as quantity take-offs to support estimating. The designer argued that since their contract with the owner only required 2D PDFs that the CM could use the BIM for reference only and it could not be relied upon with the same confidence as the 2D deliverables. This example highlights the potential pitfalls of inconsistent contract documents. One potential remedy for this challenge is to utilize order of precedence to prioritize the BIM as the source of information that governs when there are inconsistencies in project documents, such as 2D PDFs. One study found that 2D drawings still govern contracts even when BIM is developed for the project [17]. This practice will need to evolve to further promote and support BIM use among project stakeholders and throughout a project's lifecycle.

6 Conclusion and Future Work

This study highlights the importance of BIM contract requirements. It suggests that BIM use can be tied to BIM contract requirements and identifies potential areas of improvement for BIM implementation in the AEC industry. This study found a significant association between contractor and subcontract BIM use and their respective BIM contractual requirements. One strategy to improve BIM use at the project level is for owners and contractors can contractually require BIM use of their subtier partners. Another strategy to improve overall BIM use on a project is to explore is the role of the BEP within a project. This study found no significant association between BEP use and its contractual requirement. This finding could point to the slow transition of contract documents to formally address the process and development of BIM throughout a project as represented by a BEP. Future work can investigate BIM and its related contract requirements and its impact on project delivery and performance. Researchers could investigate the impact of specific clauses on BIM use during certain project phases and evaluate its impact on overall project performance. Furthermore, researchers could also investigate how to improve consistency between contracts and BEPs. Overall, increasing the understanding the role of contracts in BIM implementation can identify best practices and current challenges of the use of BIM to improve project delivery and performance.

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