www.itcon.org - Journal of Information Technology in Construction - ISSN 1874-4753

PRELIMINARY CHECKLIST PROPOSAL FOR ENHANCING BIM-BASED CONSTRUCTION PROJECT CONTRACTS

SUBMITTED: October 2020
REVISED: March 2021
PUBLISHED: July 2021
EDITOR: Esther Obonyo
DOI: 10.36680/j.itcon.2021.019

Mehmet Yavuzhan Erpay, Ress. Asst.,
Faculty of Architecture, Yıldız Technical University, Turkey;
Faculty of Architecture, Istanbul Technical University, Turkey;
myerpay@yildiz.edu.tr

Begum Sertyesilisik, Full Professor,
Faculty of Architecture, Izmir Democracy University, Turkey;
begum.sertyesilisik@idu.edu.tr

SUMMARY: *In multi-participant BIM-based construction projects (BbCP), the organization of inter-stakeholder relationships has become challenging. The emerging BIM roles and responsibilities that are not clearly defined as a standard, complicate this process further. Legal regulations and contracts prepared according to traditional construction methods are insufficient to identify these new and complex relationships. This uncertainty hinders the spread of BIM-integrated projects, causing stakeholders to have legal concerns about BIM-based projects. Within the scope of this research, the legal concerns related with BIM-based projects and critical points to be considered in the contract preparation phase were determined through literature review, case law research, first and second stage interviews and a questionnaire survey. 25 main and 32 sub-critical points were identified and recommended to be considered in the contract phase were categorized under 9 headings (i.e., administrative decisions, analysis, legal issues, allocation of risks and responsibilities, intellectual property rights (IPR), information management, interoperability, data security and the operation phase). As an outcome, this paper proposes a preliminary checklist template that can be used as an input to the contract phase of BbCP. With the support of checklist, measures can be taken at the contract stage for potential legal problems that may occur in the project life-cycle. The checklist can serve as a starting point for legislators and regulators to ensure the compatibility of traditional construction contracts with new technologies. Finally, addressing legal issues in BbCP can alleviate stakeholders' concerns and lead to the spread of BbCP in the construction industry.*

KEYWORDS*: BIM; Contract Management; Disputes in Construction; BIM Contracts*

REFERENCE: *Mehmet Yavuzhan Erpay, Begum Sertyesilisik (2021). Preliminary checklist proposal for enhancing BIM-based construction project contracts. Journal of Information Technology in Construction (ITcon), Vol. 26, pg. 341-365, DOI: 10.36680/j.itcon.2021.019*

1. INTRODUCTION

CI (construction industry) is one of the essential pillars of the economies thanks to its own and secondary industries. The CI is, however, also one of the most difficult and challenging industries to manage mainly due to its multi-disciplinary complexity and uniqueness as well as changes in building materials and construction methods. To overcome this managerial challenge, BIM offers several advantages: improved information management, interoperability potential and integrated supply chain (BSI, 2015a), effective and efficient management of tasks (Liu et al., 2017), communication and coordination improvement (Bryde et al., 2013), and reduction in delays and conflicts (Ghaffarianhoseini et al., 2017). For example, 3D and 4D models prepared in BbCP (BIM-based construction project) can be integrated to various extended reality technologies to ensure that all stakeholders are included in the project from the first stage and that possible problems are detected early (Alizadehsalehi et al., 2019). Furthermore, conflicts which can arise especially in large and complex projects can be resolved through simulations (Heigermoser et al., 2019). Moreover, communication between the design team and the owner can be enhanced by making more understandable architectural presentations with the virtual reality model (Khalili, 2021). Consequently, management of large-scale digital data has become important in this integration process (Alizadehsalehi et al., 2020).

As BIM is becoming widespread in the CI, the project processes (e.g., design, procurement, construction and operation) have started to change (Ashworth et al., 2019). Collaborative environment offered by BIM, information management has gained more value as importance of communication and coordination between stakeholders has been increased. Although BIM has several advantages, BbCP involve various risks e.g., managerial (Perrier et al., 2020), technical, legal, financial, environmental risks (Chien et al., 2014). In order to cope with these risks, key stakeholders of the project (e.g., the project owner, design team, construction team) need to work together in the preparation of the BIM contract at the contracting stage (Dougherty, 2015). Most of the standard contracts and protocols that can be applied to BbCP are created as an addendum to the master contract and they cannot cover all risks (Chong et al., 2017). Moreover, since modern legal systems are typically constructed based on conventional construction techniques, they concentrate on individual rights and responsibilities of the stakeholders (Pandey et al., 2016). In contrast, as participants need to work together in the collaborative environment of BIM to get benefit from BIM, existing legislation and regulations lack arrangements for integrated design and for regulating cooperation between stakeholders (Azhar, 2011).

Elimination and minimization of disagreements is essential for the efficient and effective implementation of the project. Increase in the number and diversity of stakeholders and digital data reveals various risks in BbCP (Liu et al., 2017). The risks that may occur during the project process can be reduced/prevented through the collaborative and communication-supported structure of BIM (Ghaffarianhoseini et al., 2017). Furthermore, these risks may turn into disputes due to some deficiencies in the contracting phase (Dougherty, 2015). The main issues that can pose these risks are: identifying BIM roles and stakeholders responsible for them (Arensman and Ozbek, 2012; Bosch-Sijtsema et al., 2017; Ussing et al., 2016); IPR (intellectual property rights) in the common information platform (Arshad et al., 2019; Manderson et al., 2015; Solihin and Eastman, 2015), software compatibility (Bynum et al. 2013; McAdam, 2010; Succar, 2010); data security (Chien et al., 2014; Dougherty, 2015; Eschenbruch and Bodden, 2018); and digital data storage (Bakhary et al. 2015; Lai et al., 2019). Preparation of a clear and detailed contract can minimize disputes in the project life-cycle (Sardroud et al., 2018).

This paper focuses on contract aspect of the BbCP and the main legal concerns related with the integration of BbCP's requirements and needs into the contract. With this aim, international guidelines, standard contracts and protocols were examined, case law research was conducted, first and second stage interviews and an online-questionnaire survey were performed. As a result, critical points to be considered in BIM-based contracts were determined and a preliminary checklist template was proposed to support the contract preparation phase of BbCP.

2. LEGAL ASPECTS OF BbCP

2.1 BIM-based Construction Project Management

BIM facilitates the information flow by providing a collaborative decision-making platform (Heigermoser et al., 2019), and brings solutions to managerial problems through stakeholders' involvement in the entire building lifecycle (Demian and Walters, 2014). Governments, universities and institutions have published several guidelines to assist project stakeholders in planning BIM integration processes. Among them the followings were

studied within the scope of this research (i.e., BBIM, 2015; CANBIM, 2012; COBIM, 2012; DASBIM, 2015; NATSPEC, 2016; NBIM, 2013; NBGO, 2017; PSUBIM, 2019; SBEnrcBIM, 2017; SBIM, 2013; USCBIM, 2012; USFBIM, 2018). Additionally, under the name of BSI Standard Publications, 2 ISO (International Organization for Standardization) (BSI, 2018a, 2018b) and 6 PAS (Publicly Available Specification) (BSI, 2013, 2014b, 2014a, 2015a, 2015b, 2018c). These guidelines were chosen based on their scope and content details.

2.1.1 BIM-based CPM process

In complex construction projects with multi-stakeholders, planning the interaction of stakeholders throughout the process can reduce risk of conflicts and disputes. Main headings, scopes and topics highlighted in the examined guidelines have been executively summarized in the Table 1.

TABLE 1: Main headings, scopes and topics highlighted in the examined guidelines.

Main headings	Main points highlighted in the documents
Extent of the process	Between pre-design and handover phases (BBIM, 2015; CANBIM, 2012; DASBIM, 2015; NATSPEC, 2016; NBGO, 2017; SBEnrcBIM, 2017; SBIM, 2013; USCBIM, 2012; USFBIM, 2018). From the organizational decisions before project initiation and operational stages after project handover (BSI, 2018a; COBIM, 2012; NBIM, 2013; PSUBIM, 2019).
Information management	The procedures related to information management are detailed or referenced to specific documents. These procedures are generally specified under 3 titles as creating, sharing and archiving (BBIM, 2015; BSI, 2013; COBIM, 2012; NATSPEC, 2016; NBIM, 2013; NBGO, 2017; PSUBIM, 2019; USCBIM, 2012; USFBIM, 2018).
Legal status of BIM requirements	The BIM goals and requirements as well as the roles and responsibilities that arise from them, should be legally binding in the contract. (BBIM, 2015; BSI, 2018a; CANBIM, 2012; COBIM, 2012; NATSPEC, 2016; NBGO, 2017; PSUBIM, 2019; SBEnrcBIM, 2017; SBIM, 2013)
IPR	In the highly integrated and collaborative environment of BIM, the definition and protection of IPR are essential and the requirements should be specified in the contract (BBIM, 2015; BSI, 2013; CANBIM, 2012; COBIM, 2012; NBIM, 2013; NBGO, 2017; PSUBIM, 2019; SBEnrcBIM, 2017; SBIM, 2013).
Operation and maintenance	The procedures for handing over the BIM model to the facility manager for the operational stage should be determined (BBIM, 2015; BSI, 2014b; COBIM, 2012; NATSPEC, 2016; NBIM, 2013; NBGO, 2017; PSUBIM, 2019; SBEnrcBIM, 2017; SBIM, 2013; USCBIM, 2012; USFBIM, 2018).

2.1.2 BIM-based CPM stakeholders and teams

A collaborative environment including all supply chain participants is needed to get benefit from BIM. Ensuring that all expertise and knowledge of stakeholders are shared with each other through effective stakeholder management is important for the success in project management process (Srinivasan and Dhivya, 2020). With the spread of BIM in the CI, new roles and responsibilities are evolved (Uhm et al., 2017). Although according to a recent study 35 different BIM related job titles have emerged (Uhm et al., 2017), there is no generally accepted definition of the duties and responsibilities of these roles (Bosch-Sijtsema et al., 2019).

According to the researchers, a specialist BIM manager should be appointed to manage and control all BIM processes and stakeholders (Eschenbruch and Bodden, 2018; Huzaimi and Fathi, 2019). Besides the manager, coordinator and modeller are among the most important BIM roles (Borrmann et al., 2018; Tulke and Schumann, 2018). The general definitions and the hierarchical scheme of BIM roles, which are described in the examined guides (i.e., BBIM, 2015; CANBIM, 2012; COBIM, 2012; DASBIM, 2015; NATSPEC, 2016; NBIM, 2013; NBGO, 2017; PSUBIM, 2019; SBEnrcBIM, 2017; SBIM, 2013; USCBIM, 2012; USFBIM, 2018) are shown in the Fig. 1.:

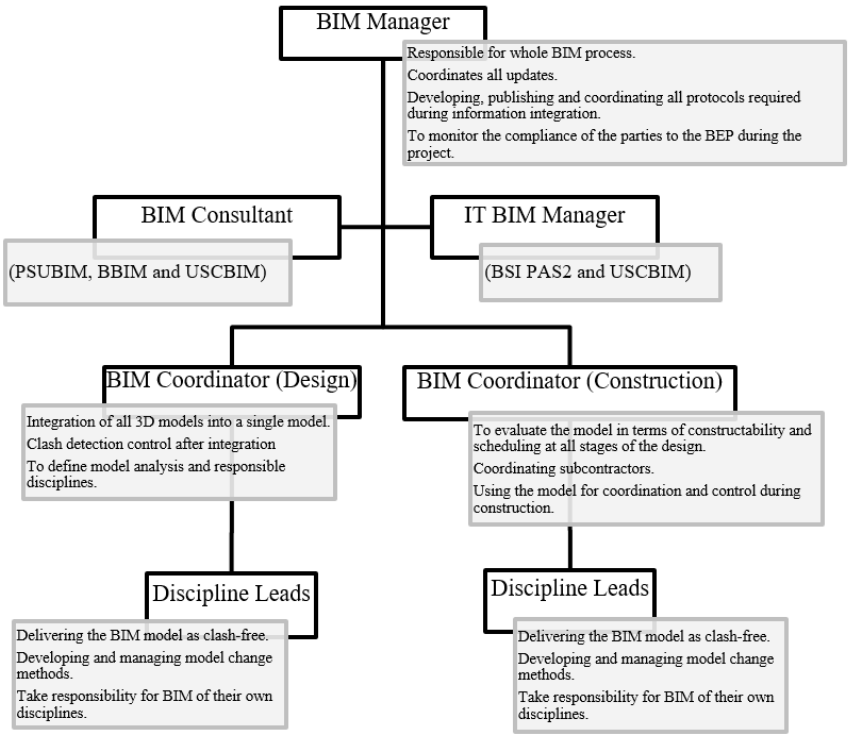

FIG. 2: Definitions and hierarchy scheme of BIM roles.

2.1.3 BIM-based CPM documents

Integration of BIM into the traditional construction process can be facilitated through the documents regulating this process. BIM Execution Plan (BEP), which contributes to the integration process through determination of the BIM requirements and goals at all project stages, is one of the most important documents (Abdirad, 2015). Although BEP content is not well defined as a standard in the literature, it should fundamentally include details on the following topics (Eschenbruch and Bodden, 2018): data production, level of detail, milestones of the process, responsible groups and coordination actors. Although the names vary, all investigated guidelines mention the BEP document. All guidelines state the importance of creating BEP in the early stages of the project for effective BIM integration. Some guides (COBIM, 2012; SBIM, 2013; NBIM, 2013; BBIM, 2015; NATSPEC, 2016; NBGO, 2017; BSI, 2018a) indicate that BEP should be seen as a dynamic document and updated through project phases. Along with the BIM Implementation Plan, various documents according to the stages of the project are highlighted (COBIM, 2012; NBIM, 2013; BSI, 2015a; NATSPEC, 2016; NBGO, 2017; PSUBIM, 2019). These documents can be classified under 3 main headings under the organizational, asset and project-based levels (BSI, 2018b) as follows:

Organizational Level: BSI ISO1 (2018b) emphasizes OIR (Organizational Information Requirements) and PIR (Project Information Requirements) respectively to determine the organization's high-level strategic objectives, portfolio planning and regulatory policies as well as to measure and monitor decisions on a project specific basis. PSUBIM (2019) recommends publishing a BIM Mission Statement document that specifies the importance of BIM to the company, and which details its usage for future corporate decisions.

Asset Level: BSI ISO1 (2018b) emphasizes the AIR (Asset Information Requirements), in which managerial and commercial decisions about the asset as well as production methods and procedures are determined. Furthermore, BSI ISO1 (2018b) emphasizes the AIM (Asset Information Model), where project-based responses to these asset decisions are specified. Moreover, while NBGO (2017) states that the expectations of the project stakeholders from the operation phase should be specified, NBIM (2013) recommends alternative investment evaluations to be made considering the building life-cycle.

Project Level: While the NBGO (2017) points out that the client must specify the design and facility approaches regarding the owner's demands, NATSPEC (2016) specifies a document called Project BIM Brief, which defines the needs of the employer during the project process. Similarly, BSI ISO1 (2018a) recommends the EIR (Exchange Information Requirements), which defines the information that the client must fulfil at the project close-out phase as well as the PIM (Project Information Model), which defines the information requirements and procedures in the project delivery phase. Differently, PSUBIM (2019) recommends the BIM Use Selection Worksheet, which regulates when each stakeholders will undertake BIM tasks throughout the process and which specifies their BIM competency levels.

Integration of BIM into the contract is challenging as it contains large amount of information directly used by stakeholders. Standard contracts and protocols have been established to overcome this challenge (Abdirad, 2015). The actual use of these documents, however, has not yet become widespread in the CI (Al-Shammari, 2014). Although many researchers (Arensman and Ozbek, 2012; Ussing et al., 2016) indicate that international standards should be established to prevent legal problems that may arise in BIM integration, they also agree that country specific differences should be considered. Within the scope of the research, 3 standard contracts [i.e., CIOB (the Chartered Institute of Building) (2013), JCT (Joint Contracts Tribunal) (2016), and NEC (New Engineering Contract) (2017)]; and 3 protocols [i.e., AIA (American Institute of Architects) E203 (2013), CIC (Construction Industry Council) BIM Protocol (2018), and CDOC (Consensus Documents) 301 (2015)] used in the BIM integration process were examined. Main headings, scopes and topics highlighted in these documents have been provided in the Table 2.

TABLE 2: Main headings, scopes and topics highlighted in the examined standard contracts and protocols.

Main headings	Main points highlighted in the documents
Allocation of responsibilities	The employer should establish a completed protocol for defining and sharing of responsibilities as well as ensure that the protocol is integrated into all project agreements (CIC, 2018; JCT, 2016).
	Participants are responsible for their contribution to the model, the data generated from their contribution, and the data generated by contractually lower tiers of the participants (CDOC, 2015).
IPR	The written consent of the data-generating party is required for the usage and modification of data to ensure the protection of IPR (AIA, 2013; CIC, 2018).
	Shared data can only be used by the recipient party for the relevant construction work (AIA, 2013; CDOC, 2015; CIC, 2018).
Information management	The participants should establish a protocol to manage the centralized electronic documents management system AIA (2013).
	The models expected from stakeholders through project stages should be described in the protocol according to the project stages (JCT, 2016; CIOB, 2013).
	The participant cannot be held responsible for damages resulting from unauthorized data use and modification (CDOC, 2015; CIC, 2018).
	The software and formats to be used in the process should be determined to prevent interoperability problems (CIC, 2018; CIOB, 2013).
	All 2D drawings of the project should be extracted from the 3D common model (CDOC, 2015).
Data security and storage	Procedures should be established for uploading, viewing, modifying, backing up and archiving information on the common platform for IPR and data security (AIA, 2013; CDOC, 2015; CIOB, 2013).

2.2 Contractual Aspects of the BIM-based CPM

There are several legal concerns in the integration of BIM-based projects into contracts (Dougherty, 2015). As contractual arrangements covering BIM goals and outcomes have been repeatedly identified as a challenge locally and internationally (Kuiper and Holzer, 2013), effective contract management with written provisions is vital for regulating legal concerns and implementing necessary procedures (Fan et al., 2019). It is necessary to define new services, responsibilities and legal issues arising from changes in the construction planning through BIM

integration. Nevertheless, due to the lack of experience, there is no common strategy for BIM contracts (Eschenbruch and Bodden, 2018).

BIM requires a number of stakeholders to work collaboratively to transform data into a 3D virtual model (Papadonikolaki et al., 2019). Since traditional construction contracts are mostly bipartite documents, various legal problems may arise during this collaboration (SBEnrc The Sustainable Built Environment National Research Centre, 2017). The main causes of legal concerns and disputes about BIM are:

- Ownership of the model, risk allocation, IPR and interoperability (Jo et al., 2018).
- Responsibility of the used data, responsibility of quantities, clash detection, professional reliability and third parties related to BIM (Ussing et al., 2016).
- Unclassified and/or non-prioritized documents (Charehzehi et al., 2017).

2.2.1 Critical aspects of contract management in the BIM-based CPM

High number of stakeholders and data in BIM integration reveals various risks (Liu et al., 2017). Although collaborative nature of BIM reduces conflicts (Ghaffarianhoseini et al., 2017), some deficiencies at the contracting stage can lead to various disputes (Dougherty, 2015). Causes of conflicts that occur throughout the life-cycle of BbCP can be grouped under four main headings (Ashcraft, 2008; Arensman and Ozbek, 2012; Kuiper and Holzer, 2013; Dougherty, 2015; Ashworth et al., 2019; Huzaimi and Fathi, 2019): allocation of risks and responsibilities, IPR, interoperability, data security and documentation. They can be described as follows:

Allocation of risks and responsibilities: The modern legal structure is based on the distinct concept of obligations (Arensman and Ozbek, 2012), while the collaborative and integrated system of BIM mixes levels of responsibility between different stakeholders (Azhar, 2011). Additionally, unlike the signature and stamp system in paper-based documentation, it is more difficult to identify responsible persons in the integrated model (Schapke et al., 2018). Consequently, the main contract should be supported by additional forms and protocols to protect the stakeholders involved in the BIM system (Azhar, 2011; Hsu et al., 2015).

IPR: The collaborative environment entails the risk of exposing and sharing data valuable to stakeholders (Hsu et al., 2015; Solihin and Eastman, 2015). Therefore, contractual status and ownership rights of the information generated and tools used in the project should be determined (McAdam, 2010; Kuiper and Holzer, 2013; Hsu et al., 2015).

Interoperability: Throughout the interactive and dynamic project process, the 3D common model must be on a controllable platform (Lai et al., 2019). Moreover, a contractually binding protocol regarding the production, exchange, share, approval, publication and certification of data in the project process should be established (Eastman et al., 2010; Siemens, 2017; Schapke et al., 2018).

Data security and documentation: Main problems of digital information transformation are ownership and data security issues of BIM deliverables (Solihin and Eastman, 2015). Additionally, accessibility of electronic data by all stakeholders, raises concerns about unauthorized online access and ownership violations (Chien et al., 2014). For this reason, as digital information must be protected against loss, corruption, and theft (Olatunji, 2011), data need to be gradually authorized based on data's intended use and stakeholders' responsibilities (Eschenbruch and Bodden, 2018; Schapke et al., 2018).

2.2.2 Critical points of BIM-based CPM

Within the scope of this paper, international standard contracts and protocols, and international guidelines were analysed to determine the critical points of BIM-based CPM. In total, 6 standard contracts and protocols, 13 guidelines and 36 articles were examined. In these examined articles and documents, there are imperatives, recommendations and warnings for the critical points. As a result of this examination, 49 critical points of BIM-based CPM have been identified. These critical points are shown in the Table 3 where "dark grey cell" indicates documents that strongly mention the critical points whereas "light grey cell" indicates documents that weakly mention the critical points.

TABLE 3: The critical points of BIM-based CPM.

Critical Points	Standard Contracts and Protocols						BIM Guidelines												Articles
	CIC BIM (2018)	NEC4 (2017)	JCT (2016)	CDOC301 (2015)	AIA E203 (2013)	CIOB (2013)	PSUBIM (2019)	BSI Publications	USFBIM (2018)	NBGO (2017)	SBEnrcBIM	NATSPEC (2016)	BBIM (BBIM,	DASBIM (2015)	CANBIM (2012)	SBIM (2013)	NBIM (2013)	COBIM (2012)	USCBIM (2012)	
Critical points of administrative decisions																				
Organization-related Decisions							■	■									■	■		(Ashworth et al., 2019)
Asset-related Decisions								■									■	■		(Ashworth et al., 2019)
Project-related Decisions							■	■	■	■	■	■	■	■	■	■	■	■	■	(Ashworth et al., 2019)
Critical points of analysis																				
Sustainability Analysis							■	■	■	■	■	■	■	■	■	■	■	■	■	
Time and Cost Analysis						■	■	■	■	■	■	■	■	■	■	■	■	■	■	(Azhar, 2011)
Critical points of legal issues																				
BIM Execution Plan	■	■	■	■			■	■	■	■	■	■	■	■	■	■	■	■	■	(Abdirad, 2015; Lin et al., 2016; Chong et al., 2017; Eschenbruch and Bodden, 2018)
Contractual Status of Protocols	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	(Azhar, 2011; SEC group, 2017)
Contractual Status of Model					■	■		■	■			■	■		■	■				(McAdam, 2010; Azhar, 2011; Borrmann et al., 2018)
Critical points of allocation risks and responsibilities.																				
BIM Meetings					■		■	■	■	■		■	■	■	■	■		■	■	
Pre-Qualifications							■	■				■			■			■		(Oviedo-Haito et al., 2014)
Protocol for Obligations	■	■	■	■	■	■	■	■		■	■	■	■		■	■		■		(Arensman and Ozbek, 2012; Ussing et al., 2016)
BIM Process Responsible	■	■	■	■	■	■	■	■		■	■	■	■		■	■	■	■	■	(Hsu et al., 2015; Borrmann et al., 2018)
BIM Discipline Responsible									■					■						(Azhar, 2011; Borrmann et al., 2018)
BIM Consultancy							■	■					■						■	(Ussing et al., 2016; Tulke and Schumann, 2018)
BIM Requirements of Owner			■				■	■		■		■	■		■	■		■	■	(Howard and Ciliberto, 2016)

Critical Points	Standard Contracts and Protocols						BIM Guidelines												Articles
	CIC BIM (2018)	NEC4 (2017)	JCT (2016)	CDOC301 (2015)	AIA E203 (2013)	CIOB (2013)	PSUBIM (2019)	BSI Publications	USFBIM (2018)	NBGO (2017)	SBEnrcBIM	NATSPEC (2016)	BBIM (BBIM,	DASBIM (2015)	CANBIM (2012)	SBIM (2013)	NBIM (2013)	COBIM (2012)	USCBIM (2012)	
BIM Requirements of Other Parties																				
BIM Requirements Through Project Stages																				(Kuiper and Holzer, 2013; Abdirad, 2015)
BIM Deliverables Through Project Stages																				(Kuiper and Holzer, 2013; Lin et al., 2016; Papadonikolaki et al., 2019)
Definition of BIM Roles and Responsibilities																				(Arensman and Ozbek, 2012; Ussing et al., 2016; Bosch-Sijtsema et al., 2019)
Definition of BIM Tasks																				(Abdirad, 2015; Borrmann et al., 2018; Bosch-Sijtsema et al., 2019)
Critical points of intellectual property rights																				
Confidentiality of Information																				(Manderson et al., 2015; Arshad et al., 2019)
Ownership of Model																				(Arensman and Ozbek, 2012; Solihin and Eastman, 2015)
Copyrights of Produced Data																				(Manderson et al., 2015; Solihin and Eastman, 2015)
Term of Usage Letter																				(Eschenbruch and Bodden, 2018)
Critical points of information management																				
Protocol for Information																				(Dougherty, 2015; Charehzehi et al., 2017; Ghaffarianhoseini et al., 2017; Eschenbruch and Bodden, 2018)
Centralized File System																				
Level of Development																				(Ashcraft, 2008; Lin et al., 2016)

Critical Points	Standard Contracts and Protocols						BIM Guidelines												Articles
	CIC BIM (2018)	NEC4 (2017)	JCT (2016)	CDOC301 (2015)	AIA E203 (2013)	CIOB (2013)	PSUBIM (2019)	BSI Publications	USFBIM (2018)	NBGO (2017)	SBEnrcBIM	NATSPEC (2016)	BBIM (BBIM,	DASBIM (2015)	CANBIM (2012)	SBIM (2013)	NBIM (2013)	COBIM (2012)	USCBIM (2012)	
Software	■			■		■	■	■	■	■	■	■	■	■	■	■	■	■	■	(McAdam, 2010; Succar, 2010; Bynum et al., 2013)
Native Data Format	■					■		■							■					(Bynum et al., 2013)
Authority to Access	■			■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	(Solihin and Eastman, 2015; Charehzehi et al., 2017; Schapke et al., 2018)
Contact List of Authorized Users				■			■	■	■			■	■	■			■		■	
Authority to Change	■			■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	(Solihin and Eastman, 2015; Charehzehi et al., 2017; Schapke et al., 2018)
Electronic Stamps															■		■			
Authority to Share	■			■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	(Solihin and Eastman, 2015; Charehzehi et al., 2017)
Digital Data Storage					■		■	■		■		■	■		■	■	■			(Lai et al., 2019)
Digital Data Archiving					■		■	■	■	■		■	■		■		■	■	■	(Bakhary et al., 2017)
Back-up Procedures				■																(Olatunji, 2011)
Restore Procedures				■																
Critical points of interoperability																				
Modes of Collaboration					■		■	■				■	■		■	■				
Clash Detection					■		■	■	■	■	■	■	■	■	■	■	■	■	■	(Ussing et al., 2016; Li et al., 2017)
Extracting 2D Drawings From 3D Model				■					■						■					
Change Order Procedures				■		■	■	■	■	■	■	■		■	■	■		■	■	
Critical points of data security																				
Data Security for Loss, Corruption and Virus				■		■	■	■		■		■	■		■	■		■		(Chien et al., 2014; Dougherty, 2015; Eschenbruch and Bodden, 2018)
Encrypted Filing				■																
Access from Unknown Server						■														(Chien et al., 2014)
Data Insurance				■																(Manderson et al., 2015)

Critical Points	Standard Contracts and Protocols						BIM Guidelines												Articles
	CIC BIM (2018)	NEC4 (2017)	JCT (2016)	CDOC301 (2015)	AIA E203 (2013)	CIOB (2013)	PSUBIM (2019)	BSI Publications	USFBIM (2018)	NBGO (2017)	SBEnrcBIM	NATSPEC (2016)	BBIM (BBIM,	DASBIM (2015)	CANBIM (2012)	SBIM (2013)	NBIM (2013)	COBIM (2012)	USCBIM (2012)	
Critical points of operation phase																			
As-Built Model Procedures																			
Maintenance Manuals																			
Handing Over of Model																			(Eschenbruch and Bodden, 2018)

3. RESEARCH METHODS

This paper aims to develop a proposal for a preliminary checklist template that can be considered as a potential input to the contracting phase of these projects so that the contract preparation phase of BbCP can be improved. Research flowchart is provided in Fig. 2. The objectives determined in accordance with the aim are as follows:

- To review the BIM guidelines, standard contracts and protocols.
- To determine the critical aspects and issues to be considered in the BIM-based construction contracts.
- To propose a preliminary checklist template which can be considered as a potential input in the contract preparation phase of the BbCP.

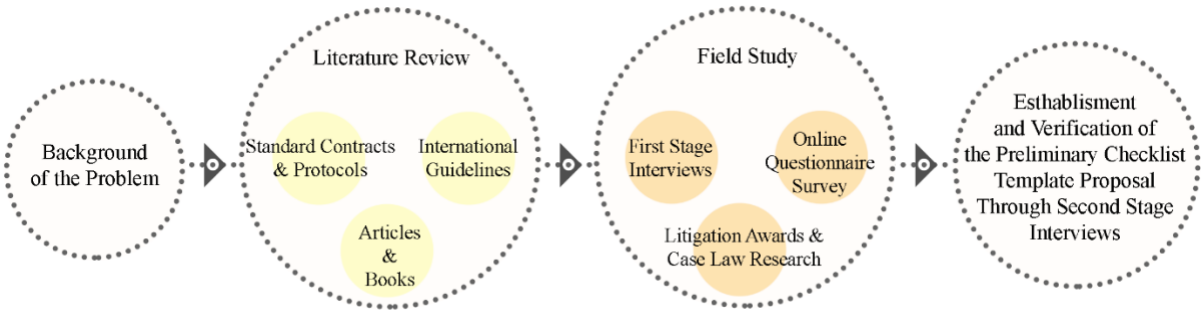

FIG. 2: Flowchart diagram of the research.

3.1 Case Laws Research

Within the scope of the study, a litigation awards and case laws research was conducted through international (Lexisnexis.com) database to investigate the causes of BIM-related disputes that arise in BbCP. Among the search results, the ones originating from the BIM and BIM processes were examined.

3.2 First Stage Interviews

First stage interviews were conducted with 5 professionals who actively use and have experience in BIM technology. Participants' information is provided in the Table 4.

TABLE 4: Interviewed professionals (First Stage).

Profession	Experience (in years)	BIM Experience (in years)	Role in the Project
Architect	20	10	BIM Designer and consultant on the design party (Airport Project)
Architect	16	7	BIM Manager and chief designer on the design party (TV&Radio Tower Complex)
Civil Engineer	26	13	BIM Director at the employer party (Metro Project)
Civil Engineer	8	6	BIM Coordinator on the engineering party (Metro Project)
Civil Engineer	25	10	Founding partner of the engineering firm

3.3 Online Questionnaire Survey

Following the interview, an online questionnaire (following the pilot study conducted to 10 professionals) was conducted via LinkedIn and e-mail to a sample of professionals with BIM-related job titles actively working in the CI. The online questionnaire, which was kept on for 6 months. In total 69 people filled in the questionnaire.

3.4 Second Stage Interviews

In order to further improve and verify the preliminary checklist template proposal, second stage interviews were conducted with 10 professionals who are experts in BIM. Professionals evaluated the created checklist in terms of design, clarity and content. Participants' information is provided in the Table 5.

TABLE 5: Interviewed professionals (Second Stage).

Profession	Experience (in years)	Professional Role
Architects	6	Project manager in the international real estate investment company.
	5	Architect in the international design office.
	20	BIM Designer, consultant, and founding partner of the international design firm.
Civil Engineers	15	Structural design engineer in the international construction firm.
	8	Managing partner in the international engineering firm.
	8	Project planner engineer in the international engineering firm.
	8	BIM Coordinator on the international engineering firm.
	17	Head of business development at international scaffolding firm.
	32	Founding partner of the international engineering firm.
	9	Tendering Engineer in international construction firm.

4. RESULTS AND DISCUSSION

4.1 Data Obtained Through Litigation Awards and Case Law Research

As a result of the research in the Lexis-Nexis database, case laws containing BIM-related disputes have been found in 3 out of 13 countries: United States, United Kingdom and Canada. Considering international case laws and literature (Ashcraft, 2008; Arensman and Ozbek, 2012; Kuiper and Holzer, 2013; Dougherty, 2015; Ashworth et al., 2019; Huzaimi and Fathi, 2019), it is seen that the main reasons for the disputes in BbCP are contractual problems. To summarize, dispute causes can be categorized under the following four main headings: allocation of risks and responsibilities; ownership and usage of right of the model and data produced; interoperability problems; and data security and documentation.

Comparison of the cases found by case law research with the critical points of BIM-based CPM (Table 3) according to their core terms is shown in Table 6 where the "grey coded cell" indicates the critical points causing disputes in the cases.

TABLE 6: Critical points in the examined case laws.

Critical Points (determined based on the examined 6 standard contracts and protocols, 13 guidelines and 36 articles as presented and referred to in Table 3)	**Case laws containing BIM-related disputes.**											
	US 88641 (2019)	US 131299 (2018)	US 1267 (2017)	US 70779 (2017)	US 4320 (2017)	US 171299 (2017)	US 7805 (2017)	US 125136 (2015)	UK HT-000164 (2017)	Canada 254 (2019)	Canada 1284 (2019)	Canada 179 (2014)
Critical points of allocation risks and responsibilities												
Pre-Qualifications										■		
Protocol for Obligations	■									■		
BIM Consultancy		■				■						
BIM Requirements of Owner			■									
BIM Requirements Through Project Stages	■				■							
BIM Deliverables Through Project Stages	■				■							
Definition of BIM Roles and Responsibilities	■									■		
Critical points of intellectual property rights												
Confidentiality of Information				■					■		■	■
Ownership of Model				■					■		■	■
Copyrights of Produced Data				■					■		■	■
Critical points of information management												
Authority to Access											■	
Authority to Share											■	
Authority to Change											■	
Critical points of interoperability												
Change Order Procedures										■		
Clash Detection								■				
Extracting 2D Drawings From 3D Model								■				
Critical points of operation phase												
As-Built Model Procedures							■					

Considering the findings obtained from the case law research; it has been determined that there are disputes arising from the issues that are emphasized (Definition of roles and responsibilities; procedures for change order and clash detection; and protocol for authorized access, sharing and confidentiality of information) and not emphasized (Procedures for pre-qualification, BIM consultancy, as-built model, and extracting 2D drawings) in the literature. The critical points where the research results correspond to the proposed preliminary checklist template proposal (Table 8) are shown with Case Law Research (CLR) coding.

4.2 Data Obtained Through Interviews and Questionnaire Survey

Following the case law research, first stage interviews and questionnaire survey was conducted with professionals within the scope of field research. In the first stage interviews, the interviewees emphasized mainly the importance of: the IPR protection, training of suppliers on BIM and updating of the legal regulations in accordance with BIM. Table 7 summarizes the critical points emphasised in these interviews.

The majority of the participants in the questionnaire survey were architects (63%) and civil engineers (21%). The project roles of the participants are as follows: BIM manager (40%), BIM coordinator (13%), BIM disciplinary manager (10%) and BIM engineer (9%). The majority of participants have less than 10 years of BIM professional experience. 67% have 2-7 years of BIM professional experience. The mean values of the responses given by the participants to the effect of BIM on the performance of various issues are shown in chart A in Fig. 3. The mean values of answers given by participants to appropriateness of BIM integration to the project types are provided in chart B in Fig. 3.

FIG. 3: The performance effectiveness (Chart A) and the appropriateness (Chart B) of BIM integration.

Results obtained through the online questionnaire survey revealed that the participants emphasized the following topics: IPR should be stated in the contract; BIM requirements, purpose and responsibilities of the owner should be defined; a data security protocol should be established; and LOD levels should be defined as standard and specified according to the project stages. Table 7 further summarizes the critical points supported by the questionnaire survey participants.

The preliminary checklist template proposal, which was created based on the literature review, case law research, first stage interview and questionnaire, was verified with second stage interviews performed with the participation of 10 professionals having BIM expertise and experience. All interviewees stated that the suggested checklist was sufficient and useful and that all identified critical points were important. Furthermore, they have specifically emphasized the points specified in Table 7.

The points emphasized in the litigation awards and case law research, first stage interviews, questionnaire survey and second stage interviews are shown in grey cells in Table 7.

TABLE 7: Points emphasized in the field research.

Critical Points (determined based on the examined 6 standard contracts and protocols, 13 guidelines and 36 articles as presented and referred to in Table 3)		**Points highlighted as a result of field research**			
		Case Law Research	First Stage Interviews	Questionnaire Survey	Second Stage Interviews
Critical points of administrative decisions					
	Organization-related Decisions				
	Project-related Decisions				
Critical points of analysis					
	Sustainability Analysis				
	Time and Cost Analysis				
	Quality & Supply Chain Analysis				
Critical points of legal issues					
	BIM Execution Plan				
Critical points of allocation risks and responsibilities					
	BIM Meetings				
	Pre-Qualifications				
	Protocol for Obligations				
	Responsible Persons for BIM Processes				
	BIM Consultant				
	BIM Requirements				
	BIM Model Requirements and Deliverables				
	Definition of BIM Tasks				
	Definition of BIM Responsibilities According to the Tasks				
Critical points of intellectual property rights					
	Confidentiality of Information				
	Ownership of Model				
	Copyrights of Produced Data				
	Term of Usage Letter				
Critical points of information management					
	Protocol for Information				
	Centralized File System				
	Level of Development				
	Type and Version of Software				
	Native Data Format				
	Authority to Access				
	Authority to Change				
	Authority to Share				
	Electronic Stamps				
	Digital Data Storage				
Critical points of interoperability					

Critical Points (determined based on the examined 6 standard contracts and protocols, 13 guidelines and 36 articles as presented and referred to in Table 3)		Points highlighted as a result of field research			
		Case Law Research	First Stage Interviews	Questionnaire Survey	Second Stage Interviews
	Clash Detection	■	■	■	
	Extracting 2D Drawings from 3D Model	■	■	■	
	Change Order Procedures	■	■	■	■
Critical points of data security					
	Data Security Protocol for Loss, Corruption and Virus		■	■	■
Critical points of operation phase					
	As-Built Model Procedures	■	■	■	■
	Operation and Maintenance		■	■	

As a result of the examination of the findings obtained from the field research and the studies in the literature, the issues highlighted under the 4 main headings (Ashcraft, 2008; Arensman and Ozbek, 2012; Kuiper and Holzer, 2013; Dougherty, 2015; Ashworth et al., 2019; Huzaimi and Fathi, 2019) are as follows:

Allocation of risks and responsibilities: BIM roles and the stakeholders responsible for these roles should be distinctly specified in the contract (Azhar, 2011; CANBIM, 2012; Arensman and Ozbek, 2012; COBIM, 2012; NATSPEC, 2016; Ussing et al., 2016; BSI, 2018a; Bosch-Sijtsema et al., 2019; PSUBIM, 2019). The contractual status of the model should be determined in case of conflict or dispute (McAdam, 2010; Azhar, 2011; CANBIM, 2012; SBIM, 2013; BBIM, 2015; NATSPEC, 2016; USFBIM, 2018). As stated under the subheadings 4.1 and 4.2 of this paper and the literature (Kuiper and Holzer, 2013; Abdirad, 2015; Lin et al., 2016; Papadonikolaki et al., 2019), BIM requirements and outputs should be defined according to the project phases. As seen in the subheadings 4.1 and 4.2 of this paper, the contract should include procedures related to supply chain (CANBIM, 2012; COBIM, 2012; Oviedo-Haito et al., 2014; BSI 2018a; PSUBIM, 2019), BIM consultancy (USCBIM, 2012; BBIM, 2015; BSI 2018a; PSUBIM, 2019), and as-build model (COBIM, 2012; SBIM, 2013; NBIM, 2013; BSI 2014b).

IPR: The most emphasized issues in the literature (Arensman and Ozbek, 2012; Manderson et al., 2015; Solihin and Eastman, 2015; Arshad et al., 2019) and under the subheadings 4.1 and 4.2 of this paper, are: the protocol for information; information confidentiality; copyright of the data produced and the authority sharing. Therefore, definition regarding the IPR should be included in the contract, and access to the common platform should be authorized (Manderson et al., 2015; Solihin and Eastman, 2015). Moreover, before the generated information is shared, a "term of usage letter" must be signed by the receiving party regarding ownership and user rights (CANBIM, 2012; AIA, 2013; CIC, 2018; Eschenbruch and Bodden, 2018).

Interoperability: It is important to regulate the stakeholders' relationships communicating through the common model and information systems (Eastman et al., 2010; Rahman et al., 2016). Therefore, as specified under the subheadings 4.1 and 4.2 of this paper, the access, change and sharing rights of the data in the common model or information system should be authorized (CDOC, 2015; CANBIM, 2012; USCBIM, 2012; COBIM, 2012; NBIM, 2013; CIOB, 2013; AIA, 2013; SBIM, 2013; BBIM, 2015; Solihin and Eastman, 2015; DASBIM, 2015; NATSPEC, 2016; NBGO, 2017; SBEnrcBIM, 2017; Charehzehi et al., 2017; Schapke et al., 2018; USFBIM 2018; BSI, 2018a; CIC, 2018; PSUBIM, 2019). As mentioned under the subheadings 4.1 of this paper, definitions and regulations for modes of collaboration, clash detection, change order procedures, centralized file system, and BIM meetings must be specified in BEP (CANBIM, 2012; USCBIM, 2012; COBIM, 2012; NBIM, 2013; SBIM, 2013; BBIM, 2015; DASBIM, 2015; Ussing et al., 2016; NATSPEC, 2016; SBEnrcBIM, 2017; Li et al., 2017; NBGO, 2017; USFBIM, 2018; BSI, 2018a; PSUBIM, 2019). As highlighted under the subheadings 4.1 and 4.2 of this paper, the LOD level should be determined as early as possible according to the project phases (Ashcraft, 2008; CANBIM, 2012; USCBIM, 2012; COBIM, 2012; NBIM, 2013; AIA, 2013; SBIM, 2013; BBIM, 2015; DASBIM, 2015; Lin et al., 2016; NATSPEC, 2016; NBGO, 2017; SBEnrcBIM, 2017; USFBIM, 2018; BSI, 2018a; PSUBIM, 2019). As noted under the subheadings 4.1 and 4.2 of this paper, all 2D drawings to be used in the project process should be extracted from the common 3D model through certain procedures (CDOC, 2015; CANBIM, 2012; USFBIM, 2018).

Data security and documentations: As mentioned under the subheadings 4.1 and 4.2 of this paper, for data security, authorized access should be given within the responsibility of stakeholders (CDOC, 2015; CANBIM, 2012; USCBIM, 2012; COBIM, 2012; NBIM, 2013; CIOB, 2013; AIA, 2013; SBIM, 2013; BBIM, 2015; Solihin and Eastman, 2015; DASBIM, 2015; NATSPEC, 2016; NBGO, 2017; SBEnrcBIM, 2017; Charehzehi et al., 2017; Schapke et al., 2018; USFBIM, 2018; BSI, 2018a; CIC, 2018; PSUBIM, 2019). In majority of the manuals (CANBIM, 2012; USCBIM, 2012; COBIM, 2012; BSI, 2013; SBIM, 2013; NBIM, 2013; BBIM, 2015; NATSPEC, 2016; NBGO, 2017; SBEnrcBIM, 2017; USFBIM, 2018; PSUBIM, 2019) and in the literature, it is emphasized that a protocol regarding data storage (Lai et al., 2019), data archiving (Bakhary et al., 2017) and data security (Chien et al., 2014; Dougherty, 2015; Eschenbruch and Bodden, 2018) should be established. As specified under the subheadings 4.1 and 4.2 of this paper, after the end of the project, the common model should be handed over to the operation team by making various corrections and simplifications (USCBIM, 2012; COBIM, 2012; SBIM, 2013; NBIM, 2013; BSI, 2014b; BBIM, 2015; NATSPEC, 2016; NBGO, 2017; SBEnrcBIM, 2017; USFBIM, 2018; Eschenbruch and Bodden, 2018; PSUBIM, 2019).

5. PRACTICAL IMPLICATION

Preliminary checklist template categorized under 9 headings is provided in the Table 8. The roots of each item has been provided referring to the relevant literature, standards and documents as well as to the field studies. Accordingly, in Table 8 QS stands for questionnaire survey, IS1 for first stage interview, IS2 for the second stage interview, CLR for case law research. The checklist consists of 25 main 32 sub-critical points as well as their descriptions and highlights. The checklist was created in line with the findings and critical points obtained from the literature review (Table 3) and field research (Table 7). Considering the proposed checklist as a support document during the contract preparation phase of BbCP can contribute to reduce the potential disputes that may arise. Furthermore, stakeholders' legal concerns arising from the BIM integration can be alleviated through integration of all stakeholders into the contract preparation phase. This paper and the proposed checklist can be considered as an input to the establishment of legal standards for BIM-based construction projects. They can be beneficial to academic researches, to academics and researchers in this field. Furthermore, the identified 9 main categories of the preliminary checklist template proposal and their relation to the Project Management Institution (PMI, 2017) knowledge areas and BSI PAS 1 (BSI, 2015a) project stages are provided in Fig. 5.

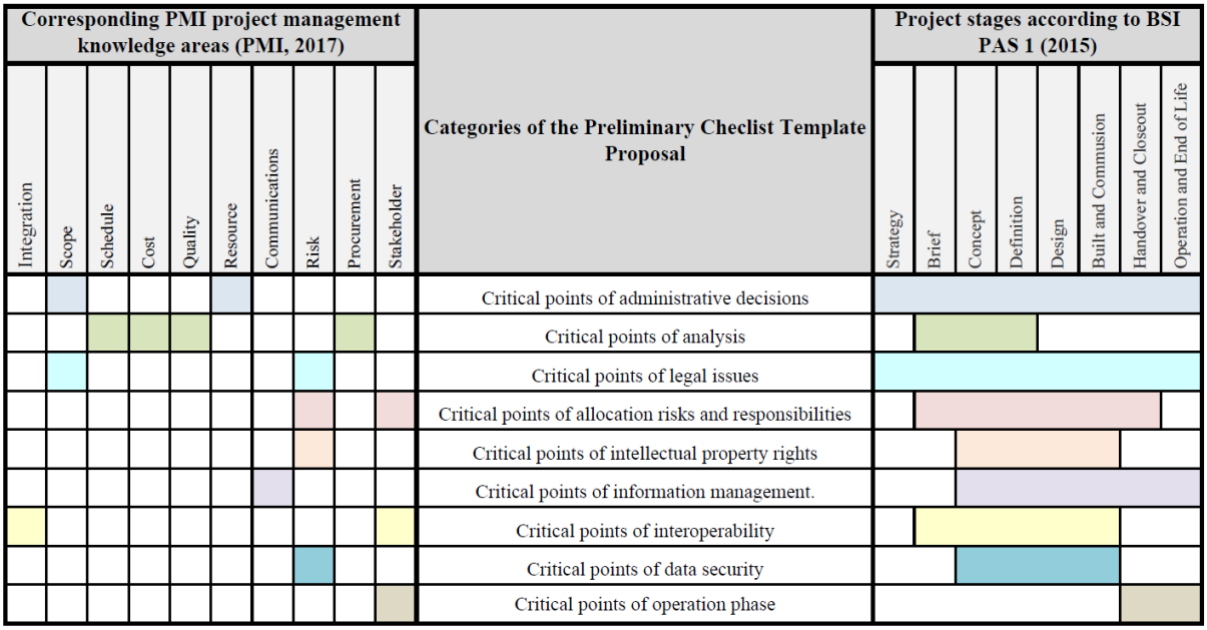

FIG. 5: The nine main categories of the proposed checklist and their relations.

TABLE 8: Checklist proposal to enhance the contract preparation phase of BbCPs.

1. Critical points of administrative decisions.
○ Organization-related Decisions (COBIM, 2012; NBIM, 2013; BSI, 2018a; Ashworth et al., 2019; PSUBIM, 2019) Define the high-level strategic goals of the organization and includes the strategic decisions of the organization, portfolio planning, regulatory tasks, and policies. Prepare a statement for the organization's future BIM-related organizational decisions, and describe why BIM is important to the organisation and how to use it. Stakeholders working with complex and large projects should determine their organizational decisions. **IS2** If the organization needs to be departmentalized for BIM applications, determine its procedures. **IS2** Set your own BIM specifications on why you prefer BIM and how to implement it. **IS2** Determine whether BIM process management will be done by the company or outsourced to third parties. **IS2**
○ Asset-related Decisions (COBIM, 2012; NBIM, 2013; BSI, 2018a; Ashworth et al., 2019) Determine the production methods and procedures as well as the managerial and commercial decisions regarding the asset.
○ Project-related Decisions (CANBIM, 2012; USCBIM, 2012; COBIM, 2012; NBIM, 2013; SBIM, 2013; NBIM, 2015; DASBIM, 2015; NATSPEC, 2016; SBEnrcBIM, 2017; NBGO, 2017; USFBIM, 2018; BSI, 2018a; Ashworth et al., 2019; PSUBIM, 2019) **IS, QS** Measure and monitor that organizational decisions are supported in a particular project.

2. Critical points of analysis.
The analysis should be planned considering the entire building life cycle. **IS2**
○ Sustainability Analysis (CANBIM, 2012; USCBIM, 2012; COBIM, 2012; SBIM, 2013; NBIM, 2013; NBIM, 2015; DASBIM, 2015; NATSPEC, 2016; SBEnrcBIM, 2017; NBGO, 2017; USFBIM, 2018; BSI, 2018a; PSUBIM, 2019) **QS** Identify the analyses and their procedures to be performed to measure the environmental impact and efficiency of the project.
○ Time and Cost Analysis (Azhar, 2011; CANBIM, 2012; USCBIM, 2012; COBIM, 2012; NBIM, 2013; CIOB, 2013; SBIM, 2013; NBIM, 2015; BSI, 2015a; DASBIM, 2015; NATSPEC, 2016; SBEnrcBIM, 2017; NBGO, 2017; USFBIM, 2018; PSUBIM, 2019) **IS, QS** Determine the time and economic efficiency analysis and their procedures, taking into account the construction and operation phases of the project. Time and cost analysis also includes the marketing of the project. **IS2**
○ Quality Analysis **IS2** Identify the desired level of quality of implementations made in the project and quality measurement processes.
○ Supply Chain Analysis **IS2** Determine the Supply chain analysis and their procedures for materials and human resources should be done by considering the geography where the project will be made. **IS2**

3. Critical points of legal issues.
○ BIM Execution Plan (CDOC, 2015; CANBIM, 2012; USCBIM, 2012; COBIM, 2012; NBIM, 2013; SBIM, 2013; Abdirad, 2015; NBIM, 2015; DASBIM, 2015; JCT, 2016; Lin et al., 2016; NATSPEC, 2016; NBGO, 2017; NEC, 2017; SBEnrcBIM, 2017; Chong et al., 2017; Eschenbruch and Bodden, 2018; USFBIM, 2018; BSI, 2018b; CIC, 2018; PSUBIM, 2019) **IS, QS** BEP should be created comprehensively with the contribution of all project participants in line with the requirements of the owner, specific to the project. Make sure that the contract and BEP are compatible and there are no contradictions. **IS2** Milestones of the project should also be specified in BEP. **IS2**
○ Contractual Status of Documents (CDOC, 2015; Azhar, 2011; CANBIM, 2012; USCBIM, 2012; COBIM, 2012; NBIM, 2013; CIOB, 2013; AIA, 2013; SBIM, 2013; NBIM, 2015; DASBIM, 2015; JCT, 2016; NATSPEC, 2016; NBGO, 2017; NEC, 2017; SBEnrcBIM, 2017; USFBIM, 2018; BSI, 2018a; CIC, 2018; PSUBIM, 2019) Determine the contractual and legally binding status of the documents (protocol, guideline and/or standard) used in case of dispute.
○ Contractual Status of Model (McAdam, 2010; Azhar, 2011; CANBIM, 2012; AIA, 2013; SBIM, 2013; CIOB, 2013; NBIM, 2015; NATSPEC, 2016; Borrmann et al., 2018; USFBIM, 2018) Determine the contractual and legally-binding status of the common BIM model and the information it contains in case of Dispute.

4. Critical points of allocation risks and responsibilities.

- BIM Meetings (COBIM, 2012; USCBIM, 2012; SBIM, 2013; NBIM, 2015; DASBIM, 2015; NATSPEC, 2016; NBGO, 2017; BSI, 2018a; USFBIM, 2018; PSUBIM, 2019) **IS, QS**

  Establish the protocol that includes the communication procedures and meeting schedules for collaborative utilization.

  Make sure that any changes that occur during BIM meetings are revised immediately in the BIM model. **IS2**

- Pre-Qualifications (CANBIM, 2012; COBIM, 2012; Oviedo-Haito et al., 2014; NATSPEC, 2016; BSI, 2018a; PSUBIM, 2019) **CLR, IS, QS**

  Prepare a comprehensive pre-qualification in terms of BIM competency and risk management capacity of suppliers before being included in the project.

- Protocol for Obligations (CDOC, 2015; CANBIM, 2012; Arensman and Ozbek, 2012; COBIM, 2012; CIOB, 2013; AIA, 2013; SBIM, 2013; NBIM, 2015; NATSPEC, 2016; Ussing et al., 2016; JCT, 2016; NBGO, 2017; NEC, 2017; SBEnrcBIM, 2017; BSI, 2018a; CIC, 2018; PSUBIM, 2019) **CLR, QS**

  Identify the obligation and liability issues of each party in relation to allocation of risk and responsibility.

- Responsible Persons for BIM Processes (CDOC, 2015; Azhar, 2011; CANBIM, 2012; USCBIM, 2012; COBIM, 2012; NBIM, 2013; CIOB, 2013; AIA, 2013; BSI, 2013; SBIM, 2013; NBIM, 2015; DASBIM, 2015; Hsu et al., 2015; JCT, 2016; NATSPEC, 2016; NBGO, 2017; NEC, 2017; SBEnrcBIM, 2017; Tulke and Schumann, 2018; USFBIM, 2018; Borrmann et al., 2018; CIC, 2018; PSUBIM, 2019) **IS, QS**

  Identify who is responsible according to BIM processes
  - BIM Process Responsible (Manager)
  - BIM Main Discipline Responsible (Coordinator)
  - BIM Sub-Discipline Responsible (Discipline Lead)
  - BIM Consultant (USCBIM, 2012; BSI, 2013; NBIM, 2015; PSUBIM, 2019) **CLR, IS**
  - BIM Information Technology Manager (USCBIM, 2012; BSI, 2013)

- BIM Requirements (USCBIM, 2012; CANBIM, 2012; COBIM, 2012; CIOB, 2013; SBIM, 2013; Kuiper and Holzer, 2013; Abdirad, 2015; NBIM, 2015; NATSPEC, 2016; Howard and Ciliberto, 2016; JCT, 2016; NBGO, 2017; BSI, 2018a, 2018b; PSUBIM, 2019) **CLR, IS, QS**

  Determine the requirements throughout project stages for effective BIM integration.
  - For Owner
  - For Other Parties

- BIM Model Requirements and Deliverables (CANBIM, 2012; USCBIM, 2012; COBIM, 2012; CIOB, 2013; SBIM, 2013; Kuiper and Holzer, 2013; NBIM, 2015; JCT, 2016; Lin et al., 2016; NATSPEC, 2016; NBGO, 2017; BSI, 2018b, 2018a; Papadonikolaki et al., 2019; PSUBIM, 2019) **CLR, IS, QS**

  Determine the objectives, requirements and outcomes of the common BIM model according to the project stages.

- Definition of BIM Tasks (USCBIM, 2012; CANBIM, 2012; COBIM, 2012; NBIM, 2013; SBIM, 2013; Abdirad, 2015; NBIM, 2015; DASBIM, 2015; NATSPEC, 2016; NBGO, 2017; SBEnrcBIM, 2017; USFBIM, 2018; Borrmann et al., 2018; BSI, 2018a, 2018b; PSUBIM, 2019; Bosch-Sijtsema et al., 2019) **CLR, IS, QS**

  Identify the tasks required to achieve the objectives, requirements and outcomes of the common BIM model determined according to the project stages.

- Definition of BIM Responsibilities According to the Tasks (CDOC, 2015; CANBIM, 2012; USCBIM, 2012; Arensman and Ozbek, 2012; COBIM, 2012; NBIM, 2013; CIOB, 2013; AIA, 2013; SBIM, 2013; NBIM, 2015; DASBIM, 2015; JCT, 2016; NATSPEC, 2016; Ussing et al., 2016; NBGO, 2017; NEC, 2017; SBEnrcBIM, 2017; CIC, 2018; USFBIM, 2018; BSI, 2018a, 2018b; PSUBIM, 2019; Bosch-Sijtsema et al., 2019) **CLR, QS**

  Identify the people responsible for the tasks required to achieve the objectives, requirements and outcomes of the common BIM model determined according to the project stages.

5. Critical points of intellectual property rights.

- Confidentiality of Information (CDOC, 2015; CANBIM, 2012; COBIM, 2012; CIOB, 2013; AIA, 2013; BSI, 2013; SBIM, 2013; NBIM, 2015; Manderson et al., 2015; NATSPEC, 2016; NBGO, 2017; SBEnrcBIM, 2017; CIC, 2018; PSUBIM, 2019; Arshad et al., 2019) **CLR, IS, QS**

  Identify the information that should be confidential by stakeholders such as design works, rates and prices that produced or used throughout the project.

  The definition of confidential information should also be specified. **IS2**
  - Ownership of Model (CANBIM, 2012; Arensman and Ozbek, 2012; COBIM, 2012; BSI, 2013; SBIM, 2013; NBIM, 2015; Solihin and Eastman, 2015; NATSPEC, 2016; SBEnrcBIM, 2017; NBGO, 2017; PSUBIM, 2019) **CLR, IS, QS**

    Identify ownership rights of the common BIM model during project process and for operation and maintenance stage.

    Ownership of the model can switch between the stakeholders depending on the project stages. **IS2**

5. Critical points of intellectual property rights.

- Copyrights of Produced Data (CDOC, 2015; CANBIM, 2012; COBIM, 2012; AIA, 2013; BSI, 2013; SBIM, 2013; NBIM, 2015; Solihin and Eastman, 2015; Manderson et al., 2015; NATSPEC, 2016; NBGO, 2017; NEC, 2017; SBEnrcBIM, 2017; CIC, 2018; PSUBIM, 2019) **CLR, IS, QS**

  Identify copyrights of information produced by all disciplines in line with project goals throughout the process.
  - Term of Usage Letter (CANBIM, 2012; AIA, 2013; CIC, 2018; Eschenbruch and Bodden, 2018) **QS**

6. Critical points of information management.

- Protocol for Information (CDOC, 2015; CANBIM, 2012; USCBIM, 2012; COBIM, 2012; NBIM, 2013; AIA, 2013; BSI, 2013; SBIM, 2013; NBIM, 2015; Dougherty, 2015; DASBIM, 2015; JCT, 2016; NATSPEC, 2016; Ghaffarianhoseini et al., 2017; NBGO, 2017; SBEnrcBIM, 2017; Charehzehi et al., 2017; Eschenbruch and Bodden, 2018; USFBIM, 2018; CIC, 2018; PSUBIM, 2019) **QS**

  Identify the processes of converting construction applications to as-built models and those responsible for control of this process. The information protocol should include an information map that contains all the information produced and shared according to the stages of the project. **IS2**
  - Centralized File System (CANBIM, 2012; USCBIM, 2012; COBIM, 2012; AIA, 2013; BSI, 2013; NBIM, 2013; NBIM, 2015; NATSPEC, 2016; NBGO, 2017; USFBIM, 2018; PSUBIM, 2019) **QS**

    Set up a centralized file system where documents are shared, stored and archived for effective information management throughout the project process.
  - Level of Development (Ashcraft, 2008; CANBIM, 2012; USCBIM, 2012; COBIM, 2012; NBIM, 2013; AIA, 2013; SBIM, 2013; NBIM, 2015; BSI, 2015a; DASBIM, 2015; Lin et al., 2016; NATSPEC, 2016; NBGO, 2017; SBEnrcBIM, 2017; USFBIM, 2018; PSUBIM, 2019) **IS, QS**

    Determine the development levels of the information to be used according to the stages of the project as much as the needs of the stakeholders.
    - Software
      - Type and Version of Software (Succar, 2010; McAdam, 2010; CANBIM, 2012; USCBIM, 2012; COBIM, 2012; NBIM, 2013; CIOB, 2013; BSI, 2013; SBIM, 2013; Bynum et al., 2013; NBIM, 2015; DASBIM, 2015; NATSPEC, 2016; NBGO, 2017; SBEnrcBIM, 2017; USFBIM, 2018; CIC, 2018; PSUBIM, 2019) **QS**

        Specify the types and versions of the software in which the information to be used according to the project stages will be created.

        Update procedures should also be determined. **IS2**
        - Native Data Format (CANBIM, 2012; BSI, 2013; Bynum et al., 2013; CIOB, 2013; CIC, 2018) **QS**

          Specify that information should be shared and archived in the native data format in which the information is produced to prevent corruption and loss of information.

          Industry Foundation Classes (IFC) can be used. **IS2**
    - Authority to Access (CDOC, 2015; CANBIM, 2012; USCBIM, 2012; COBIM, 2012; NBIM, 2013; CIOB, 2013; AIA, 2013; BSI, 2013; NBIM, 2015; Solihin and Eastman, 2015; DASBIM, 2015; NATSPEC, 2016; NBGO, 2017; SBEnrcBIM, 2017; Charehzehi et al., 2017; Schapke et al., 2018; USFBIM, 2018; CIC, 2018; PSUBIM, 2019) **CLR, QS**

      Provide authorized access to data in the common model to prevent data corruption, loss and errors.
      - Contact List of Authorized Users (CDOC, 2015; USCBIM, 2012; BSI, 2013; NBIM, 2013; NBIM, 2015; DASBIM, 2015; NATSPEC, 2016; USFBIM, 2018; PSUBIM, 2019)

        Identify the contact information of authorized users to monitor changes and revisions in the common model, and to resolve potential problems quickly.
    - Authority to Change (CDOC, 2015; CANBIM, 2012; USCBIM, 2012; COBIM, 2012; NBIM, 2013; CIOB, 2013; AIA, 2013; BSI, 2013; SBIM, 2013; NBIM, 2015; Solihin and Eastman, 2015; DASBIM, 2015; NATSPEC, 2016; NBGO, 2017; SBEnrcBIM, 2017; Charehzehi et al., 2017; Schapke et al., 2018; USFBIM, 2018; CIC, 2018; PSUBIM, 2019) **CLR, IS, QS**

      Provide authorized modification permissions to the data in the model to prevent conflict caused by changing data without controlling.
      - Electronic Stamps (CANBIM, 2012; NBIM, 2013) **QS**

        Use electronic signature or stamp so that the status of the information, the last changes and the people responsible for the information can be followed.
    - Authority to Share (CDOC, 2015; Eastman et al., 2010; CANBIM, 2012; USCBIM, 2012; NBIM, 2013; CIOB, 2013; AIA, 2013; BSI, 2013; SBIM, 2013; NBIM, 2015; Solihin and Eastman, 2015; DASBIM, 2015; NATSPEC, 2016; NBGO, 2017; SBEnrcBIM, 2017; Charehzehi et al., 2017; USFBIM, 2018; CIC, 2018; PSUBIM, 2019) **CLR, QS**

Provide authorized sharing of data in the common model to prevent data from being shared to unauthorized 3rd parties.

- Term of Usage Letter (CANBIM, 2012; AIA, 2013; CIC, 2018; Eschenbruch and Bodden, 2018) **QS**

  Before sharing the created information with other stakeholders, be sure to sign the Term of Usage Letter, where the information usage and sharing permissions are specified.

- Documentation

Determine the procedures for storing the produced and shared information during the project and archiving it at the end of the project.

- Digital Data Storage (CANBIM, 2012; AIA, 2013; BSI, 2013; SBIM, 2013; NBIM, 2013; NBIM, 2015; NATSPEC, 2016; NBGO, 2017; Lai et al., 2019; PSUBIM, 2019) **IS, QS**

  Determine the procedures for storing all data of the project and the BIM model during the project process.
- Digital Data Archiving (CANBIM, 2012; USCBIM, 2012; COBIM, 2012; AIA, 2013; BSI, 2013; NBIM, 2013; NBIM, 2015; NATSPEC, 2016; Bakhary et al., 2017; NBGO, 2017; USFBIM, 2018; PSUBIM, 2019)

  Determine the archiving procedures of all data of the project and the BIM model after the close-out phase of the project.
- Back-up and Restore Procedures of Data (CDOC, 2015; Olatunji, 2011)

  Set backup and restore procedures for Deterioration and loss problems that may occur in the 3D common model.

7. Critical points of interoperability.

- Modes of Collaboration (CANBIM, 2012; COBIM, 2012; AIA, 2013; BSI, 2013; SBIM, 2013; NBIM, 2013; NBIM, 2015; NATSPEC, 2016; PSUBIM, 2019) **IS, QS**

  Identify procedures, priorities and critical points for the collaboration of different disciplines in the common model.
  - Clash Detection (CANBIM, 2012; USCBIM, 2012; COBIM, 2012; NBIM, 2013; AIA, 2013; SBIM, 2013; NBIM, 2015; BSI, 2015a; DASBIM, 2015; Ussing et al., 2016; NATSPEC, 2016; SBEnrcBIM, 2017; Li et al., 2017; NBGO, 2017; USFBIM, 2018; PSUBIM, 2019) **CLR, IS, QS**

    Determine the clash detection procedures to be performed over the common model during the design phase to prevent overlapping construction implementations during the construction phase.
  - Extracting 2D Drawings from 3D Model (CDOC, 2015; CANBIM, 2012; USFBIM, 2018) **CLR, IS, QS**

    To avoid differences between the model and construction implementations, determine the procedures required to extract all 2D drawings that will be used during the construction application from the 3D model.
- Change Order Procedures (CDOC, 2015; CANBIM, 2012; USCBIM, 2012; COBIM, 2012; SBIM, 2013; CIOB, 2013; DASBIM, 2015; NATSPEC, 2016; SBEnrcBIM, 2017; NBGO, 2017; BSI, 2018a; USFBIM, 2018; PSUBIM, 2019) **CLR, IS, QS**

  Set change order procedures to reduce time and cost related issues that will occur due to any changes in the project.

  The software and platform to be used for the change order must also be specified. **IS2**

  Change order transmittals in the project need to be archived to ensure that stakeholders are noticed the changes and take responsibility. **IS2**

8. Critical points of data security.

- Data Security Protocol for Loss, Corruption and Virus (CDOC, 2015; CANBIM, 2012; COBIM, 2012; CIOB, 2013; SBIM, 2013; Chien et al., 2014; NBIM, 2015; BSI, 2015b; Dougherty, 2015; NATSPEC, 2016; NBGO, 2017; Eschenbruch and Bodden, 2018; PSUBIM, 2019) **IS, QS**

  Establish a data security protocol to protect the BIM model and its digital data from loss, corruption and theft.

  Databases used internally and among stakeholders should be organized in different ways. **IS2**
  - Encrypted Filing (CDOC, 2015)

    Identify encrypted filing systems and system procedures for data security.
  - Access from Unknown Server (CIOB, 2013; Chien et al., 2014) **QS**

    Identify procedures for accessing unknown servers to protect data from viruses or theft.
  - Data Insurance (CDOC, 2015; Manderson et al., 2015)

    Use data insurance to cover financial losses that will arise from any problems with data security.

9. Critical points of operation phase.

- As-Built Model Procedures (COBIM, 2012; BSI, 2013; SBIM, 2013; NBIM, 2013) **CLR, IS, QS**

  Identify the processes of converting construction applications to as-built models and those responsible for control of this process.

  The layouts should be updated regularly during the construction phase of the project. **IS2**

- Operation and Maintenance

  Prepare the necessary procedures for the operation and maintenance phase after the project is realized for an effective BIM integration

  - Handing Over of Model (USCBIM, 2012; COBIM, 2012; SBIM, 2013; NBIM, 2013; BSI, 2014b; NBIM, 2015; NATSPEC, 2016; NBGO, 2017; SBEnrcBIM, 2017; USFBIM, 2018; Eschenbruch and Bodden, 2018; PSUBIM, 2019) **IS, QS**

    Specify the necessary regulations regarding the models that will be transferred to the operator following the realization of the project.
  - Maintenance Manuals (COBIM, 2012; USCBIM, 2012; BSI, 2014b; NBGO, 2017; SBEnrcBIM, 2017; USFBIM, 2018; PSUBIM, 2019)

    Indicate the necessary procedures for the transfer of maintenance manuals related to construction materials and technical equipment used in the project to the operator.

6. CONCLUSION

This paper proposed a preliminary checklist template that can be considered as a potential input to the contracting phase of these projects so that the contract preparation phase of BbCP can be improved. With this aim, existing standard contracts, protocols and guidelines were examined and compared to each other. Furthermore, legal disputes in BbCP were investigated through litigation awards and case law research in international databases. Subsequently, first stage interviews and questionnaire surveys were conducted with BIM professionals. Based on the findings obtained through literature review, litigation awards and case law research, first stage interviews and questionnaire survey, the proposed checklist template has been created. Lastly, the proposed checklist template was verified through the second stage interviews. The proposed checklist template consists of 25 main 32 sub-critical points.

Future studies on the legal issues of BbCP are recommended to focus on electronic contracts, where the BIM model can be part of the contract. In this way, the common model, which is one of the most important advantages of BIM, becomes legally binding among stakeholders.

In conclusion, the proposed preliminary checklist template can be used as an input to be considered for supporting the contract preparation phase of BbCP considering project-specific requirements and limitations. The proposed template can be useful to reduce legal concerns of stakeholders in the CI arising from BIM integration and to support the spread of BIM in the CI. With the development of construction technologies, the proposed preliminary checklist template can be updated or further developed with the experience and expertise gained from existing and future BbCP. Finally, the proposed preliminary checklist can be useful for BIM-based projects stakeholders as well as for lawmakers and public institutions dealing with legislation related to construction practices.

ACKNOWLEDGEMENT

This paper has been prepared within the scope of and based on the M.Sc. thesis/dissertation of Mr. Mehmet Yavuzhan Erpay and his M.Sc. thesis/dissertation supervisor Prof. Dr. Begum Sertyesilisik.

REFERENCES

Abdirad, H. (2015) Advancing in building information modelling (BIM) contracting: Trends in the AEC/FM industry, AEI 2015: Birth and Life of the Integrated Building - *Proceedings of the AEI Conference 2015,* (March), pp. 1–12. doi: 10.1061/9780784479070.001.

Alizadehsalehi, S., Hadavi, A., and Huang, J. C. (2019) BIM/MR-Lean Construction Project Delivery Management System. 2019 IEEE Technology & Engineering Management Conference (TEMSCON). doi:10.1109/temscon.2019.8813574

Alizadehsalehi, S., Hadavi, A., and Huang, J. C. (2020) From BIM to extended reality in AEC industry. Automation in Construction, 116, 103254. doi:10.1016/j.autcon.2020.103254

Al-Shammari, M. A. (2014) An appraisal of the protocol that was published by the Construction Industry Council (CIC) to facilitate the use of Building Information Modelling (BIM) on projects, Proceedings 30th Annual Association of Researchers in Construction Management Conference, ARCOM 2014, (September 2014), pp. 623–632.

American Institute of Architects (AIA) (2013) AIA Document E203– 2013: Building Information Modelling and Digital Data Exhibit. United States.

Arensman, D. B. and Ozbek, M. E. (2012) Building Information Modelling and Potential Legal Issues, *International Journal of Construction Education and Research*, 8(2), pp. 146–156. doi: 10.1080/15578771.2011.617808.

Arshad, M. F., Thaheem, M. J., Nasir, A. R., and Malik, M. S. A. (2019) Contractual Risks of Building Information Modelling: Toward a Standardized Legal Framework for Design-Bid-Build Projects, *Journal of Construction Engineering and Management*, 145(4), pp. 1–13. doi: 10.1061/(ASCE)CO.1943-7862.0001617.

Ashcraft, H. W. (2008) Building information modelling: a framework for collaboration, *Society of Construction Law International Conference*, 28(June), p. 5.

Ashworth, S., Tucker, M. and Druhmann, C. K. (2019) Critical success factors for facility management employer's information requirements (EIR) for BIM', *Facilities*, 37(1–2), pp. 103–118. doi: 10.1108/F-02-2018-0027.

Azhar, S. (2011) Building information modelling (BIM): Trends, benefits, risks, and challenges for the AEC industry', *Leadership and Management in Engineering*, 11(3), pp. 241–252. doi: 10.1061/(ASCE)LM.1943-5630.0000127.

Bakhary, N. A., Adnan, H. and Ibrahim, A. (2017) Improving construction claim management in Malaysian construction industry, *MATEC Web of Conferences*, 138. doi: 10.1051/matecconf/201713805003.

Belgian Guide ADEB-VBA (BBIM) (2015) Building Information Modelling – *Belgian Guide for the construction Industry*. Brussel. Available at: http://adeb-vba.be/the-guide-to-bim.pdf.

Borrmann, A., König, M., Koch, C., and Beetz J. (2018) *Building Information Modelling: Why?What? How?*. in Borrmann, A. et al. (eds) Building Information Modelling: Technology Foundations and Industry Practice. Switzerland: Springer, pp. 1–21. doi: https://doi.org/10.1016/j.autcon.2018.10.024.

Bosch-Sijtsema, P. M., Gluch, P. and Sezer, A. A. (2019) Professional development of the BIM actor role, *Automation in Construction*, 97(November 2018), pp. 44–51. doi: 10.1016/j.autcon.2018.10.024.

British Standards Institution (BSI) (2013) PAS 1192-2 *Specification for information management for the capital / delivery phase of construction projects using building information modelling*, BSI Standards Publication. United Kingdom.

British Standards Institution (BSI) (2014a) BS 1192-4: 2014 *Collaborative production of information Part 4: Fulfilling employer's information exchange requirements using COBie* - Code of practice, BSI Standards Publication. Available at: http://shop.bsigroup.com/forms/BS-1192-4/.

British Standards Institution (BSI) (2014b) PAS 1192-3:2014 *Specification for information management for the operational phase of assets using building information modelling*, BSI Standards Publication. doi: Published by the British Standard Institute. British Standard Limited. ISSN9780580781360. /BIM TASK GROUP.

British Standards Institution (BSI) (2015a) BS 8536-1-2015 *Briefing for design and construction - Part 1: Code of practice for facilities management (Buildings infrastructure)*, BSI Standards Publication.

British Standards Institution (BSI) (2015b) PAS 1192-5:2015 *Specification for security-minded building information modelling, digital built environments and smart asset management*, British Standards Publication. Available at: https://shop.bsigroup.com/ProductDetail/?pid=000000000030314119.

British Standards Institution (BSI) (2018a) BS EN ISO 19650-1:2018 *Organization and digitization of information about buildings and civil engineering works, including building information modelling (BIM) - Information management using building information modelling: Part 1: Concepts and principles*, British Standards Publication.

British Standards Institution (BSI) (2018b) BS EN ISO 19650-2:2018 *Organization and digitization of information about buildings and civil engineering works, including building information modelling (BIM) - Information management using building information modelling: Part 2: Delivery phase of the assets*, British Standards Publication.

British Standards Institution (BSI) (2018c) PAS 1192-6:2018 *Specification for collaborative sharing and use of structured Health and Safety information using BIM*, British Standards Publication.

Bryde, D., Broquetas, M. and Volm, J. M. (2013) The project benefits of building information modelling (BIM), International Journal of Project Management, 31(7), pp. 971–980. doi: 10.1016/j.ijproman.2012.12.001.

Bynum, P., Issa, R. R. A. and Olbina, S. (2013) Building information modelling in support of sustainable design and construction', *Journal of Construction Engineering and Management*, 139(1), pp. 24–34. doi: 10.1061/(ASCE)CO.1943-7862.0000560.

Canada BIM protocol AEC (CANBIM) (2012) *AEC (CAN) BIM Protocol v1.0. Canada*.

Charehzehi, A. et al. (2017) Building information modelling in construction conflict management, *International Journal of Engineering Business Management*, 9, pp. 1–18. doi: 10.1177/1847979017746257.

Chien, K. F., Wu, Z. H. and Huang, S. C. (2014) Identifying and assessing critical risk factors for BIM projects: Empirical study, *Automation in Construction*, 45, pp. 1–15. doi: 10.1016/j.autcon.2014.04.012.

Chong, H. Y., Fan, S. L., Sutrisna, M., Hsieh, S. H., and Tsai, C. M. (2017) Preliminary contractual framework for BIM-enabled projects, *Journal of Construction Engineering and Management*, 143(7). doi: 10.1061/(ASCE)CO.1943-7862.0001278.

Common BIM Requirements. (2012). *COBIM Series 11 Management of a BIM project*. Finland: The COBIM Project.

Consensus Documents (2015) *ConsensusDocs 301: Building Information Modelling (BIM) Addendum*.

Construction Industry Council (CIC) (2018) *Building Information Modelling (BIM) Protocol Second Edition: Standard Protocol for use in projects using Building Information Models*. Great Britain.

Demian, P. and Walters, D. (2014) The advantages of information management through building information modelling', *Construction Management and Economics*, 32(12), pp. 1153–1165. doi: 10.1080/01446193.2013.777754.

Department of Administrative Services (DASBIM) (2015) *BIM Guidelines*. United States.

Dougherty, J. M. (2015). *Claims, disputes and litigation involving BIM*. Abingdon, Oxon: Routledge. doi: 10.4324/9781315689012

Eastman, C. M., Jeong, Y. S., Sacks, R., and Kaner, I. (2010) Exchange model and exchange object concepts for implementation of national BIM standards, *Journal of Computing in Civil Engineering*, 24(1), pp. 25–34. doi: 10.1061/(ASCE)0887-3801(2010)24:1(25).

Eschenbruch, K. and Bodden, J. L. (2018) *Integrating BIM in construction contracts, Building Information Modelling*: Technology Foundations and Industry Practice, pp. 303–313. doi: 10.1007/978-3-319-92862-3_17.

Fan, S. L., Chong, H. Y., Liao, P. C., and Lee, C. Y. (2019) Latent Provisions for Building Information Modelling (BIM) Contracts: A Social Network Analysis Approach, *KSCE Journal of Civil Engineering*, 23(4), pp. 1427–1435. doi: 10.1007/s12205-019-0064-8.

Ghaffarianhoseini, A., Tookey, J., Ghaffarianhoseini, A., Naismith, N., Azhar, S., Efimova, O., and Raahemifar, K. (2017) Building Information Modelling (BIM) uptake: Clear benefits, understanding its implementation, risks and challenges, *Renewable and Sustainable Energy Reviews*, 75(September 2016), pp. 1046–1053. doi: 10.1016/j.rser.2016.11.083.

Heigermoser, D. et al. (2019) BIM-based Last Planner System tool for improving construction project management', *Automation in Construction*, 104(March), pp. 246–254. doi: 10.1016/j.autcon.2019.03.019.

Heigermoser, D., García de Soto, B. and Abbott E. L. S. (2019) BIM-based Last Planner System tool for improving construction project management, *Automation in Construction*, 104(March), pp. 246–254. doi: 10.1016/j.autcon.2019.03.019.

Howard, J. and Ciliberto, C. (2016) Why BIM, and Appropriate BIM Contracts, are Critical to Project Success., *Design Cost & Data*, 60(1), p. 16. Available at: http://ezproxy.leedsbeckett.ac.uk/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=edb&AN=114615418&site=eds-live&scope=site.

Hsu, K. M., Hsieh, T. Y. and Chen, J. H. (2015) Legal risks incurred under the application of BIM in Taiwan, *Proceedings of the Institution of Civil Engineers: Forensic Engineering*, 168(3), pp. 127–133. doi: 10.1680/feng.14.00005.

Huzaimi Abd Jamil, A. and Syazli Fathi, M. (2019) Contractual issues for Building Information Modelling (BIM)-based construction projects: An exploratory case study, *IOP Conference Series: Materials Science and Engineering*, 513(1). doi: 10.1088/1757-899X/513/1/012035.

Jo, T. M., Ishak, S. S. M. and Rashid, Z. Z. A. (2018) Overview of the Legal Aspects and Contract Requirements of the BIM Practice in Malaysian Construction Industry, *MATEC Web of Conferences*, 203. doi: 10.1051/matecconf/201820302011.

Joint Contracts Tribunal (JCT) (2016) *Design and Build Contract (DB)*, United Kingdom: Thomson Reuters.

Khalili, A. (2021). An XML-based approach for geo-semantic data exchange from BIM to VR applications. *Automation in Construction, 121*, 103425. doi:https://doi.org/10.1016/j.autcon.2020.103425

Kuiper, I. and Holzer, D. (2013) Rethinking the contractual context for Building Information Modelling (BIM) in the Australian built environment industry, *Australasian Journal of Construction Economics and Building*, 13(4), pp. 1–17. doi: 10.5130/ajceb.v13i4.3630.

Lai, H., Deng, X. and Chang, T. Y. P. (2019) BIM-Based Platform for Collaborative Building Design and Project Management', *Journal of Computing in Civil Engineering*, 33(3), pp. 1–15. doi: 10.1061/(ASCE)CP.1943-5487.0000830.

Li, X., Xu, J. and Zhang, Q. (2017) Research on Construction Schedule Management Based on BIM Technology, *Procedia Engineering*, 174, pp. 657–667. doi: 10.1016/j.proeng.2017.01.214.
Lin, Y. C., Chen, Y. P., Huang, W. T., and Hong, C. C. (2016) Development of BIM execution plan for BIM model management during the pre-operation phase: A case study', *Buildings*, 6(1). doi: 10.3390/buildings6010008.
Liu, Y., van Nederveen, S. and Hertogh, M. (2017) Understanding effects of BIM on collaborative design and constructionAn empirical study in China, *International Journal of Project Management*, 35(4), pp. 686–698. doi: 10.1016/j.ijproman.2016.06.007.
Manderson, A., Jefferies, M. and Brewer, G. (2015) Building information modelling and standardised construction contracts: A content analysis of the GC21 contract, *Construction Economics and Building*, 15(3), pp. 72–84. doi: 10.5130/AJCEB.v15i3.4608.
McAdam, B. (2010) Building information modelling: the UK legal context, *International Journal of Law in the Built Environment*, Vol. 2(3), pp. 246–259. doi: 10.1108/17561451011087337.
National Building Specifications (NATSPEC) (2016) *NATSPEC National BIM Guide*. Australia.
National Institute of Building Sciences (NBGO) (2017) *National BIM Guide for Owners*, National Institute of Building Sciences. United States. Available at: www.nibs.org.
New Engineering Contract (NEC) (2017) *New Engineering Contract 4 (NEC4): Engineering and Construction Contract*. Great Britain.
Norway Statsbygg (NBIM) (2013) *Statsbygg BIM Manual Version 1.2.1*, Statsbygg. Oslo, Norway. Available at: http://www.statsbygg.no/Files/publikasjoner/manualer/StatsbyggBIM-manual-ver1-2-1eng-2013-12-17.pdf.
Olatunji, O. A. (2011) A preliminary review on the legal implications of BIM and model ownership, *Electronic Journal of Information Technology in Construction (ITcon)*, 16(August 2010), pp. 687–696.
Oviedo-Haito, R. J. et al. (2014) Survival factors for subcontractors in economic downturns, *Journal of Construction Engineering and Management*, 140(3). doi: 10.1061/(ASCE)CO.1943-7862.0000811.
Pandey, A., Shahbodaghlou, F. and Burger, J. (2016) Construction Research Congress 2016 2039, *Proceedings Construction Research Congress 2016*, pp. 2039–2049. doi: 10.1061/9780784479827.203.
Papadonikolaki, E., van Oel, C. and Kagioglou, M. (2019) Organising and Managing boundaries: A structurational view of collaboration with Building Information Modelling (BIM)', *International Journal of Project Management*, 37(3), pp. 378–394. doi: 10.1016/j.ijproman.2019.01.010.
Pennsylvania State University (PSUBIM) (2019) *BIM Project Execution Planning Guide - Version 2.2*. United States.
Perrier, N., Bled, A., Bourgault, M., Cousin, N., Danjou, C., Pellerin, R. and Roland, T. (2020). Construction 4.0: a survey of research trends. *Electronic Journal of Information Technology in Construction (ITcon)*, Vol. 25, pg. 416-437, DOI: 10.36680/j.itcon.2020.024
Project Management Institution (PMI) (2017) *A Guide to the Project Management Body of Knowledge.* PMBOK® Guide – Sixth Edition.
Rahman, R. A. et al. (2016) Comparing Building Information Modelling Skills of Project Managers and BIM Managers Based on Social Media Analysis, *Procedia Engineering*, 145, pp. 812–819. doi: 10.1016/j.proeng.2016.04.106.
Schapke, E., Beetz, J., König, M., Koch, C., and Borrmann, A. (2018) Collaborative Data Management, in Borrmann, A. et al. (eds) *Building Information Modelling: Technology Foundations and Industry Practice*. Switzerland: Springer US, pp. 251–276. doi: https://doi.org/10.1007/978-3-319-92862-3.
SEC group (2017) *First Steps to BIM Competence: A Guide for Specialist Contractors*. Available at: https://www.thebesa.com/media/2899/bim-competence-final.pdf.
Siemens AG (2017) *'BIM @ Siemens Real Estate'*.
Singapore Building and Construction Authority (SBIM) (2013) *Singapore BIM Guide Version 2*, BIM Guide Workgroup. Available at: http://www.corenet.gov.sg/integrated_submission/bim/BIM/Singapore BIM Guide_V2.pdf.
Solihin, W. and Eastman, C. (2015) Classification of rules for automated BIM rule checking development, *Automation in Construction*, 53, pp. 69–82. doi: 10.1016/j.autcon.2015.03.003.
Srinivasan, N. P. and Dhivya, S. (2020) An empirical study on stakeholder management in construction projects, *Materials Today: Proceedings*, 21, pp. 60–62. doi: 10.1016/j.matpr.2019.05.361.
Succar, B. (2010) Building Information Modelling Maturity Matrix, *Handbook of Research on Building Information Modeling and Construction Informatics: Concepts and Technologies*, pp. 65–103. doi: 10.4018/978-1-60566-928-1.ch004.

The Chartered Institute of Building (CIOB) (2013) *Contract for use with Complex Projects*, First Edition 2013. Scotland.

The Sustainable Built Environment National Research Centre (SBEnrcBIM) (2017) *National BIM Guidelines and Case Studies for Infrastructure: SBEnrc Project 3.28.* Australia.

Tulke, J. and Schumann, R. (2018) BIM Manager, in Borrmann, A. et al. (eds) *Building Information Modelling: Technology Foundations and Industry Practice*. Switzerland: Springer. ss, pp. 293–302. doi: https://doi.org/10.1007/978-3-319-92862-3.

Uhm, M., Lee, G. and Jeon, B. (2017) An analysis of BIM jobs and competencies based on the use of terms in the industry, *Automation in Construction*, 81(October 2016), pp. 67–98. doi:10.1016/j.autcon.2017.06.002.

University of South Florida (USFBIM) (2018) *BIM Guidelines and Standards: For Architects, Engineers and Contractors*, University of South Florida | BIM Guidelines and Standards. doi: 10.4324/9781315169965.

University of Southern California (USCBIM) (2012) *Building Information Modelling (BIM) Guidelines: For Design Bid Build Contracts Version 1.6*, USC Capital Construction Development and Facilities Management Services. United States. Available at: https://facilities.usc.edu/uploads/documents/cas/BIMGuidelines_VS1_6_2012.pdf.

Ussing, L. F., Svidt, K. and Wandahl, S. (2016) Legal Aspects Connected to the Use of BIM in the Danish Building Sector, Construction Research Congress 2016: Old and New Construction Technologies Converge in Historic San Juan, *Proceedings of the 2016 Construction Research Congress*, CRC 2016, pp. 528–537. doi: 10.1061/9780784479827.054.