Contractual Risks of Building Information Modeling: Toward a Standardized Legal Framework for Design-Bid-Build Projects

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Abstract: Building information modeling (BIM) is an encouraging development in the architecture, engineering, construction, and operations (AECO) industry due to its data-rich digital representation of building components. Although BIM is technically mature, its legal and contractual systems are yet to be standardized. Motivated by this need, the current study has developed a framework for legal and contractual risks within BIM. In this study, 14 significant risks were identified from 10 published taxonomies, and five standard and three custom BIM contracts were reviewed to assess their coverage and check their redressal strategies. On the basis of the triangulation of information gathered from published contracts, expert opinion, and custom manuscripts, mitigation strategies for the legal risks were proposed and formalized into a contractual framework designed for a design-bid-build delivery system. This study contributes to the body of knowledge and practice by helping the AECO community understand the current level of legal and contractual maturity of BIM, and by stimulating the technological and legal fraternities to sufficiently deliberate the contractual uncertainties in order to facilitate the uptake of BIM in the AECO industry. **DOI: 10.1061/(ASCE)CO.1943-7862.0001617.**

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Introduction

Building information modeling (BIM) is a major development in the architecture, engineering, construction, and operations (AECO) industry, owing to its intelligent and data-rich digital representation of building projects that can be used as an object-oriented three-dimensional (3D) model (Eastman et al. 2011; Sampaio 2017). More information can then be added to the physical dimensions to cater to time (fourth dimension), cost (fifth dimension), sustainability (sixth dimension), facilities management (seventh dimension), safety (eighth dimension), and so on (Eastman et al. 2011). When completed, the virtual model contains the precise and necessary geometrical and associated information needed to support the construction, fabrication, procurement, facilities management, demolition, and recycling activities of a building project (Azhar et al. 2008; Pishdad-Bozorgi et al. 2018). This virtual model facilitates the role and function of architect/engineer (A/E) and contractor through clash detection and the identification of potential problems that may occur at later stages of construction and operation (Azhar 2011). BIM can be realized as a systematic process that contains all aspects, disciplines, and arrangements of a facility within a single comprehensive model.

Such characteristics of BIM have helped this technology attain a global acceptance and adoption. In developed countries such as Finland, Sweden, Norway, Germany, France, Singapore, and Australia, various projects have been completed using this technology (Mihindu and Arayici 2008). A number of megaconstruction projects—for example, the Shanghai World Expo Cultural Center and Shanghai Tower in China, and the Walt Disney Concert Hall, Museum of Pop Culture (also called EMP Museum) at Seattle Center and Washington National Park in the US—have been successfully completed using BIM (Chien et al. 2014). In addition, during preparation of the Beijing Olympics 2008, highly complex projects such as The Bird's Nest and Water Cube were aided by this promising technology. The continent-level comparison study of Jung and Lee (2015) highlighted the expansion of BIM adoption globally. Their study pointed out that North America (Canada and the US) had the most advanced BIM adoption, whereas Oceania (New Zealand and Australia) and the European Union countries, France and Italy, could be considered the regions with the second most advanced level of BIM adoption, particularly for the design phase. However, Middle East/Africa was considered a beginner in this area of expertise and was ranked in the third position. Finally, Asia was ranked fifth, and South America was at the lowest level in BIM adoption and allied services.

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Although some countries lead the others in the adoption of BIM, it can be seen that with all its benefits, BIM is still at an exploratory stage in the industry (Edirisinghe et al. 2016). The benefits of BIM in the form of savings in time and cost, improvement in quality, coordination and communication (Bryde et al. 2013), stakeholder satisfaction (Azhar et al. 2015), better implementation of occupational safety (Azhar et al. 2012), and effective achievement of sustainability (Kumar et al. 2017) have been sufficiently reported in the literature. However, such value addition comes with its own uncertainties and risks (Ahmad et al. 2018). One such limitation is the unavailability of universal contractual guidelines, which drops the overall efficiency because of the reduction of BIM deliverables to noncontractual items in projects (Olatunji and Akanmu 2014). Although some contractors choose to implement BIM on a voluntary basis (Kumar et al. 2017), a well-structured, balanced, and clear set of contractual guidelines will help boost the BIM value proposition (Eadie et al. 2015). Moreover, a recent study on BIM adoption in China also emphasizes the development of a clear set of BIM guidelines (Herr and Fischer 2018).

The development of such guidelines is driven by the need to address legal risks regarding the creation, usage, and management of BIM-associated information. Depending on the usage of BIM among project stakeholders, specific contractual guidelines and provisions will be needed to cope with the lack of predisposed strategies and outdated contracts (Kuiper and Holzer 2013). Responding to this demand, various contract documents have been developed to manage BIM and its related information. Presently, five contracting systems that incorporate BIM are available in the industry: ConsensusDOC 301 BIM Addendum (ConsensusDOCS 2008), Architects Engineers and Contractors BIM Protocol (AEC 2012), American Institute of Architects E203 (AIA 2013), Construction Industry Council BIM Protocol (CIC 2013), and Chartered Institute of Builders, Time and Cost Management Contract (CIOB 2015).

ConsensusDOCS 301 BIM Addendum is the oldest of the standard contract documents. The developers of this system, acknowledging the longer, wider, and deeper penetration of traditional contracts in the industry, tried to expand the existing forms of agreement instead of drafting a whole new set of documents for BIM. Lowe and Muncey (2009) concluded that inadequate change-management culture of the construction industry may result in further problems if the entirely new contracting regime is introduced. Further, AEC (2012) released AEC BIM Protocol version 2.0 as an improvement over version 1.0. This contract document urges the use of best practices. The American Institute of Architects drafted E203 as an integrated project delivery (IPD) contract that can be used as an addendum to existing general conditions for traditional delivery methods (AIA 2013). Similarly, the Construction Industry Council BIM Protocol makes the minimum changes necessary to the pre-existing contractual arrangements for BIM in construction projects (CIC 2013). This contractual system is limited to the design-build (DB) project delivery method. Furthermore, the time and cost management contract is an improvement over the Contract for Complex Projects by CIOB (2015).

Upon detailed study, it is found that these contracts do not sufficiently cater to various risks and uncertainties involved in BIM-based project delivery (Al-Shammari 2014), which opens a space for custom manuscript contracts (Abdirad 2015). These custom contracts are based on best practices and exclusively developed for a limited scope of application, but they are rarely known and do not justify generalization. Thus, there are still many unclear legal requirements for the contract structure and policy and for the contractual relationships and obligations associated with the BIM model and security (Chong et al. 2017).

Due to the lack of clarity, projects have encountered legal disputes (Olatunji 2015), pushing the practitioners toward alternative modes of contracting (Abdirad 2015). However, these alternative modes are nonstandardized, which complicates the legal matters of BIM and hinders its adoption. Cases such as these point to one problem: lack of a legal foundation for implementation of BIM in the AECO industry (Alwash et al. 2017). This lack of predisposed strategies for BIM implementation results in practical problems of model ownership, sharing of financial opportunities, control of data, and emerging risks. Further complicating this scenario is that there is a complete lack of BIM contractual framework for projects procured against a design-bid-build (DBB) system of delivery. The question arises: why focus on BIM contractual framework for DBB? The answer is that not only DBB performs better in cost, due to its use of competitive bidding, than DB, which clearly has a better schedule (Minchin et al. 2013) and claims (Hashem et al. 2018) performance, but DBB is also a widely utilized option as almost 52% of total projects are procured through it (Duggan and Patel 2013). In addition, DBB is a preferred system of procurement for public projects due to better productivity and fewer cost changes (Park and Kwak 2017), and the owner's desire to maintain control over the project (Ibbs et al. 2003). However, the focus of this paper is not to compare DBB and DB per se but only to point toward the gap in literature by which the existing contractual systems mostly prefer to operate inside DB regime of project delivery.

To address the gap in literature and respond to the mounting challenge of a dedicated contracting system for BIM in the context of the DBB project delivery method, this study identified potential legal problems in BIM implementation from the point of view of prime stakeholders. On the basis of the content analysis of synthesized literature, the significant legal problems were highlighted. Further, using a triangulation approach that included existing contracting systems, expert opinion from AECO practitioners, and custom manuscripts, a standardized legal framework was developed for seamless induction of BIM in mainstream contracts. The findings of this research will contribute to the body of knowledge by providing a detailed analysis of existing contracting systems, legal risks of BIM implementation, and dedicated contractual provisions of such an implementation. The contribution to industry is in the form of a functional and applicable contracting system that addresses all the identified legal risks associated with the implementation of BIM in the AECO industry.

Review and Synthesis of Existing Research

A comprehensive review was performed to study and critique the existing publications relevant to the selected topic. To do so, a two-stage review was conducted in which the legal risks of BIM were studied initially using a total of 10 published taxonomies. Each research taxonomy was studied in detail and the relative impact of each risk was identified through a two-step content analysis. In the first step, the relative frequency of appearance of each legal risk was noted, and in the second step its qualitative assessment was performed to place it into one of three impact categories: high (H), medium (M), and low (L). Then in the second stage of the review, the five existing contractual systems were studied.

Legal Risks of BIM

Existing research has discussed the advantages and challenges of BIM in greater detail (Newton and Chileshe 2012; Bryde et al. 2013; Migilinskas et al. 2013). The uncertainties associated with BIM implementation have been categorized into technical, managerial, environmental, financial, and legal categories (Chien et al. 2014); or into software, design, and legal liabilities (Eadie et al. 2015); or even more concisely, into technical and legal risks (Azhar 2011). For this study, the concise categorization was adopted, under which technical risks are exemplified as inadequate project experience, lack of software compatibility, model management difficulties, and inefficient data interoperability (Chien et al. 2014). Further, the legal risks, which form the central focus of this study, are exemplified as cost compensation, professional liability, and legislation and judicial precedence (Manderson et al. 2015). It should be noted that the technical risks of BIM actively feed into its legal uncertainty, and therefore addressing the latter will result in the resolution of former (Olatunji 2011; Manderson et al. 2015).

Following the first stage of literature review, a total of 14 legal risks were identified from the relevant articles, and their description was formalized, as given in Table 1.

To determine the implication and magnitude of these risks, a two-step content analysis, as previously explained, was performed using quantitative and qualitative assessment of identified legal risks. For quantitative analysis, the frequency of appearance was used, and qualitative analysis was based on the impact of these risks in the views of authors of selected articles (Newton and Chileshe 2012; Bryde et al. 2013; Migilinskas et al. 2013; Siddiqui et al. 2016; Ullah et al. 2016). The subjectivity in interpretation of results and conclusions of published studies cannot be eliminated, and therefore its responsibility is entirely assumed by the authors of this paper. However, to objectively understand the version of published studies, the papers were read multiple times and the literal as well as the figurative connotation of the content was evaluated. For example, the risk of cost compensation has high impact (H) according to Chong et al. (2017) because it had a mean value of 1.11 with an average mean of 0.64. But according to Eadie et al. (2015), it has a low impact because it was ranked at 13th position in the top 16 legal issues. However, McAdam (2010) listed it at 5th position out of the top 8 issues, which makes its impact medium (M). Whereas these authors rank this risk at different numbers, authors such as Alwash et al. (2017) and Abdirad (2015) did not discuss this risk at all. Similarly, the risk of standard of care, which is a fundamental concern for the health and reliability of digital data, has been ranked high (H) by Abdirad (2015), as it captures the unique, real-time, and synchronized data input pattern not witnessed in the less data-rich standalone computer-aided design (CAD) environments. But with unique features come robust heuristics that enforce the necessary mechanism to ensure that every party is liable for its data entry. Keeping that in view, Alwash et al. (2017) rated it as a medium (M) risk. And further, Arensman and Ozbek (2012) categorized it as a low (L) risk because it was chronologically presented at the end. On the other hand, Manderson et al. (2015) and Kuiper and Holzer (2013) did not discuss this risk at all. Similarly, all other risks were synthesized from the literature using such a detailed process, and great care was taken in interpretation of the literature.

Although Pareto analysis, also known as the 80/20 rule, has been used in the past as a screening strategy to eliminate the less impactful factors (Ullah et al. 2017), in order to conduct a holistic analysis the current study did not opt to eliminate any identified risk, regardless of the resulting lower total score. It is pertinent that the total score is a linear product of cumulative frequency and overall impact, which is derived by converting the qualitative scale into a numerical scale based on the weighted average of impact from each paper.

As presented in Table 2, the risk of intellectual property is the most common in working with BIM and has been treated as having a high impact in 80% of reviewed papers. It has been reported by many authors, such as Fan (2013) and Olatunji (2015). Researchers have yet to decide on the model ownership, and the literature is

Table 1. Details of legal risks of BIM

Risk ID	Legal risk	Description	Selected references
LR1	Intellectual property	Protection of intellectual property of design and input data	Olatunji (2011), Arensman and Ozbek (2012), Fan (2013), Manderson et al. (2015), and Alwash et al. (2017)
LR2	Professional liability	Professional liability of shared information	Arensman and Ozbek (2012), Manderson et al. (2015), and Alwash et al. (2017)
LR3	Conditions of contract	Contract directs modeling deliverables and its sharing	Manderson et al. (2015) and Alwash et al. (2017)
LR4	Data Interoperability	When BIM files are exchanged, data loss may occur	Olatunji (2011), Bryde et al. (2013), Porwal and Hewage (2013), Won et al. (2013), and Chien et al. (2014)
LR5	Protocols, processes, and responsibilities	Development of communication structure between parties	Olatunji (2011), Arensman and Ozbek (2012), and Manderson et al. (2015)
LR6	Data security	Security against data corruption, theft or manipulation	Olatunji (2011) and Manderson et al. (2015)
LR7	Cost compensation	Cost of model management and its reimbursement by stakeholders involved	Olatunji (2011), Arensman and Ozbek (2012), and Manderson et al. (2015)
LR8	Unclear BIM standards	Unclear BIM standards and contracts to operate	Azhar (2011), Arensman and Ozbek (2012), and Chien et al. (2014)
LR9	Standard of care and professional negligence	Parties are appreciated to render professional services with reasonable judgment to prevent loss	Arensman and Ozbek (2012) and Alwash et al. (2017)
LR10	Admissibility of electronic-based documents	Admissibility of digital documents in court or local administration	Olatunji (2011) and Alwash et al. (2017)
LR11	Model management difficulties	As model is updated, more accurate data entry is required, which causes model management difficulties	Gu and London (2010), Bryde et al. (2013), Porwal and Hewage (2013), Won et al. (2013), Chien et al. (2014), and Ozorhon and Karahan (2016)
LR12	Legal validation of design	Vetting of design from local administration	Manderson et al. (2015) and Alwash et al. (2017)
LR13	Lack of software compatibility	Each firm is working with its typical software and hardware tools that cause compatibility issues	Luthra (2010), Azhar (2011), Migilinskas et al. (2013), Porwal and Hewage (2013), and Chien et al. (2014)
LR14	Legislation and judicial precedence	Legislation for BIM to operate	Olatunji (2011) and Manderson et al. (2015)

Table 2. Content analysis of legal risks of BIM by legal type

Legal risk	Chong et al. (2017)	Alwash et al. (2017)	Manderson et al. (2015)	Eadie et al. (2015)	Abdirad (2015)	Kuiper and Holzer (2013)	Arensman and Ozbek (2012)	Olatunji (2011)	McAdam (2010)	Thompson and Miner (2006)	Frequency	Overall impact	Qualitative score	Total score
LR1	M	H	H	H	H	H	H	H	M	H	10	H	4.6	46
LR2	H	H	H	H	M	H	H	M	H	M	10	H	4.4	44
LR3	H	H	H	H	H	H	—	—	H	—	7	H	5	35
LR4	M	M	H	H	M	M	—	H	H	—	8	H	4	32
LR5	H	—	M	M	M	H	—	M	H	—	7	M	3.6	25.6
LR6	H	—	M	M	M	M	—	H	M	—	7	M	3.5	24.5
LR7	H	—	M	L	—	—	M	L	M	H	7	M	3	21
LR8	H	—	—	M	H	—	—	M	—	H	5	H	4.2	21
LR9	M	M	—	L	H	—	L	M	M	—	7	M	2.7	19.1
LR10	M	M	M	—	M	—	—	L	M	—	6	M	2.6	15.9
LR11	M	—	—	M	M	—	—	—	M	M	5	M	3	15
LR12	—	H	L	—	—	L	—	—	M	—	4	M	2.5	10
LR13	—	L	—	M	—	M	—	—	—	M	4	M	2.5	10
LR14	—	—	M	—	L	—	—	M	M	—	10	M	2.3	6.9

Note: H = high risk; M = medium risk; and L = low risk.

inconclusive on the party that possesses the intellectual claim over the BIM model. After the risk of model ownership, the issue of professional liability is most prominent. Design consultants stand liable for the design contributions of others, including default changes by software (Arensman and Ozbek 2012; Manderson et al. 2015).

Further, BIM contractual frameworks need to define the modeling products and the information that will be available for review and distribution. Also, it should clearly state how BIM will work under different project delivery methods (Manderson et al. 2015). Researchers and industry professionals have repeatedly discussed the interoperability issues. When software tools are not working smoothly, potential issues can arise (Olatunji 2015). Further, owing to its innovative organizational structure, BIM requires new roles and responsibilities. Research has reported that a new set of professional services involved in BIM protocols are yet to standardize (Olatunji 2011).

Because BIM is a fully digital system, the shift from traditional documents to e-communication has caused concerns over data security. Ensuring that data is well protected against loss, its control access and any possible financial losses in case of a breach are major concerns (Manderson et al. 2015). But all this is not going to come free of charge. As BIM requires a new set of professional skills and initial cost, its cost compensation should be discussed, deliberated, and resolved. Since there do not exist precise contracts for BIM, it is still unclear how the participants will be compensated for the added cost (Chien et al. 2014). Also, the BIM product delivery and criteria for model building are not standardized. BIM stakeholders are obligated to use sensible professional judgment to prevent any loss (Alwash et al. 2017).

Contracting Systems of BIM

As previously explained, five contract documents are currently available in the industry that incorporate some of the legal risks of BIM. These documents are ConsensusDOCS 301 BIM Addendum (ConsensusDOCS 2008), AEC BIM Protocol (AEC 2012), AIA E203 (AIA 2013), CIC BIM Protocol (CIC 2013), and CIOB Time and Cost Management Contract (CIOB 2015). These systems provide a foundation for research and development as well as the adoption of a standardized contracting system for BIM implementation. Using the identified risks, provided in Table 1, it is synthesized that these systems respond to some risks quite adequately but tend to forgo others.

A summary of the content analysis of contract documents points to the fact that ConsensusDOCS BIM Addendum, despite being the oldest, briefly discusses more risks than others but does not specify any contractual provisions for conditions of the contract and legal validation of design. Further, AEC BIM Protocol released its latest version, 2.0, in 2012, which encourages use of best practices for ownership of data and model management difficulties. However, the best practices are subject to the level of BIM implementation, which is quite limited.

The AIA E203 BIM addendum covers fewer risks, overlooking major issues like professional liability that is described by other BIM contracts. Similarly, CIC BIM Protocol, by proposing to apply best practices, gives generic information. It instructs to appoint a BIM manager and has a specimen for a BIM management plan. But it remains silent on various issues such as standard of care, cost compensation, and legal validation of design. Finally, CIOB Time and Cost Management Contract is the latest document that has incorporated BIM. It discusses how the contract will help in the case that a separate BIM contractor is appointed. But it, too, does not address the cost compensation, conditions of contract, and data security of the BIM model. Nevertheless, it encourages the use of a mutually developed model management protocol. If stakeholders do not devise one, then AIA G202 BIM management protocol takes precedence (CIOB 2015).

As provided in Table 3, a quantitative synthesis of several risks responded to by each contracting system out of the total identified risks reveals that ConsensusDOCS 301 BIM Addendum has the maximum coverage of 79%, followed by CIOB Time and Cost Management Contract and CIC BIM Protocol with coverage of 71%. On the other hand, E203-2013 and AEC BIM Protocol have the minimum coverage of 57%. The strength of existing systems is their coverage of the copyright or intellectual property issue, which is discussed by all of them. It is regarded that ownership of the model shall remain with the party who develops it. A license must be issued to any other party using it. Similarly, issues such as interoperability are briefly discussed, and a common data environment is recommended for smooth work. This clause can be used for improving software compatibility, as discussed by the BIM addenda. However, various other risks are not addressed by all the systems; for example, the risks of condition of contract and admissibility of electronic-based documents protocols are either partly addressed or not addressed at all.

Table 3. Content analysis of contracting systems of BIM

Risk ID	ConsensusDOCS (2008)	AEC (2012)	AIA (2013)	CIC (2013)	CIOB (2015)
LR1	Parties will warrant to other parties about their ownership or copyrights.	Apply best practices.	Transmitting party is owner of digital data.	Project team shall own the model.	The copyrights and any information extracted shall remain with the contractor. No one else can grant intellectual property rights (IPR).
LR2	The A/E is responsible for its duty.	—	—	Project team member shall have no liability to employer and vice versa.	Contractor is responsible for its duty.
LR3	—	—	—	Discuss the case of DB contract.	—
LR4	Common file format to be developed in BIM execution plan.	Common data environment approach is applicable.	Model management protocol will discuss.	Project team member shall have no liability in case of corruption of digital data.	Contractor shall provide common data environment and file transfer protocol.
LR5	Owner will appoint information manager and will chair BIM execution plan meetings.	Project BIM execution plan shall be put in place.	Project participants shall prepare a modeling protocol.	Specimen provided.	BIM modeling protocol to be established. Contractor shall notify the contract administrator regarding the appointment of a person to coordinate.
LR6	Information manager shall maintain security of model.	Project data shall be saved on network servers with monitored access.	Model management protocol will discuss.	Information requirements specimen is provided.	—
LR7	Cost of information manager to be settled and covered by owner.	—	—	—	—
LR8	Document shall be used as addendum to main contract.	BIM protocol shall serve as BIM standard.	Document shall be used as BIM standard.	Document shall be used as standard.	Detailed standard contract is provided.
LR9	All parties are responsible for their data input duty.	—	—	—	Contractor shall be responsible.
LR10	—	—	—	—	—
LR11	Parties shall prepare a BIM execution plan.	BIM execution plan shall be put in place.	Architect or project participants shall prepare a modeling management protocol.	Owner appoints an information manager.	BIM model shall be maintained by contractor in accordance with BIM protocol which shall be prepared by stakeholders. If not, AIA BIM addendum must be used.
LR12	—	Noneditable version to be produced.	—	—	Drawings can be extracted in accordance with BIM protocol.
LR13	To be addressed in BIM execution plan.	Common software shall be decided in BIM execution plan.	Architect is responsible.	Project team member shall have no liability.	Contractor shall select a common data environment.
LR14	Addendum shall take precedence.	—	—	The protocol shall take precedence.	If BIM is used, then this clause and appendix shall take precedence.

It can be concluded that none of the available contract documents encompasses all the risks of BIM reported in the recent studies of legal implications of BIM and addressed in the preliminary contractual framework developed by Chong et al. (2017). Furthermore, necessary remedies regarding the judicial precedence of the contract along with the legal validation of design and risk allocation are not provided anywhere in the literature. This gap justifies the need for standard contract documents, data security, and incorporation of new roles and responsibilities (Herr and Fischer 2018).

Research Methodology

To sufficiently meet the set objectives, this study follows a four-stage research methodology, as shown in Fig. 1. Maximum effort has been put to ensure a scientifically sound and conveniently replicable methodology. The details are explained in the subsequent sections.

Initial Study

Initially, a broad set of recent studies was analyzed to find the research gap. The latest published articles on information and communication technology (ICT) and on automation in civil engineering and construction were consulted, which guided the way toward the current state of development of BIM attributes. When the basics of recent literature on BIM were analyzed, a gap in research was found in the form of weak contractual support for a full-fledged implementation of BIM, even though this technology is gaining a good reputation in the market. However, because its contractual obligations are not yet met, project participants are voluntarily

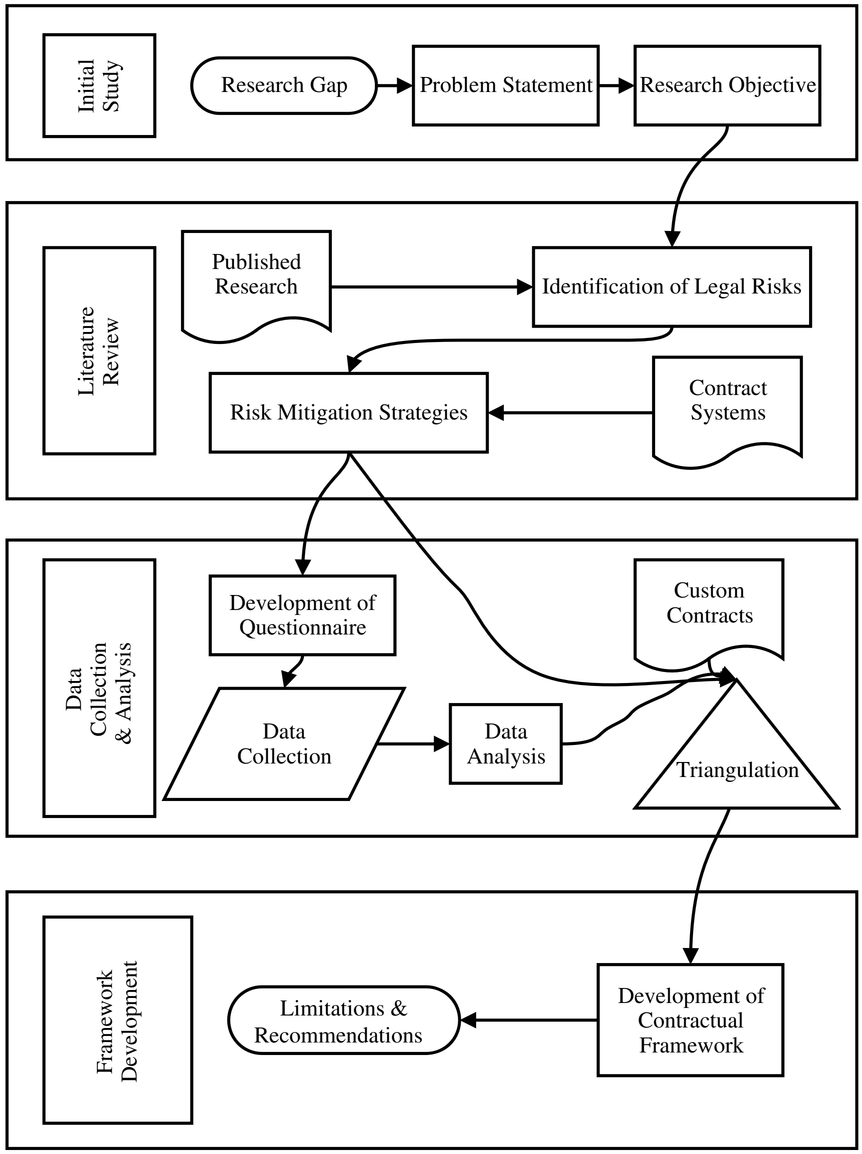

Fig. 1. Research methodology.

implementing BIM (Kumar et al. 2017). Considering this limitation, a research statement was developed regarding necessary contracts for BIM. As per this statement, the current study proposes a well-structured and balanced contractual framework for managing the legal uncertainties of BIM implementation in construction projects procured through DBB, which will result in a smooth induction of BIM into the AECO industry.

Literature Review

To cover as much recent literature as possible, an inverted pyramid approach was adopted under which many papers were consulted initially and screening was performed in the later stages to identify the most relevant papers. To do this, research papers were searched online using Science Direct, Taylor & Francis Online, Emerald Insight, ASCE, Google Scholar, and Scopus libraries, with the keywords BIM, Contracts, and Legal Risks.

Initially, a total of 79 research papers were retrieved. A first-level screening was performed by carefully reading the abstracts and conclusions of these papers. As a result, papers not dealing with contractual and legal risks were filtered, resulting in a short list of only 37 papers. In the second-level screening, these papers were analyzed in detail to identify the ones purely discussing the legal risks and offering a risk taxonomy. In response to this exercise, irrelevant papers were eliminated and content analysis of the remaining 10 papers was carried out to identify legal risks, as previously described and presented in Table 2. In a separate activity, five standard contracting systems were studied in detail to find the mitigation strategies and best practices to manage the identified risks, as given in Table 3. Finally, the past research was synthesized.

Data Collection and Analysis

On the basis of the detailed synthesis, risk mitigation strategies identified from the past research and contract documents were incorporated into a questionnaire survey that was distributed to practitioners to incorporate expert opinion. The questionnaire had two sections. In the first section, the demographic information of the respondents was solicited, including their personal and professional details such as experience, organizational position in the project, and country of practice. The second section had 14 questions aimed at identifying the appropriate mitigation strategy for each legal risk from a pool of multiple possible strategies extracted through review of recent relevant literature and contract documents. Respondents were asked to pick any one or to comment if more than one response was necessary. The target respondents were academicians and industry professionals, including architects and engineers, contract and BIM managers, and contractors and facility managers. The questionnaire was initially developed in the English language; later, due to the demand of potential respondents from Latin America, a Spanish version was also developed. The survey targeted over 500 potential respondents using online tools including official email, professional networks such as LinkedIn and Opportunity, research networks such as Academia and ResearchGate, and social networks such as Facebook and Google+, between July 2017 and November 2017.

Responses were analyzed to identify the industry trends. Then, to obtain the most appropriate and efficient mitigation options for an effective contractual framework, a triangulation approach was carried out. In research, triangulation is used to gather the observation of research issues from two or more different points (Flick 2004). In the current study, a three-point reference system of triangulation was employed using relevant literature, industry trends, and custom contracts to identify the optimum response strategy for each legal risk. To obtain real data from the field, the custom contract manuscripts were studied. Out of three documents, two (Contracts 1 and 3) were departmental guidelines published in the US in the years 2011 and 2015, respectively, and Contract 2 was specific to an infrastructure project located in Qatar and developed in 2013 and is currently in vogue.

Framework Development

After triangulation of the collected and analyzed information, proposed risk mitigation strategies were incorporated into a contractual framework that maps the identified legal risks with their optimum response strategies. The proposed framework is customized for DBB-based projects and explained using a descriptive form, providing information on the responsibilities of each stakeholder and possible mitigation strategy for each risk. Finally, on the basis of the limitations of the proposed contractual framework, future research recommendations are provided to improve BIM contracting systems.

Results and Analysis

Demographic Information on Survey Respondents

Following an extensive reach to BIM experts, 150 valid responses were collected. The respondents were asked about their country of practice and this information was aggregated into a regional categorization. As a result, most respondents were found to come from Asia (30%), as shown in Fig. 2. Jung and Lee (2015) studied the continent-level BIM adoption and found that the status of BIM adoption in Asia is perceived as in other advanced continents, which validates the higher percentage of respondents in the current study.

Responses were collected from a range of experienced industry professionals as well as researchers, as presented in Table 4. It is apparent that 85% of the respondents had less than 10 years of experience. The reason is mainly that BIM is a relatively new technology and it is gaining experience with time, as discussed by Yan and Damian (2008), Chien et al. (2014), and Gerges et al. (2017). Thus, most of the direct experience of BIM will remain on the less-experienced side of the distribution. Further, all respondents were

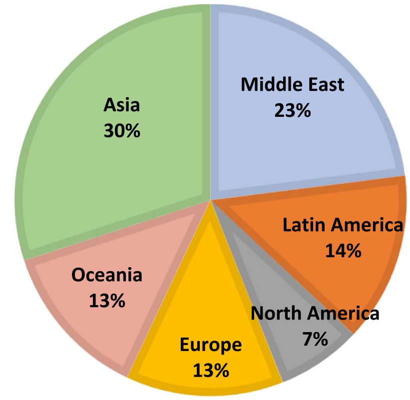

Fig. 2. Regional distribution of respondents.

Table 4. Demographic information on respondents

Options	Responses (%)
Years of experience	
1–5	51
6–10	34
11–15	5
16–20	5
21 and above	4
Qualification	
B.Sc./B.Engg.	44
M.Sc./M.Engg./PgDip.	39
Ph.D.	6
Others	10
Position	
Architect	19
BIM manager	9
Consultant	10
Project manager	6
Institutions	
Government	5
Semigovernment	13
Private	56
Academia	18

well qualified, having a minimum of four years of postsecondary education, as also followed by Chong et al. (2017). Most respondents held key positions such as architect and BIM manager. According to Zahrizan et al. (2013) and Ding et al. (2015), architects are the foremost field practitioners of BIM and have more experience than any other key management personnel. It is also important to note that BIM manager is a post-BIM adoption job title that serves both A/E and contractor, and professionals occupying this position possess the necessary skills to develop, operate, and manage BIM-related matters (Barison and Santos 2010). Thus, the BIM managers who participated in this survey represented both A/E and contractor organizations. In addition, a sizable portion of design and contract management consultants working on behalf of client organizations participated in the survey. Finally, 55% of respondents occupied technical positions such as BIM operator/modeler working for A/E and contractors, and project engineer; managerial positions such as construction manager and site manager; and academic positions such as university professor and graduate student working on BIM research and development.

Many responses were collected from experts belonging to private organizations and academia. As discussed by Zahrizan et al. et al. (2013), the private firms are more inclined toward BIM adoption than their public counterparts. These statistics helped ensure the quality of the survey sample and enhanced the reliability of findings of this study. However, a limitation of this sample is lack of direct involvement of client/owner organizations, which may be justified by the presence of their representatives in the roles of A/E and consultants. Furthermore, at such an initial stage, the involvement of technical as well as subject matter experts would facilitate the process of developing a workable legal framework that can later be expanded by directly incorporating the stance of client organizations.

Mitigation Strategies

The respondents were asked to select the most appropriate mitigation strategy for each identified legal risk. In the case that the respondent's opinion was different from the available strategies, they were invited to provide their own strategy. The data collected from the questionnaire survey is given in Table 5, in which the frequency for each strategy shows its applicability and user preference against the mentioned risk.

With an aim to identify the most appropriate strategy to manage the legal risks of BIM, on the basis of the triangulation approach each risk was addressed through published standard contract systems, industry experts, and custom contracts. The results reveal that for the mitigation of risk of intellectual property (LR1), the standard contracts emphasize that the model shall remain with the designer or developer, which has also been discussed by Chong et al. (2017). The survey results seem to endorse this opinion; most respondents (44%) suggested that copyrights and any information extracted shall remain with the A/E, along with a sizeable population (23.33%) who advocated the application of best practices. However, the reviewed custom contracts do not provide any effective resolution. Therefore, on the basis of the triangulation it can be inferred that the A/E shall have the ownership of the model and will act as a central entity in case of any dispute.

As with intellectual property, the survey results suggest that in case of professional liability (LR2), the A/E would assume responsibility for its data input (42.67%), and nearly half of this proportion support the application of best practices (22.67%). In lieu of this trend, custom contracts also emphasize the liability of the A/E for its input. The same line of argument is maintained by the published contracts, which validate the results of the survey data.

Further, the published contracts, except for CIC BIM Protocol (CIC 2013), remain silent on the conditions of contract (LR3), and CIC BIM Protocol, too, is limited to the case of DB. With regard to the custom contract manuscripts, only Contract 2 defines that the A/E shall be responsible for contract administration; the others do not offer any contractual provision for LR3. Survey results suggest that the modeling deliverable and sharing shall be discussed in the BIM execution plan (43.33%), transferring the liability issue to the A/E because this party has also been allocated LR2. Further, data interoperability (LR4) is one of the most important and discussed risks (Olatunji 2011; Chong et al. 2017). The published contracts suggest that a common data environment for BIM shall be specified in the execution plan, whereas the custom contracts make this the A/E's responsibility. Survey results suggest that an execution plan made in concurrence of all stakeholders (44.67%) will be preferred, as discussed for LR3.

For protocols, processes, and responsibilities (LR5), all published contracts specify that the execution plan or protocol specified for each project shall be prepared. In addition to this, all custom contracts declare the A/E to be liable for devising such a plan, which shall discuss the creation of any new roles and responsibility of such roles. Survey results concur with this by stating that the A/E shall prepare a BIM execution plan (22.00%) and that the client shall appoint an information manager (41.33%) who would be responsible for smooth execution of BIM implementation along with chairing the BIM execution plan meetings (ConsensusDOCS 2008). Moreover, results reinforce the need for data security (LR6), suggesting that the data should be protected on network servers (Chen et al. 2016). Moreover, the custom contracts add that the A/E will be responsible for its security. Survey results are tilted toward saving data on network servers (46.00%) and suggest that each superseded file shall be saved and its log shall be maintained (26.67%). It is apparent that survey respondents show a high level of awareness in terms of digital data management.

Cost bearing and compensation (LR7) are important aspects in implementing BIM (Barlish and Sullivan 2012). The published contract systems and custom contracts do not provide a solid basis to clarify the cost bearing and compensation of stakeholders involved. Survey results explicate that the client should take the financial responsibility by assuming extra cost (42.67%) and further state that best practices may be applied to resolve any ambiguities (26.00%). This puts the client at the center of financial liability for BIM implementation. But this transfer of responsibility is not without its perks; the client also receives advantages due to reduced issues and improved quality of the final product (Bryde et al. 2013).

However, achieving such advantage would require some standardized procedures and protocols. Unfortunately, all published contracts try to address the issues due to lack of BIM standards (LR8), but certain gaps were identified in all documents that need improvements to avoid ambiguities. Custom contracts were created mainly to address these gaps and to improve field practices. Survey results suggest that all risk mitigation strategies shall be compiled into one addendum of a standard contract for future use (43.33%).

Standard of care (LR9) was discussed by two standard contracts (ConsensusDOCS 2008; CIOB 2015). It is clear from published documents and past practices that every stakeholder is responsible for its own input and will be liable for its own scope only. Contract 2 specified that the A/E shall be responsible, but survey results suggest that all parties will be responsible for their input (43.33%), as dictated by ConsensusDOCS (2008) and set as a precedent in Spearin case law. Thus, keeping in view the privity issues and not compromising on data security, every party must take responsibility for its own data input, and any party acting upon faulty data input by another party will not be held responsible for it.

With the induction of smart systems such as CAD, BIM, and geographic information system (GIS) in the field of civil engineering, it is necessary that digital documents should be admissible (LR10) and read in concurrence with the conditions of contract as discussed for the case of two-dimensional (2D) drawings (Bunni 2013). Published contracts do not seem to have evolved for this stage, but custom contracts have attempted to resolve this deficiency by allowing the model to be acceptable in specific formats with digital stamping. Survey results discuss that digital documents should be considered part of the contract, as suggested by nearly half the respondents (48.67%).

Further, for model management (LR11), all custom as well as standard contracts demand the new role of model manager and discuss an execution plan. Survey results are divided into two major strategies in this regard: the BIM model shall be maintained by the A/E in accordance with BIM protocol that shall be prepared by the stakeholders (33.33%), and parties shall prepare a BIM execution plan with mutual understanding (32%). If a BIM execution plan is prepared by all stakeholders and the A/E will manage it due to professional liability and ownership, other risks like conditions of contract (LR3) and data interoperability (LR4) will be automatically resolved.

Table 5. Survey responses

Risk ID	Mitigation strategy	Frequency (%)
LR1	Copyrights and any information extracted shall remain with the A/E.	44.00
	Apply best practices (prevailing in previous projects that can be settled by stakeholders involved).	23.33
	Parties will warrant about their copyrights.	22.00
	Project team shall own the model.	9.33
LR2	The A/E is responsible for its duty.	42.67
	Apply best practices.	22.67
	Data provider (designer or contractor) shall be responsible.	20.67
	Project team member shall have no liability to employer and vice versa.	12.00
LR3	Modeling deliverable and sharing shall be discussed in BIM execution plan.	43.33
	Modeling deliverable shall be specified by the client. Noneditable versions of model shall be shared.	22.00
	Modelling deliverable shall be specified by the A/E. Construction-ready BIM model shall be transmitted to constructor.	22.00
	Apply best practices.	10.67
LR4	Common file format to be developed in BIM execution plan.	44.67
	The A/E shall provide common data environment.	30.00
	Apply best practices.	24.00
LR5	Client will appoint information manager who shall develop BIM execution plan and chair BIM execution plan meetings.	41.33
	BIM manager shall be appointed.	26.00
	The A/E shall prepare a BIM execution plan.	22.00
	Apply best practices.	9.33
LR6	Project data shall be saved on network servers with monitored access.	46.00
	Each superseded file shall be saved and its log shall be maintained.	26.67
	Apply best practices.	26.00
LR7	Client will bear the additional cost.	42.67
	Apply best practices.	26.00
	Consultant (A/E) will bear the additional cost.	20.00
	Contractor will bear the additional cost.	7.33
LR8	Contractual framework shall be incorporated into an addendum of standard contract document.	43.33
	All remedies of contractual risks shall develop a BIM standard.	28.00
	Apply best practices.	28.00
LR9	All parties are responsible for their data input duty.	43.33
	Spearin doctrine shall govern (and parties shall not be responsible for faulty data provided by other).	27.33
	Contractor shall be appreciated to render professional services with reasonable judgment to prevent loss.	16.00
	Apply best practices.	12.67
LR10	Digital data should be treated as a part of contract document.	48.67
	Apply best practices.	17.33
	Hard data governs over soft data.	16.00
	2D drawings shall be plotted to be presented in court or local administration.	15.33
LR11	BIM model shall be maintained by the A/E in accordance with BIM protocol that shall be prepared by stakeholders.	33.33
	Parties shall prepare a BIM execution plan with mutual understanding.	32.00
	The A/E is responsible for model management.	22.00
	Apply best practices.	10.67
LR12	Noneditable version to be produced that can be presented in local administration.	41.33
	Drawings can be extracted in accordance with BIM protocol.	26.67
	Apply best practices.	18.00
	2D drawings shall be plotted to be presented in court or local administration.	12.67
LR13	Common software shall be decided in BIM execution plan.	56.00
	Apply best practices.	24.67
	Project team member shall have no liability in case of incompatibility.	16.00
LR14	If BIM is used, then this addendum shall govern.	57.33
	Apply best practices.	40.00

Legal validation of design (LR12) requires the plotting of drawings. Two out of five contract systems discuss this issue and propose the solution in the form of plotting of drawings. Custom contracts emphasize the responsibility of the A/E for the legal validation of design. Survey results state that a noneditable version must be produced that can be presented in local administration (41.33%) and that such drawings can be extracted in accordance with BIM protocol and execution plan (26.67%).

Software compatibility risk (LR13) is discussed by all standard and custom contracts. It is the A/E's responsibility to suggest a common software to manage this issue. Custom contracts suggest specified software if the A/E does not dictate one. Survey results

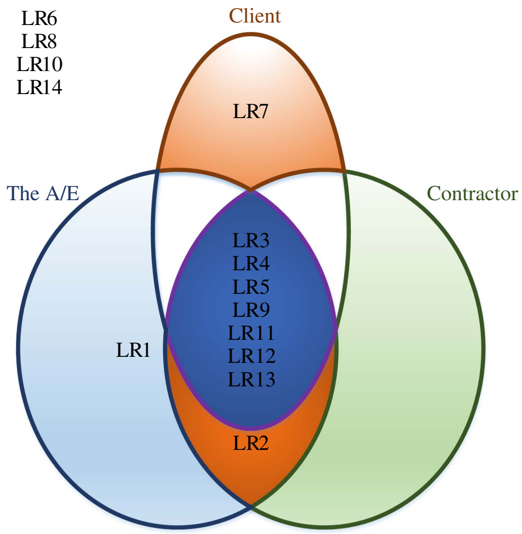

Fig. 3. Proposed contractual framework.

validate the AEC (2012) clause that common software shall be decided in the BIM execution plan (56.00%).

Risk of legislation and judicial precedence (LR14) was catered in the same pattern by all standard and published contracts by suggesting that an addendum shall be specified for BIM and will be applicable if BIM is used. More than half the survey respondents agreed and stated that if BIM is used, then this addendum shall govern (57.33%).

Proposed Contractual Framework

Using the data collected through various syntheses and surveys, a contractual framework for DBB is proposed. The framework uses three dimensions of information in the form of published contracts, survey response, and custom contract manuscripts to provide the information triangulation. Owing to the integrated nature of BIM, the roles and responsibilities of various stakeholders seem to overlap, as shown in Fig. 3. It is argued in the literature that the overlap of responsibilities, although it may seem confusing to relevant stakeholders, ensures a better, effective redressal of risks and contractual relationships (Porwal and Hewage 2013).

As a contribution of the proposed framework, all identified risks are allocated to the respective owners who will bear the responsibility of managing and mitigating them. For example, the A/E is the owner of risk of intellectual property (LR1), who will be responsible for digital data, and any information extracted will remain with this party. Further, the A/E and contractor share the risk of professional liability (LR2) and will stand liable for their data input duty. For the risk of cost compensation, the contractual framework recommends the extra cost to be borne by the client. Furthermore, it is proposed that insurance-related matters also be managed by the same party. Seven risks have been shared by all the stakeholders, and therefore not a single party will be exclusively liable for their mitigation, such as the risk of conditions of the contract (LR3), which will be mitigated by an elaborate BIM execution plan to be developed by all the stakeholders and managed by the A/E. Similarly, the risk of data interoperability (LR4) will be mitigated by identifying a common software in the BIM execution plan, also covering lack of software compatibility (LR13).

Furthermore, four risks will be mitigated by the contract framework itself because not a particular party owns them as they exist purely due to nonexistence of a standardized contracting system for BIM. For example, risk of data security (LR6) is managed in such a way that the data will be saved on system networks with monitored access. Similarly, risk of unclear BIM standards (LR8) will be mitigated by sufficient description of all risks and declaration of their owners by the proposed framework. Further, for the risk of admissibility of electronic-based documents (LR10), the contractual framework suggests that such documents, including digitally stamped models, will be treated as part of contract documents. However, the hard data will govern over the soft data. Lastly, for legal validation of design (LR12), the contractual framework suggests that 2D drawings can be presented in local administration for validation. A summary of proposed framework with respect to all legal risks and their most preferred mitigation strategies is given in Table 6.

It should be noted that these mitigation strategies echo the best of the survey response along with standard and custom contracts manuscripts. Although they are discussed separately, they can be incorporated into a streamlined system that although it may not produce an ideal framework, ensures practicability as well as legal robustness by assigning proper roles and responsibilities to relevant entities. For example, the A/E acts as a pivotal body for all major risks. It has copyright over data so all other major risks are also borne by it. Beside devising a BIM execution plan on the directions

Table 6. Summary of proposed risk mitigation strategies

Risk ID	Proposed mitigation strategy
LR1	Copyrights and any information extracted shall remain with the A/E.
LR2	The A/E or any data provider (contractor or third party) is responsible for its duty and shall be liable for its input data.
LR3	The A/E shall provide common data environment and a common file format will be developed in BIM execution plan.
LR4	Modelling deliverables and sharing shall be discussed in BIM execution plan and client will direct the A/E about modelling deliverables.
LR5	Client will appoint information manager who shall chair BIM execution plan meetings.
LR6	Project data shall be saved on network servers with monitored access. Each superseded file shall be saved and its log shall be maintained.
LR7	Client will bear costs of model development.
LR8	Contractual framework shall be incorporated into addendum of standard contract document.
LR9	All parties are responsible for their own data input duty.
LR10	Digital data in general and BIM (archived and digitally signed data with time stamps) in particular will be treated as part of contract documents.
LR11	BIM model shall be maintained by the A/E in accordance with BIM execution plan.
LR12	Non-editable version (2D drawings) to be produced according to BIM protocol and execution plan which will be presented in local administration
LR13	Common software shall be decided in BIM execution plan.
LR14	If BIM is used, then this addendum shall govern.

of the client, the A/E will be maintaining it throughout project life cycle. It should also be noted that the A/E acts as a major stakeholder in DBB contract systems because it is introduced into the project earlier than the contractor (Hale et al. 2009).

Despite this argument, the proposed framework still needs a critical review of its applicability and soundness, for which three professionals from academia and industry were approached. The senior BIM researcher from academia offered positive and critical feedback for the proposed framework. It was suggested that the provided risk allocation and response mitigation strategies are adequate and will help in resolving the legal risk of BIM. Another senior BIM researcher, as well as encouraging the sound basis of the proposed framework, suggested that more depth was needed by incorporating more legal risks into the framework. The industry professional suggested that issues like the employer's information requirement (EIR) and the data drop should be incorporated into the framework. Thus, the proposed framework may act as a point of departure in the face of these suggestions, to stimulate future research that must focus not only on enhancing the structure and contents of the proposed framework but also on operationalizing its clauses and observing their value addition.

Conclusions

BIM is gaining a significant reputation in the AECO industry, and its rate of adoption has substantially increased. A detailed review of the published literature highlights that the legal risks of BIM should be mitigated through predisposed strategies. Several contract documents discuss legal risks associated with BIM but do not cover all of them. This study explored 14 legal risks of BIM through literature review and found that intellectual property, professional liability, cost compensation, and data interoperability are the most significant risks. An analysis of recently published contract systems, expert opinion, and custom contracts in light of legal risks resulted in the identification of risk owners and possible mitigation strategies. These strategies were then incorporated into a contractual framework that was discussed with industry professionals as well as academic researchers for further improvement.

The proposed framework operates within the DBB project delivery method for easy and smooth implementation of BIM. It can become part of any existing DBB contract by being issued as an addendum, which reduces the effort of formulating a new set of contract documents. Furthermore, this study discusses the owner of the BIM execution plan and how this plan will operate; either the plan is devised by the stakeholders from scratch, or an already published plan can be used. With all that done, a complete set of contract documents is obtained that will help in execution of BIM to its fullest. Thus, the contribution of this study is twofold: it identifies the critical legal risks that must be managed for smooth induction of BIM in construction projects, and it provides a stepping stone in the form of a contract framework toward the standardization of a contractual system for implementing BIM in the AECO industry. This study will inspire AECO community to devise a panacea for the contractual uncertainties of BIM in AECO projects.

It is pertinent to note that this paper takes an inside view of the knowledge gap, and as a result, it offers a contractual and legal framework for implementing BIM in construction projects delivered through the traditional DBB system. Larger, nonoperational legal and technical risks surfaced due to the advent of BIM—such as the practice of A/E by untrained and nonlicensed individuals, involuntary data fudging, and data drop due to the n-tier distributed architecture of cloud-based data repositories—are beyond the scope of this paper. Although an extreme scenario, there is a logical possibility that BIM data provided in the form of objects by an intelligent and preprogrammed system may represent the unlawful practice of architecture and engineering. However, redressal of the same has not been incorporated in this paper.

Additionally, the kernel of knowledge gained by this study is in the recognition that because risk is a function of role and responsibility and therefore may take multiple forms and represent differing levels of concern to respective parties, the proposed mitigation strategies may differ depending upon who assumes the risk, challenging the very foundation of standardization. Despite this recognition, a standard contractual and legal framework may still ensure better implementation of BIM without demanding repetitive efforts to configure contracting systems.

In light of recommendations from the experts and limitations of this research in its scope and details, research efforts are encouraged toward operationalizing the proposed framework by formulating a robust system of roles, rights, and privileges that ensures data privacy and security. Once it has been operationalized, enhancements can be made by directly incorporating the stance of client organizations. Further, issues such as EIR and data drop must be sufficiently addressed either through BIM protocol or execution plan. The structure and mechanics of the BIM execution plan, which has been emphasized by the proposed contractual framework, has not been discussed in this paper. Future research focusing on the development of a detailed BIM execution plan will tactically and operationally help in providing a standardized contractual framework for BIM implementation in the AECO industry.

Data Availability Statement

All data generated or analyzed during this study are included in the published paper. Information about the *Journal*'s data-sharing policy can be found here: http://ascelibrary.org/doi/10.1061/(ASCE)CO.1943-7862.0001263.

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Supplemental Data

Survey data is available online in the ASCE Library (www.ascelibrary.org).

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