ISTANBUL TECHNICAL UNIVERSITY ★ GRADUATE SCHOOL OF SCIENCE ENGINEERING AND TECHNOLOGY

AN INVESTIGATION INTO THE IMPROVEMENT OF THE CONTRACT PREPARATION PHASE OF THE BIM-BASED CONSTRUCTION PROJECTS

M.Sc. THESIS

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ISTANBUL TEKNİK ÜNİVERSİTESİ ★ FEN BİLİMLERİ ENSTİTÜSÜ

BIM-BAZLI İNŞAAT PROJELERİNİN SÖZLEŞME HAZIRLIK AŞAMASININ İYİLEŞTİRİLMESİNE YÖNELİK BİR İNCELEME

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Mehmet Yavuzhan Erpay, a M.Sc. student of İTU Graduate School of Science Engineering and Technology student ID 502171411, successfully defended the thesis/dissertation entitled "AN INVESTIGATION INTO THE IMPROVEMENT OF THE CONTRACT PREPARATION PHASE OF THE BIM-BASED CONSTRUCTION PROJECTS", which he prepared after fulfilling the requirements specified in the associated legislations, before the jury whose signatures are below.

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To my family,

FOREWORD

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July 2020

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(Architect)

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ABBREVIATIONS

AIM	**:** Asset Information Model
AIR	**:** Asset Information Requirements
BEP	**:** BIM Execution Plan
BIM	**:** Building Information Modeling
CI	**:** Construction Industry
CPM	**:** Construction Project Management
EIR	**:** Exchange Information Requirements
IPD	**:** Integrated Project Delivery
IPR	**:** Intellectual Property Rights
ISO	**:** International Organization for Standardization
OIR	**:** Organisational Information Requirements
PAS	**:** Publicly Available Specification
PIM	**:** Project Information Model

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AN INVESTIGATION INTO THE IMPROVEMENT OF THE CONTRACT PREPARATION PHASE OF THE BIM-BASED CONSTRUCTION PROJECTS

SUMMARY

Building information modeling (BIM) is gaining its importance through the advantages it can provide to the project stakeholders. It has the potential to support competitiveness of the construction companies through enhanced and lean processes contributing to the cost and time effectiveness and customer satisfaction. Regulating the relationships of stakeholders throughout the entire building life cycle can become, however, a challenge as all stakeholders in various phases of the project share information through the common BIM model. Stakeholders in the construction industry can experience concerns in BIM processes due to legal difficulties as well as difficulties, claims, and disputes in the contract execution phase. Consequently, this situation can obstacle the spread of BIM integration into projects.

This research aims to contribute to the improvement of the contract preparation phase of the BIM-based construction projects through a preliminary checklist template proposal which can be considered as a potential input in the contract preparation phase of these projects. With this aim, the following objectives have been addressed: 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; and to propose a preliminary checklist template which can be considered as a potential input in the contract preparation phase of the BIM-based construction projects.

The first objective has been achieved through literature review and review of relevant international guidelines, standard contracts, and protocols. The second objective has been achieved through analyses of legal issues and causes of disputes related with BIM-based construction projects based on the litigation awards and case-law research conducted in national and international databases. Furthermore, for the accomplishment of the second objective, interviews have been performed with professionals working in the BIM-based construction projects who are experienced in and having expertise in BIM. Additionally, to achieve the second objective, an online questionnaire survey has been applied to professionals and academics who have expertise in BIM and/or experience in working in BIM-based construction projects. The third objective has been achieved through the preparation of the preliminary checklist template based on the findings obtained through literature review, interviews, and online questionnaire. Furthermore, the proposed preliminary checklist template has been further improved through interviews with professionals and academics who have expertise in BIM and/or experience in working in BIM-based construction projects.

Research revealed 4 main topics related with legal concerns, claims and disputes in BIM-based construction projects as: allocation of risks and responsibilities, intellectual property rights, interoperability, data security and documentation.

The proposed preliminary checklist template can support the contract preparation phase of the BIM-based construction projects. The proposed preliminary checklist template prepared based on the literature survey, interviews and questionnaire survey performed within the scope of this research consists of 25 main and 32 sub topics advised to be considered in the contract preparation phase of BIM-based construction projects. The main and sub topics in the proposed preliminary checklist template have been grouped into 9 categories in compliance with the BIM-based construction project phases and important aspects. These 9 categories are: organizational and managerial decisions; procedures for analyses; contractual priorities in the process; risk and responsibility allocation; intellectual property rights; information management; interoperability; data security and project operation phase.

The proposed preliminary checklist template has been prepared as a proposal and it is recommended to be adapted to the project specific requirements and contracting parties needs. Accordingly, alterations can be done in the proposed preliminary checklist template to adapt it to the project and contracting parties' requirements. Furthermore, this preliminary checklist template needs to be kept updated with the changes and developments in the construction industry and BIM-based construction projects. For this reason, future studies can be performed on updating of this preliminary checklist template based on the future developments and changes.

The proposed preliminary checklist template is expected to improve the contract preparation phase of the BIM-based construction projects as it can be used as a potential input and complementary tool which can be considered together with all other project-specific requirements and constrains as well as experience and expertise of the contracting parties in the contract preparation phase. Furthermore, this proposed preliminary checklist template, if used appropriately and as a complementary input to be considered together with the project specific constraints and requirements can have potential to contribute to the reduction in claims and disputes in the contract execution phase. This preliminary checklist template needs to be kept updated with the help of future researches as well as the experiences and expertise gained in the BIM-based construction projects.

This research is expected to be useful to the academics, public entities, and construction industry stakeholders.

BIM-BAZLI İNŞAAT PROJELERİNİN SÖZLEŞME HAZIRLIK AŞAMASININ İYİLEŞTİRİLMESİNE YÖNELİK BİR İNCELEME

ÖZET

İnşaat projeleri teknik inşaat yöntemleri kullanılarak işlevselliğin ve estetik kaygıların amaçlandığı karmaşık bir yapıya sahiptir. Gelişen inşaat teknolojilerinin getirdiği avatajlar sayesinde inşaat projelerinin boyutu ve karmaşıklığı artmıştır. Projeye dahil olan paydaş sayısı ve uzmanlıkları da zaman içinde artış göstermiştir. Projenin başlangıcından tamamlanmasına kadar ortak amaç doğrultusunda birlikte çalışmak zorunda olan paydaşların ilişkileri karmaşıklaşmıştır. Yapı bilgi modellemesi (YBM) modern inşaat projelerindeki karmaşık süreçleri kolaylaştırmak ve hızlandırmak için kullanılan bir bilgi paylaşım teknolojisidir. YBM ile organizasyonel karar aşamalarından yapının işletme ve bakım evresini de kapsayacak şekilde yıkılışına kadar olan süreç planlanmaktadır.

Projenin paydaşlarına sağladığı birçok avantaj ile YBM'nin inşaat sektöründeki önemi gün geçtikçe artmaktadır. YBM sistemindeki gelişmiş ve yalın süreçler müşteri memnuniyetine ve projenin maliyet ve zaman verimliliğine katkıda bulunarak inşaat şirketlerinin rekabetçiliğini destekleme potansiyeline sahiptir. Bununla birlikte, projenin çeşitli aşamalarında paydaşların ortak YBM modeli aracılığıyla bilgi paylaşması nedeniyle, proje yaşam döngüsü boyunca tüm paydaşların birbirileri ile olan ilişkilerinin düzenlenmesi büyük bir zorluk haline gelebilir.

Çok katılımcılı YBM süreçlerinde paydaşların hak ve sorumlulukları ile ilgili çeşitli yasal sıkıntılar çıkabilmektedir. İnşaat sektöründeki paydaşlar, yasal sıkıntılar ve sözleşmenin uygulanması sırasında yaşanan çeşitli zorluklar, uyuşmazlıklar ve anlaşmazlıklar nedeniyle YBM süreçlerine dair endişeler yaşayabilirler. Bu durum YBM'nin projelere entegrasyonunun yaygınlaşmasını olumsuz etkileyebilir.

Bu çalışma, sözleşme hazırlanırken kullanılacak bir ön kontrol listesi şablonu oluşturarak YBM-bazlı inşaat projelerinin sözleşme hazırlık aşaması iyileştirmeyi amaçlamaktadır. Bu amaç doğrultusunda belirlenen hedefler şunlardır: YBM entegrasyonu için oluşturulmuş kılavuzların, standart sözleşme ve protokollerin incelenmesi; YBM-bazlı inşaat sözleşmeleri hazırlanırken dikkat edilmesi gereken konuların belirlenmesi; ve YBM-bazlı inşaat projelerinin sözleşme aşamasında kullanılabilecek bir ön kontrol listesi şablonu oluşturmaktır.

İlk hedefi gerçekleştirmek için literatür taraması ve konuyla ilgili uluslararası kılavuzlar, standart sözleşmeler ve protokoller incelenmiştir. Bu dökümanların kapsamları ve kullanımlarına dair detaylar karşılaştırılmış güçlü ve zayıf yönleri literatür araştırmalarıyla desteklenerek belirlenmiştir. İkinci hedefte, YBM-bazlı inşaat projelerinde ortaya çıkan yasal endişeler ve anlaşmazlık sebeplerinin belirlenmesi için ulusal ve uluslararası veri tabanlarında dava ve mahkeme kararları araştırması yapılmıştır. Ayrıca, Türkiye' deki YBM-bazlı projelerde rol almış ve YBM konusunda uzman olan profesyoneller ile yer aldıkları projeler üzerinden mülakatlar yapılmıştır. Ek olarak, ikinci hedefi gerçekleştirmek için YBM-bazlı projelerde rol

almış profesyonellerle ve/veya YBM konusunda araştırmaları olan uzman akademisyenlerle çevrimiçi anket çalışması yapılmıştır. Üçüncü hedefi gerçekleştirmek için literatür taraması, dava ve mahkeme kararları araştırması, mülakatlar ve çevrim içi anket çalışmaları sonucunda elde edilen bulgular üzerinden ön kontrol listesi şablonu oluşturulmuştur. Ayrıca önerilen ön kontrol listesi şablonu, YBM-bazlı projelerde rol almış profesyonellerle ve/veya YBM konusunda araştırmaları olan uzman akademisyenlerle yapılan mülakatlarla geliştirilmiştir.

Araştırma sonucunda YBM-bazlı inşaat projelerindeki yasal endişeler ve ortaya çıkan çatışma ve anlaşmazlık konuları 4 ana başlıkta toplanmıştır. Bu konular; risklerin ve sorumlulukların paylaşımı, fikri mülkiyet hakları, birlikte çalışabilirlik, ve verilerin güvenliği ve belgelendirilmesidir.

İlk olarak, YBM ile birlikte ortaya çıkan yeni rollerin ve görevlerin tanımlanmaması, ve çok katılımcılı YBM sisteminde sorumlulukların ve risklerin uygun bir şekilde paylaşılmaması, proje sürecinde aksaklıklara sebep olmaktadır. Ayrıca paydaşların yüksek riskli gördükleri projelere katılırken kendilerini korumak amacıyla fiyat yükseltebilmesi toplam proje maliyetini artırabilir.

İkinci olarak, üretilen tüm bilgilerin ortak platformda herkesin erişimine açık olması YBM'nin avantajlarından birisidir. Fakat paydaşlar için ticari değeri olan veya mülkiyet hakları bulunan bilgilerin paydaşlar tarafından izinsiz görüntülenme veya paylaşılma riski bulunmaktadır. Bu sebeple paydaşlar ürettikleri bilgileri paylaşmakta endişeler duymaktadırlar. Bu durum YBM'nin işbirlikçi yapısını zedelemektedir.

Üçüncü olarak, tüm inşaat disiplinlerinin ortak model üzerinden bilgi paylaşımı ve değiştirme imkanı olduğu için disiplinler arası iletişim önem kazanmaktadır. Ancak diğer paydaşların bilgisi olmadan modelde yapılan değişiklikler inşaat uygulamalarında yanlışlık, eksiklik ve çakışmalara sebep olmaktadır. Ayrıca farklı yazılımlar yada yazılımların farklı sürümleri tarafından paylaşılan veriler takımlar arası uyumsuzluk oluşturmaktadır.

Son olarak, YBM ile dijitalleşen proje verilerinin elektronik anlamda kayıplara, bozulmalara ve çalınmalara açık olması veri güvenliği endişelerini ortaya çıkarmaktadır. Verilerin depolandığı daha sonra da arşivlendiği veri tabanlarının fiziksel veya siber tehditlere açık olması da diğer bir veri güvenliği endişesidir. Ayrıca projenin kapanış evresinde projeye ait imalat modelinin ve bakım kılavuzlarının arşivlenerek tesis yönetim ekibine devredilmesi, etkili ve verimli YBM entegrasyonu için gereklidir.

Bu araştırma sonucunda elde veriler ve önerilen ön kontrol listesi şablonu, inşaat sektöründe yer alan ve YBM-bazlı proje sözleşmesi oluşturmak isteyen paydaşlar tarafından kullanılabilir. Sözleşme hazırlanırken yasal yönlerden göz önünde bulundulması gereken kritik noktalar hakkında fikir sahibi olabilirler. Ayrıca YBM-bazlı projede yer alacak ve yasal yönlerden endişeleri bulunan paydaşlar için faydalı olabilir.

Önerilen ön kontrol listesi şablonu YBM-bazlı inşaat projelerinin sözleşme hazırlık aşamasına destek olabilir. Bu çalışma kapsamında yapılmış olan kaynak taraması, mülakatlar ve anket çalışması ile elde edilen veriler ile hazırlanmış ve önerilmiş olan ön kontrol listesi şablonu YBM-bazlı inşaat projelerinin sözleşmelerinin hazırlanması aşamasında dikkat edilmesi önerilen 25 ana konu ve 32 alt konudan oluşmaktadır. Önerilen ön kontrol listesi şablonundaki ana ve alt konular, YBM-bazlı inşaat projelerinin aşamaları ve önemli noktalarına göre 9 kategoride gruplanmıştır. Bu sekiz

kategori sırasıyla: organizasyonel ve yönetimsel kararlar; sürdürülebilirlik, zaman ve maliyet analizleri; süreçteki sözleşmesel öncelikler; risk ve sorumluluk dağıtımları; fikri mülkiyet hakları; bilgi yönetimi; birlikte çalışılabilirlik; veri güvenliği; ve projenin işletme aşamasıdır.

Önerilen ön kontrol listesi şablonunun, sözleşme taraflarının uzmanlıkları ve deneyimleri ile beraber, projenin gereksinimleri ve kısıtlamaları doğrultusunda, destekleyici ve tamamlayıcı bir döküman olarak kullanılmasıyla YBM-bazlı inşaat projelerinin sözleşme hazırlık aşamasının iyileştirilmesine katkısı olabileceği beklenmekte ve sözleşme yürütme aşamasında oluşabilecek hak talebi ve uyuşmazlık çıkma riskinin azaltılmasına katkısı olabileceği değerlendirilmektedir.

Oluşturulmuş olan ön kontrol listesi şablonu öneri olarak geliştirilmiş olup her projenin ve sözleşme taraflarının ihtiyaçlarına ve özgün koşullarına yönelik olarak adapte edilmesi önerilmektedir. Bu kapsamda, önerilen ön kontrol listesi şablonunda projeye ve sözleşme taraflarının ihtiyaçlarına ve özgün koşullarına uygun olacak şekilde eklemeler, düzeltmeler ve çıkarmalar yapılabilir. Bununla birlikte, BIM-bazlı inşaat projelerinden elde edilen tecrübe ve uzmanlıklar ile inşaat sektöründe ve BIM-bazlı projelerdeki gelecekteki gelişmeler dikkate alınarak önerilen ön kontrol listesinin sürekli güncellenmesi ile gelecekteki değişen koşullara ve ihtiyaçlara cevap verebilmesi sağlanabilir. Bu nedenle, gelecekteki çalışmaların önerilen ön kontrol listesinin değişen koşullar ve ihtiyaçlara yönelik güncellenmesi üzerine yapılması önerilmektedir.

Son olarak bu çalışmanın, benzer konuda akademik çalışma yapan akademisyenlere ve inşaat uygulamalarına dair yasal düzenlemeler yapan kamu kuruluşlarına yardımcı olacağı düşünülmektedir.

1. INTRODUCTION

1.1 Background of the Problem

The construction industry (CI) is among the important pillars of the economies due to its contribution to the economic development of the countries. In common cases, the CI and its secondary industries contribute to the employment rate of the countries. The CI is, however, one of the most difficult industries to be managed because of the complexity, uniqueness and numerous disciplines it contains. Furthermore, changes in construction materials and construction methods have affected the management of the projects.

In construction projects where there are many participants, the basic relationships between these participants are determined by the construction contracts to realize the project management effectively and efficiently. Simply, a contract is a agreement or promise guaranteed by law (Semple et al., 1994). Construction contracts should clearly state the rights and responsibilities of the participants. However, with the changing project delivery systems, the clarity between rights and responsibilities has started to decrease.

Innovations in construction systems and changes in user expectations have led to specializations in the CI. The amount and variety of the information in the project expanded with these specialties. Similarly, the amount of information has increased during the design and construction phase of buildings, as well as throughout the entire life cycle. National Building Specifications (2016) stated: “Building Information Management (BIM) is a process for creating and managing information on a construction project across the project life cycle.” The CI's acceptance and use of BIM has remarkably increased in recent years. The various advantages offered by BIM have been effective in this trend. Improved information management throughout the building lifecycle, interoperability potential, and integrated supply chain are some of these advantages (BSI, 2013). Additionally, increasing time and cost efficiency (McGraw Hill, 2014) and reducing delays and disputes (Ghaffarianhoseini et al., 2017)

have enabled BIM to gain international recognition. As BIM becomes more common in the CI, processes of the project (designing, procurement, construction, and operation) are started to change (Ashworth et al., 2019). Nevertheless, construction contracts have not been able to adapt to this change over the years.

BIM offers many advantages as well as effective and efficient management of tasks (Liu et al., 2017). The five featured reasons why agents in the CI prefer BIM are; cost and time reduction, communication and coordination improvement, and increase in quality (Bryde et al., 2013). BIM has advantages not only during the design and construction phase but also throughout the entire lifecycle of the building (Fountain and Langar, 2018). During the operation phase, the information collected through a BIM process could be beneficial. The collected information can be used in the range of commissioning, spatial management, maintenance, quality control, energy management and the close-out phase of the building (Becerik-Gerber et al., 2012). It should be noted that inter-stakeholder communication and coordination are crucial to benefiting from the advantages of BIM. This requires a managerial challenge. Therefore, the interoperable environment created by BIM itself can be used to overcome this challenge.

Despite the great advantages of BIM, BIM-based projects have several problems. BIM integration includes a variety of risks which are technical, managerial, environmental, financial and legal risks (Chien et al., 2014). In order to cope with these risks, various arrangements should be made in the contracting phase. The key stakeholders of the project such as owner, design team, construction team, and companies in the supply chain need to work together when preparing the BIM contract (Dougherty, 2015). In April 2016, the UK government legislated a code requiring the use of BIM level 2 in public projects. Contractual improvements, supporting documents and guidelines can help construction companies to adapt to BIM level 2 (WPSP, 2011). Several standard contracts can be used in BIM-based projects. Most of the standard BIM agreements and protocols are created as an addendum to the existing master agreement (Chong et al., 2017). Therefore, these standard contracts cannot eliminate all problems. Moreover, since modern legal systems are generally designed according to traditional construction methods, they focus on individual rights and responsibilities of stakeholders (Pandey et al., 2016). Conversely, in the collaborative nature of BIM, participants need to work together for the efficient and effective use of BIM. Hence,

existing laws and regulations lack arrangements for integrated design and for regulating stakeholder cooperation (Azhar et al., 2012). The main problems that arise during the integration of BIM-based projects into the contract have been the starting point of this research.

1.2 Research Aim and Objectives

This research aims to improve the contract preparation phase of the BIM-based construction projects through preliminary checklist template proposal which can be considered as a potential input in the contract preparation phase of these projects. This research has the following main objectives (Table 1.1.): (1) To review the BIM guidelines, standard contracts and protocols; (2) To determine the critical aspects and issues to be considered in the BIM-based construction contracts; and (3) To propose a preliminary checklist template which can be considered as a potential input in the contract preparation phase of the BIM-based construction projects. This research focuses on the integration of BIM into the pre-construction phase of the projects. Within the scope of the research, in-depth interviews were conducted with participants who worked in different roles (e.g. BIM designer and consultant, BIM manager and chief designer, BIM director and BIM coordinator) in BIM-based projects.

Table 1.1 : Research aim and objectives

Aim	Objectives	Research methods
To improve the contract preparation phase of the BIM-based construction projects through preliminary checklist template proposal which can be considered as a potential input in the contract preparation phase of these projects.	To review the BIM guidelines, standard contracts and protocols	Literature Review
	To determine the critical aspects and issues to be considered in the BIM-based construction contracts	Literature review, litigation awards and case-law research, in-depth interviews with experts (first stage and second stage interviews), online questionnaire survey
	To propose a preliminary checklist template which can be considered as a potential input in the contract preparation phase of the BIM-based construction projects.	Literature review, in-depth interviews with experts (first stage and second stage interviews), online questionnaire survey

1.3 Research Methods and Dissertation Content

In this dissertation, a comprehensive literature review has been conducted on the articles, books and standard documents related to the research aim and objectives. Interview and online questionnaire survey questions have been developed to apply to the interviewees based on the literature review. BIM specialists who took part in complex projects have been interviewed. Additionally, a survey was conducted with local and foreign BIM specialists via LinkedIn and e-mail. A preliminary checklist template has been established which can be considered to be used during the integration of BIM-based projects into the contract in accordance with literature review and field study. Afterwards, the verification study of the checklist was carried out with the interviewees.

This research consists of five successive chapters (Figure 1.1). Chapter 1 provides background information on the subject and sets out the concept and objectives of the research.

Chapter 2 focuses on the differences of BIM-based project management through process, documentation and stakeholders. Afterwards, the BIM contracts are investigated and the critical aspects of contract management are determined. In addition, the main causes and effects of claims and disputes arising from BIM-based construction contracts will be identified. The outcomes of the literature review will form the basis of the interview and survey questions in the following chapters.

In Chapter 3, critical aspects in BIM-based project contracts will be selected using the literature review. First and second stage interviews and survey questions will be identified in the consideration of these critical points.

Chapter 4 contains the information obtained as a result of the litigation awards and case law research. Further, this section contains data obtained through the interviews with BIM specialists and professionals having experience and expertise working with BIM, who view the contract from different perspectives. In addition, this section includes the results of the surveys created in ITU data collection system and sent to local and foreign BIM experts via LinkedIn and e-mail. The results obtained from the field study will be discussed with the literature, the similarities and differences will be indicated. After the discussion section, a checklist will be established during the

integration of BIM into the contract. Verification studies of the preliminary checklist template will be carried out by interviewing the participants in the field study.

Chapter 5 presents the results and conclusions of the research. In this section, the results of the validated checklist are explained in detail. In addition, recommendations and limitations for future research have been provided.

2. LEGAL ASPECTS OF BIM-BASED CONSTRUCTION PROJECTS

In this part of the dissertation, a detailed literature review was made on the legal aspects of BIM-based construction projects management (CPM). Firstly, the characteristic features of BIM-Based projects in terms of process, stakeholders and documents were investigated through literature, guides, standard contracts and protocols. Afterwards, contractual aspects of BIM-Based CPM was examined. In line with the findings obtained from the literature review, the critical points of BIM-based CPM from the legal perspective are specified.

2.1 BIM-based Construction Project Management (CPM)

As the CI is a competitive industry, companies need to be innovative in terms of their methods of the delivery system as well as products and construction materials (Olawumi and Chan, 2018). Optimizing the project delivery system can provide a competitive advantage to the company in the market by reducing the problems, money and time losses. Regardless of the project scale, each project needs management. Project management, however, has also become challenging due to the evolution of construction technology, procedures and organizational structures (Hendrickson and Au, 2000). BIM brings solutions for project management problems in the CI by providing a collaborative common platform for various stakeholders involved throughout the project life-cycle (Demian and Walters, 2013). This collaborative decision-making platform facilitates the information flow for project management (Heigermoser et al., 2019). The most appropriate delivery system is integrated project delivery (IPD) to get benefit from these advantages of BIM (Wright, 2012). IPD allows BIM's collaborative environment and communication capabilities to effectively monitor, control the project and resolve conflicts when necessary (Rokooei, 2015). Thus, project stakeholders (e.g. owner, design team, construction team and project manager, etc.) can handle the project more effectively and efficiently (Ganah and John, 2015).

The decision-making process needs to be based on the most up-to-date and accurate data to enhance effectiveness of the project management. To ensure this, the project manager must be in contact with all stakeholders (Scheffer et al., 2018). Integration, communication, and stakeholder management are crucial for creating a collaborative environment between teams. Especially in complex projects, these key areas need to be managed well for effective information sharing (Papadonikolaki et al., 2019). In addition, stakeholders' personalities, experiences and training are important for collaboration, conflict management and interoperability in BIM-based project management (Davies et al., 2015).

Governments, universities and institutions around the world have published various guidelines to assist the project stakeholders in planning these processes. All these guidelines state that the given recommendations or requirements do not describe legal contractual conditions, and that the risk is in the users. Within the scope of this dissertation, 13 of them have been examined (Table 2.1). Under the name of BSI Standard Publications, 2 ISO (International Organization for Standardization) and 6 PAS (Publicly Available Specification) documents published by the same institution on different dates were examined. While choosing these guidelines, their scope and details of their contents have been considered. These guidelines have been examined with respect to the titles of defined process, roles and responsibilities, and documents.

Table 2.1 : BIM guidelines examined within the scope of the dissertation.

Name	Country	Year	Abbreviation in Text
The Pennsylvania State University BIM Project Execution Planning Guide - Version 2.2	USA	2019	PSUBIM
BSI Standards Publications	UK	2018	BSI
University of South Florida, BIM Guidelines and Standards	USA	2018	USFBIM
National BIM Guide for Owners	USA	2017	NBGO
National BIM Guidelines and Case Studies for Infrastructure	Australia	2017	SBEnrcBIM
The National Building Specifications, National BIM Guide	Australia	2016	NATSPEC

Name	Country	Year	Abbreviation in Text
Belgian Guide for the CI – BIM	Belgium	2015	BBIM
Department of Administrative Services BIM Guidelines	USA	2015	DASBIM
Canada BIM Protocol	Canada	2014	CANBIM
Singapore BIM Guide V.2	Singapore	2013	SBIM
Norway Statsbygg BIM Manual 1.2.1	Norway	2013	NBIM
Common BIM Requirements	Finland	2012	COBIM
University Of Southern California BIM Guidelines	USA	2012	USCBIM

2.1.1 BIM-based CPM process

Construction projects are complex and multi-participatory. Proper planning of interacting stakeholders throughout the process can reduce the conflicts and disputes that can arise. The planning of the whole process is crucial in BIM-based projects that aim to establish a collaborative environment from the initial phase of the process. The transition of project management from a team-oriented approach to multiple processes and behavioural management is in line with the complex deliverables and roles of BIM (Söderlund, 2004). While some of the guides examined within the scope of the research describe this process step by step, some of them were created as requirements and recommendations under various topics. 8 out of 13 guides took the BIM model as the focal point and identified the whole process in this model in terms of inputs and outputs. The rest of the guides consider the BIM model as a product/component of the process. The majority of the guides define the process from the pre-design to the handover phase at the end of the project. BSI, NBIM and COBIM, however, have included organizational goals in the BIM process. These guides recommend to start by determining the project location and type by making feasibility and alternative project analyses. Once the project has been identified, the process begins with defining BIM requirements and objectives in all guidelines (BBIM, BSI PAS1, CANBIM, COBIM, DASBIM, NATSPEC, NBGO, NBIM, PSUBIM, SBEnrcBIM, SBIM, USCBIM, USFBIM). They (BBIM, BSI PAS1, CANBIM, COBIM, DASBIM, NATSPEC,

NBGO, NBIM, PSUBIM, SBEnrcBIM, SBIM, USCBIM, USFBIM) recommend defining the details, procedures and responsible parties of the information to be shared in line with the BIM goals.

All guidelines (BBIM, BSI, CANBIM, COBIM, DASBIM, NATSPEC, NBGO, NBIM, PSUBIM, SBEnrcBIM, SBIM, USCBIM, USFBIM) contain information about simulation and analysis made on the BIM model to achieve BIM goals. The guides listed energy, solar, coordination, schedule, cost estimation, and sustainability analysis. The degree of detail about the analysis differs. In the majority majority (BBIM, BSI PAS1, CANBIM, DASBIM, NATSPEC, NBIM, PSUBIM, SBEnrcBIM, SBIM, USCBIM), these analyses have been identified by listing their names at various stages of the BIM process. Unlike others; USFBIM, NBGO, and COBIM pay particular attention to these analyses, and make reference to the documents produced on how to perform these analyses in detail. They also suggest that simulating better and worse scenarios with comparative analysis during the pre-design phase.

All guidelines (BBIM, BSI, CANBIM, COBIM, DASBIM, NATSPEC, NBGO, NBIM, PSUBIM, SBEnrcBIM, SBIM, USCBIM, USFBIM) provide recommendations and requirements about information management in varying levels of detail. These can generally be categorized under three main headings, namely: creating, sharing and archiving the information. At the pre-design stage, the type and detail level of the generated information during the BIM stages should be determined (BBIM, 2015; BSI PAS1, 2018; BSI ISO2, 2018; CANBIM, 2014; COBIM, 2012; NATSPEC, 2016; NBGO, 2017; PSUBIM, 2019; SBIM, 2013; USCBIM, 2012). It was also recommended to identify the responsible parties and the procedures for information sharing (BBIM, 2015; BSI PAS1, 2015; CANBIM, 2014; COBIM, 2012; DASBIM, 2015; NATSPEC, 2016; NBGO, 2017; NBIM, 2013; PSUBIM, 2019; SBEnrcBIM, 2017; SBIM, 2013; USCBIM, 2012; USFBIM, 2018). Afterwards, there are instructions for archiving and handing over to the operator during the project close-out phase (BBIM, BSI PAS1, COBIM, NATSPEC, NBGO, NBIM, PSUBIM, SBEnrcBIM, SBIM, USCBIM, USFBIM). In all but 4 of the guides, all these procedures are either detailed in the guide (BSI, COBIM, NBGO, PSUBIM) or referred to (BBIM, NATSPEC, NBIM, USCBIM, USFBIM) specific documents. In DASBIM, CANBIM, SBEnrcBIM, and SBIM, the process is not elaborated on and is provided as recommendations. Most guides (BBIM, BSI PAS1, CANBIM, COBIM,

NATSPEC, NBGO, NBIM, PSUBIM, USCBIM, USFBIM) agree that the information should be coded from the general to the specific and should include time, version, location, author and responsibilities, etc. They (BBIM, BSI PAS1, CANBIM, COBIM, NATSPEC, NBGO, NBIM, PSUBIM, USCBIM, USFBIM) state that it is important for this coding system to be implemented by all stakeholders to ensure coordination between teams working together. They (BBIM, BSI PAS1, CANBIM, COBIM, NATSPEC, NBGO, NBIM, PSUBIM, USCBIM, USFBIM) specify that it is necessary for effective interoperability to match the extensions of the documents produced with the software. BBIM specified that minimizing the number of imported and exported documents can enhance the project quality by reducing the errors and unnecessary reworks. According to USCBIM, the design and construction team must use the project collaboration server, which is a special file naming system produced by the institution.

Digitalization of the information has brought new concerns about the protection of stored data. More than half of the guides attached importance to data security. NBGO and NATSPEC indicate that the project teams should establish a protocol which determines the level of access and use among the project teams to prevent virus attack, data loss, data corruption, and data misuse. According to BBIM, this protocol should be contractually binding. CANBIM also recommends archiving the model in native authoring format against loss and corruption of information generated during the project process.

9 (BBIM, BSI PAS1, CANBIM, COBIM, NATSPEC, NBGO, PSUBIM, SBEnrcBIM, SBIM) out of 13 guides agree that the definite contract is essential for a successful BIM integration. PSUBIM stated that the Design-Build or IPD system is more suitable for BIM integration and that BIM can be successfully integrated into all delivery systems. According to these guidelines (BBIM, BSI PAS1, CANBIM, COBIM, NATSPEC, NBGO, PSUBIM, SBEnrcBIM, SBIM), regardless of the project delivery system, the roles and responsibilities that arise due to the BIM goals and deliverables determined in the Pre-design phase, should be clearly defined in the contract. SBEnrcBIM states that the collaborative environment of BIM affects the relationships between teams in traditionally bipartite contracts, hence roles and responsibilities are blurred between teams. These emerging risks need to be allocated in a balanced way, considering the benefits of teams from BIM, the ability to control and compensate for

the risks (SBEnrcBIM, 2017). According to the NATSPEC, whether to use multiple models (ie. Design and Construction) or a combined single model needs to be specified in the contract. BBIM and COBIM specify that the content and requirements of the BIM model, as well as the procedures for transforming it into an as-built model in the process, should be added to all design contracts in a binding manner. Regarding the contract management, USFBIM and CANBIM emphasize that all information and 2D drawings of the project should be derived from the 3D BIM model to reduce the disagreements between the parties. They (USFBIM and CANBIM) also mention, however, that the BIM model is not a contract document and the 3D model is not binding in any conflict or dispute. Although SBIM agrees with the recommendations of USFBIM and CANBIM, it predicts that the BIM model will be part of the contract in the future.

In the high integration and collaborative environment of BIM, defining and protecting Intellectual Property Rights (IPR) is another important issue. Except for 4 guides (DASBIM, NATSPEC, USCBIM, USFBIM) all of them have requirements on this subject. Most of the guides (BBIM, BSI PAS1, CANBIM, COBIM, NBGO, NBIM, PSUBIM, SBEnrcBIM, SBIM) state that the project deliverables and ownership rights should be clearly and inclusively defined among the contract parties. If the design team has copyright-related concerns about libraries or objects, COBIM recommends that the relevant provisions should be written in the contract. According to BSI, the usage rights of the information to be produced at the beginning and during the project should be added to the project's information protocol. SBIM states that sharing the information produced by the author does not mean transfer of ownership rights. Moreover, it (SBIM), also states that the receiving party's right to use, change and transmit the information is limited to the scope of the project. Therefore, CANBIM recommends using terms of usage letter to protect IP while sharing information. After the authorized person signs the terms of usage letter, the digital document should be shared (CANBIM, 2014). In addition, NBIM and CANBIM suggest the use of unique electronic stamps to monitoring the condition of the information.

Except for DASBIM and CANBIM, all guidelines have mentioned the procedures for handing over the BIM model to the facility manager for the operation and maintenance phase upon completion of the project. These guides (BBIM, BSI PAS1, COBIM, NATSPEC, NBGO, NBIM, PSUBIM, SBEnrcBIM, SBIM, USCBIM, USFBIM)

contain recommendations and requirements for the transfer of model and information. Most guides (BSI PAS3, CANBIM, COBIM, DASBIM, NBGO, PSUBIM, SBEnrcBIM, SBIM, USCBIM) agree that BIM-based projects must be considered with the operational phase in mind. They (BSI PAS1, CANBIM, COBIM, DASBIM, NBGO, PSUBIM, SBEnrcBIM, SBIM, USCBIM) state that establishing an operation and maintenance program can reduce the overall maintenance costs by improving building performance and reducing repairs. USFBIM suggests that the operation and maintenance manual prepared by the construction team after the completion of the project should include cut sheets, installation instructions and recommends maintenance tasks. According to BSI ISO1, SBIM and COBIM, construction implementations should be integrated into the BIM model as built and transferred to the operations team. Furthermore, NBIM states that the as-built model should be cleaned from the irrelevant information for the facility manager and should be transformed to Facility Manager and Operation BIM model.

2.1.2 BIM-based CPM stakeholders and teams

A collaborative working environment is required to obtain maximum efficiency from BIM. This environment needs to be spread across all participants, from the supply chain to the final product. In addition, all these expertise and know-how are shared among all stakeholders through this environment (Prentice, 2015). Therefore, effective stakeholder management is crucial to the success and quality of the project (Srinivasan and Dhivya, 2020). According to the project management body of knowledge (2017), stakeholder management includes people, groups and organizations that can affect the project and management strategies of the impact of these stakeholders on the project. Generally, construction projects consist of 3 main stakeholders: owner, design team and construction team. In addition, many stakeholders are involved in this process, including subcontractors, suppliers, consultants, operators, and authorities, etc. As BIM has become widespread in the CI, new tasks and responsibilities have been developed (Uhm et al., 2017). These areas of expertise have turned into new teams involved in the project (Dougherty, 2015). A recent study revealed 35 different job titles related to the different tasks and responsibilities of BIM (Uhm et al., 2017). Although there has been an increase in the standardization of BIM, further studies need to be carried out on the roles and responsibilities of BIM since there are currently no widely agreed definitions of these roles (Bosch-Sijtsema et al., 2017). Likewise, there

is no comprehensive research on how BIM's deliverables affect these roles and relationships (Papadonikolaki et al., 2019). Furthermore, project actors may need to take roles beyond their professions as a result of changing deliverables and integrated activities (Jaradat et al., 2013).

Among the many BIM-related roles, the most important roles are the BIM Manager, the BIM Coordinator, and the BIM Modeller (Borrmann et al., 2018). According to the AEC BIM protocol (2012), the BIM manager has an organizational strategic role, the BIM coordinator is responsible for interdisciplinary model sharing, and the BIM modellers are the producers of the models. These emerging roles can adversely affect cooperation if they are not properly coordinated and managed. (Akintola et al., 2017).

Team establishment phase is critical in creating a collaborative working environment (Borrmann et al., 2018). There is no ready-made system for this, continuous coordination and management of multi disciplines is required (Papadonikolaki et al., 2019). The employer can sign protocols with their subcontractors to make information modelling a common goal among all stakeholders (Borrmann et al., 2018). These protocols determine the software to be used, the format of the information, naming, and numbering of the files (CIC, 2018). Moreover, it should be noted that the protocol is a priority in any conflict between the teams (BESA, 2017). The team must list the goals and agree on how to measure the objectives that are achieved (FERMILAB, 2015). There are many team members, responsibilities and objectives in this collaborative environment (Uhm et al., 2017). According to the researchers, a specialized BIM manager should be appointed to identify, monitor and support participants involved in the project within the BIM's information flow, as well as to manage BIM protocols, goals and responsibilities (Eschenbruch and Bodden, 2018; Holzer, 2016; Tulke and Schumann, 2018; Huzaimi Abd Jamil and Fathi, 2019).

All guides (BBIM, BSI, CANBIM, COBIM, DASBIM, NATSPEC, NBGO, NBIM, PSUBIM, SBEnrcBIM, SBIM, USCBIM, USFBIM) mention BIM roles and responsibilities at varying levels of detail. CANBIM and NBIM are not only described in detail but only as a definition. Although the names of the roles change, a 3-level BIM management hierarchy is similar in the majority (BBIM, BSI PAS1, CANBIM, COBIM, NATSPEC, NBGO, NBIM, PSUBIM, SBEnrcBIM, SBIM, USCBIM) of these guides. This system consists of the BIM manager responsible for the entire BIM process and strategies, the BIM coordinators responsible for interdisciplinary

compliance, and the Discipline BIM Leads/Modellers responsible for the model of each major discipline (Figure 2.1). USFBIM and DASBIM, however, have not defined the BIM manager who is responsible for the whole process. According to these guidelines (USFBIM and DASBIM), the Design BIM Coordinator is responsible for the design phase, while the Construction BIM Coordinator is responsible for the construction phase. Unlike others, PSUBIM, BBIM and USCBIM recommend appointment of a third party BIM consultant for stakeholders who are not familiar with BIM processes. The BSI PAS 2 Document and USCBIM emphasized that the Information Technology (IT) Manager has an important role and should be responsible for the management of the unified model and the supervision of common data throughout the process.

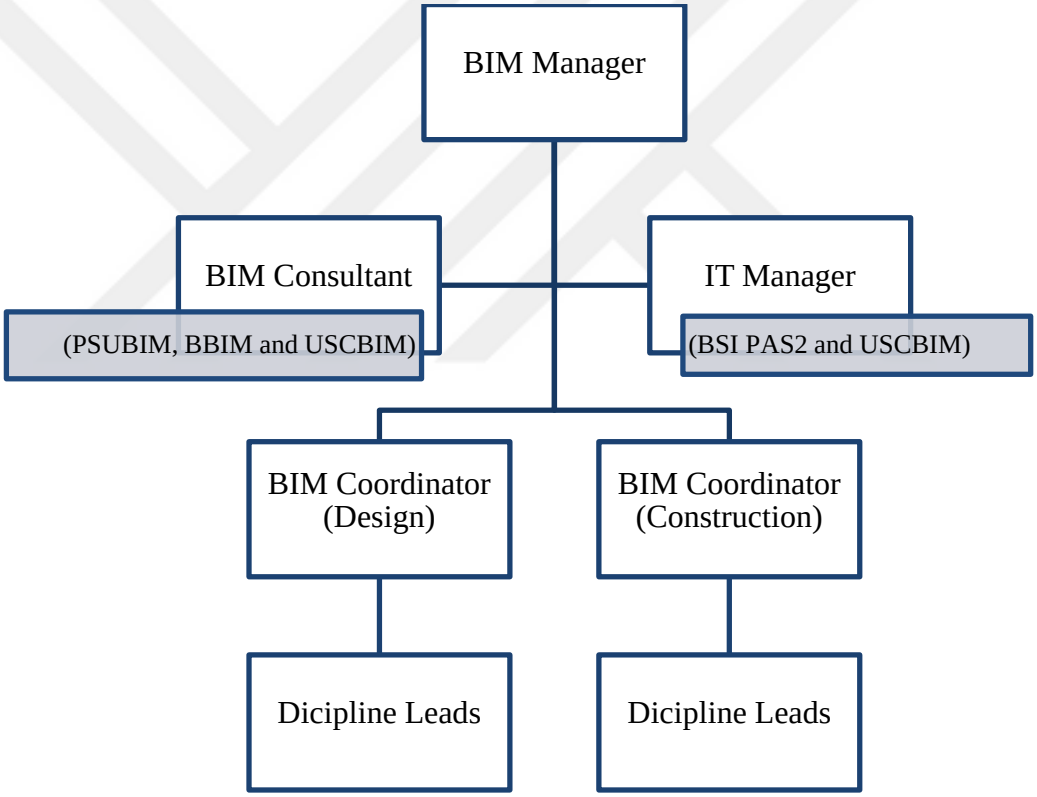

Figure 2.1 : Scheme of hierarchy between BIM roles (Based on the information obtained from the following guidelines: BBIM, BSI, CANBIM, COBIM, DASBIM, NATSPEC, NBGO, NBIM, PSUBIM, SBEnrcBIM, SBIM, USCBIM, USFBIM).

The guides (BBIM, BSI, CANBIM, COBIM, DASBIM, NATSPEC, NBGO, NBIM, PSUBIM, SBEnrcBIM, SBIM, USCBIM, USFBIM) assigned responsibilities and obligations to BIM roles according to different stages of the project. The overall responsibilities of BIM roles can be summarized as follows (Table 2.2).

Table 2.2 : Responsibilities according to BIM roles (Based on the information obtained from the guidelines).

BIM Roles	Responsibilities
BIM Manager	• Responsible for whole BIM process. • Coordinates all updates. • Developing, publishing and coordinating all protocols required during information integration. • To monitor the compliance of the parties to the BEP during the project.
BIM Coordinator (Design)	• Integration of all 3D models into a single model. • Clash detection control after integration • To define model analysis and responsible disciplines.
BIM Coordinator (Construction)	• To evaluate the model in terms of constructability and scheduling at all stages of the design. • Coordinating subcontractors. • Using the model for coordination and control during construction.
Discipline Leads	• Delivering the BIM model as clash-free. • Developing and managing model change methods. • Take responsibility for BIM of their own disciplines.

2.1.3 BIM-based CPM documents

It can be a great challenge to include a complex and innovative concept such as BIM in the construction process. Therefore, documents regulating the process can facilitate the integration of BIM. In this respect, one of the most important documents is the BIM Execution Plan (BEP). BEP contributes to the BIM integration process by identifying requirements at every stage of the project (Abdirad, 2015). Each stakeholder contributing to the project should prepare their own BEP (e.g. BEP for design, construction and facility management) (Siemens, 2017). It can also be created in two phases as pre-contract and post-contract to determine how the project will be carried out by the delivery team (Scheffer et al., 2018). Although the requirements for the content of BEP are not well defined as a standard in the literature, BEP should

essentially include details on the following issues (Eschenbruch and Bodden, 2018): data production, level of detail, milestones of the process, responsible groups and coordination actors. Besides, BEP has several core elements, namely (Lin et al., 2016): Strategy, process management, team establishment, collection and documentation of information, common model, and model usage. With these core factors, a successful BIM implementation can be done (Lin et al., 2016). Working on a common platform is very important as it can accelerate the transfer of information and reduce misunderstandings (Schapke et al., 2018). BIM guidelines for design and construction has focused on communication and working on a common platform during the BEP process (DCAMM, 2015). Nonetheless, there is not enough definition in the literature on the roles of the parties in the BEP on an organizational, asset and project basis (Ashworth et al., 2019).

Although it varies in name, a BEP, which describes the process and standards of BIM tasks, is mentioned in all guides (BBIM, BSI, CANBIM, COBIM, DASBIM, NATSPEC, NBGO, NBIM, PSUBIM, SBEnrcBIM, SBIM, USCBIM, USFBIM). These plans indicate the project-specific protocols (e.g. goals, software, contact list, exchange process, file format, model's status, etc.). All guides (BBIM, BSI, CANBIM, COBIM, DASBIM, NATSPEC, NBGO, NBIM, PSUBIM, SBEnrcBIM, SBIM, USCBIM, USFBIM) stated that the establishment of BEP in the early stages of the project is important to achieve BIM objectives. Moreover, some guides (BBIM, BSI, CANBIM, COBIM, NATSPEC, NBGO, SBIM) mention the need to update the BEP throughout the project stages and consider it as a live document. Nevertheless, the range of the defined execution plan differs according to the guidelines. Even though most guides (BBIM, CANBIM, DASBIM, NBGO, NBIM, PSUBIM, SBEnrcBIM, SBIM, USCBIM, USFBIM) mention a single BEP, BSI, NATSPEC, and COBIM suggested that the parties should create their own BEP and combine them. They (BSI, NATSPEC, and COBIM) stressed that when combining the plans, the technical standards of the teams, the skills and technological maturities of the team members should be checked through a certain qualification. BBIM emphasized that the new participating stakeholder should be informed about the process and sign a contract to accept BIM's needs and duties. Further, SBIM points out that it is necessary to go to the next stage after all conflicts are resolved to reduce or eliminate problems that may arise later in the process.

In addition to BEP, some guides (BSI, COBIM, NBIM, PSUBIM) emphasize various documents according to the stages of the project. These documents can be classified under 3 main headings, as (BSI ISO1, 2018) Organizational, asset, and project-based. BSI ISO 1 has attached importance to Organizational Information Requirements (OIR) and Project Information Requirements (PIR) for organizational decisions. OIR defines the high-level strategic goals of the organization and includes the strategic decisions of the organization, portfolio planning, regulatory tasks, and policies (BSI ISO1, 2018). PIR should be created to measure and monitor that organizational decisions are supported in a particular project (BSI ISO1, 2018). PSUBIM recommended that the organization should prepare a BIM Mission Statement for future BIM-related organizational decisions. The statement should describe why BIM is important to the organisation and how to use it (PSUBIM, 2019).

Following the determination of the organizational decisions, the documents containing the decisions and definitions of the asset management come (BSI, COBIM, NBIM, PSUBIM). BSI ISO 1 emphasizes Asset Information Requirements (AIR) and Asset Information Model (AIM). AIR determines the production methods and procedures as well as the managerial and commercial decisions regarding the asset (BSI ISO1, 2018). Further, AIM defines project-based responses of organizational decisions. NBIM recommends comparing the economic, environmental and social effects of asset alternatives to be produced by performing Multiple Site Assessment Analysis, considering the building life cycle. NBGO stresses the document titled Owner Project Requirements, which specifies the functional and operational requirements of the facility by the Owner.

The project information documents which describe the recommendations and obligations of the project come after the asset decisions come (BSI, COBIM, NATSPEC, NBGO, NBIM, PSUBIM). NBGO points out that with the document Basis of Design, client should indicate the design and facility approaches regarding the demands of the owner. Moreover, according to BSI ISO 1, Exchange Information Requirements (EIR) defines the information that is determined by the project owner and that the client must meet in the handover of the project, while the Project Information Model (PIM) determines the information requirements and procedures in the Project delivery phase. With the BIM Use Selection Worksheet, PSUBIM specifies in which phases all teams will undertake BIM tasks and BIM competency levels of

teams during project delivery. Additionally, NATSPEC refers to a template called "Project BIM brief". This document describes the BIM requirements of the employer in the project process.

Standard contracts and their documents

The use of BIM is becoming widespread throughout the world, especially in complex construction projects. According to the Australian Government Productivity Commission Report (2014), governments and the private sector need to work together and set up some standards and protocols to take full advantage of BIM. Nonetheless, it is very difficult to integrate BIM into the contract, which is one of the most important phases of the construction process, due to the high amount of information it contains and the fact that this information is used directly by the parties (Miller and Lessard, 2000). Standard contracts offer a solution to overcome this challenge (Abdirad, 2015). Although various BIM protocols and contracts have been developed, their real use is uncommon (Al-Shammari, 2014). Besides, today's standard contracts are inadequate in covering all legal risks since they are behind technological developments (Manderson et al., 2015).

The contractual relationships of the BIM model and the legal requirements of terms and conditions of contract have not yet been fully clarified (Chong et al. 2017). These uncertainties in BIM integration can lead to various problems regarding model rights, financial shares and data management (Manderson et al., 2015). According to a research on the legal risks of BIM in 2019, intellectual property, allocation of responsibilities, cost awards and interoperability were identified the most common causes of disputes, respectively (Arshad et al., 2019). Therefore, it is fundamental that the contract parties first decide on the ownership of the BIM model and then fairly allocate the rights and responsibilities of the teams throughout project process (Manderson et al., 2015). As with any industry, along with the digitization in construction projects, new concerns have started to emerge in the sharing and protection of digital data (Dougherty, 2015). Hence, it is crucial to protect the data against possible corruptions and losses and to prevent financial disputes that may arise accordingly (Manderson et al., 2015). Likewise, certain data generation, sharing and archiving standards should be determined to avoid interoperability problems among teams (Olatunji, 2016). Although many international researchers (Eastman et al., 2018; Arensman et al., 2012; Hsieh et al., 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 specific differences should be considered according to countries. The Table 2.3 shows the characteristics of international protocols and standard contracts used in the BIM integration process, which are examined within the scope of the dissertation.

Table 2.3 : Standard documents and their characteristics.

Documents	Characteristics
CIC BIM Protocol (2018)	• The CIC BIM Protocol obliges project participants to produce and present the information model in accordance with the requirements of BIM (McCombe, 2018). • CIC BIM Protocol can be added to any standard contract. It brings responsibilities to both employer and supplier through BIM (Wallbank, 2016).
NEC4 (2017)	• NEC4 requires the contractor to collaborate with other participants to realize the BEP (McCombe, 2018). • It provides additional provisions to support BIM and deals with the data ownership and responsibility of the parties (NEC4, 2017). • It is a single contract that allows multiple participants to unite under one contract (Bailey et al., 2017).
JCT (2016)	• JCT includes specific provisions on cooperation, sustainability and BIM (JCT, 2016). • JCT specifies the contractor's general obligations regarding to BIM (McCombe, 2018).
CDOC301 (2008-2015 Revised)	• By including this addendum in the contract, main stakeholders (owner, design specialist and contractor) accept all obligations and responsibilities for the project to reach the desired BIM level (Olsen and Taylor, 2010). • All project participants must do their best to implement the BEP (AGCA, 2015). • There is a checklist describing the model details, responsibilities and intended use (Olsen & Taylor, 2010).
AIA E203 (2013)	• AIA E203 is a supplementary document used as a contract framework in BIM-based projects (AIA, 2013). • This document gives architects various tasks related to digital data protocols such as preparation, management and maintenance (Dougherty, 2015) • It includes the level of development (LOD) concept, which is the level of detail of the model (AIA, 2013).
CIOB (2013)	• CIOB is the first standard contract to provide BIM provisions in accordance with its terms and annexes (Olsen & Taylor, 2010). • It is more suitable for high value and complex projects (CIOB, 2013).

The Joint Contracts Tribunal (JCT) document also has a 2019 edition. Since the 2019 edition could not be obtained, the 2016 edition was examined. Among the documents reviewed, AIA, CDOC and CIC are protocols published to regulate BIM integration into the project processes. These protocols indicate that they are not the main contract, but should be used as an addendum to the main contract with legal counselling. CIOB, JCT and NEC4, on the other hand, are international standard contracts created by different institutions, include provisions for BIM integration or refer to protocols.

The consistent and realistic distribution of risks and responsibilities in the contract stage may reduce the disputes that may occur during BIM integration (Dougherty, 2015). Standard contracts and protocols attach importance to allocation of risk and responsibility (Abdirad, 2015). According to the CIC and JCT, the employer should establish a completed protocol for the definition and sharing of responsibilities and ensure that it is integrated into all project agreements. AIA notes that the receiving party is responsible for the received data without or before accepting the protocol. CDOC states that each participant is responsible for the contribution to the common model, the information generated from this contribution, and the data generated by contractually lower tiers of the participants.

The definition of the person responsible for the management and control of the common BIM model or common data environment varies according to the documents (AIA, CIC, CDOC, CIOB) Unless otherwise specified in the contract, according to AIA, the architect is responsible for the management of the common model, while CIC indicates that the employer or his/her representative is responsible. CDOC states that the BIM manager should be appointed by the owner to manage the common BIM model. CIOB assigns responsibility to the data security manager, which is specifically defined for tasks such as management of the common data environment, file transfer protocol and BIM protocols. AIA, CIC and CIOB agree that the model element authors are responsible for any conflict that will arise in the common model and they are responsible for evaluating and resolving the conflict. CDOC recommends having an insurance for losses that may occur due to conflicts and disputes, covering BIM manager services, professional services for designer and constructor and data security.

The documents contain various provisions for the protection of the ownership rights and intellectual properties of the parties. AIA and CIC state that the written consent of the data producing party is mandatory for the use and modification of digital data.

CDOC and CIC emphasize that the participant cannot be held responsible for any damage caused by the unauthorized data usage and modification. Regarding the sharing of data, AIA, CDOC and CIC specify that the receiving party can only share the data with its own employees and consultants for the relevant construction work, and not with a third party. In addition, AIA and CIC indicate that the ownership rights of information are not granted by the transmission of the digital data. According to the CDOC, in collaborative works, no participant can claim greater ownership rights than the contribution of his/her own, since the participants of collaborative works are not co-author or co-owner. Conversely, NEC4 states that the data generated by the sub-contractor in the information model belongs to the contractor and the data produced by the contractor belongs to the owner. According to CIOB, parties are responsible for storing confidential data such as design works, rates and prices produced in the project. This obligation continues for 3 years from the completion or termination of the project (CIOB, 2013).

Regulations and rules regarding interoperability can be specified in the contract to maintain the collaborative environment, which is one of the most important benefits of BIM (Dougherty, 2015). AIA states that project participants are responsible for establishing a protocol for the management and maintenance of a created centralized electronic documents management system. The created protocol must include at least the communication protocol and meeting schedules for collaborative utilization (AIA E203, 2013). According to JCT and CIOB, the protocol should indicate the procedures for the models that the participants are obliged to produce at certain stages of the project, in accordance with the information requirements. CIC and CIOB emphasize that the documents should be shared in specific software and native format to avoid problems in usage of the data during the project process. In addition, according to CDOC, all shop models, fabrication models and 2D drawings must be removed from the 3D common model to avoid any discrepancies in information exchange between stakeholders. Likewise, the contact information of the authorized users should be determined to control the changes and revisions in the common model (CDOC301, 2015). NEC4 recommends that the contractor and the project manager warn each other in a situation that adversely affects the creation or use of the information model.

Only half of the standard contracts and protocols that have been examined (AIA, CDOC and CIOB) have specified provisions regarding documentation and data

security. AIA emphasizes that when creating a centralized electronic document management system, requirements should be taken into consideration, such as initial training, storage and archiving requirements. According to the CDOC, common platform should be established by determining the authorities of participants for viewing, editing and deleting information depending on the degree of responsibility of the participants. Moreover, procedures should be established for updating and archiving the information, and backup and restoration of the common model (CDOC301, 2015). Additionally, CIOB specifies the establishment of the file transfer protocol in the designated security rules for uploading, downloading and accessing via unknown servers.

2.2 Contractual Aspects of the BIM-based CPM

One of the most important concerns about the integration of BIM-based projects into contracts is the legal aspects associated with this integration (Dougherty, 2015). A construction project's primary task is to complete the construction work in compliance with the contract requirements, but inadequate contract management may lead to conflicts (Islam and Trigunarsyah, 2017). Therefore, contractual arrangements covering BIM goals and deliverables have been repeatedly defined as a challenge, locally and internationally (Kuiper and Dominik, 2013). To overcome this challenge, effective contract management with written provisions is vital to regulate legal concerns and to implement necessary procedures (Fan et al., 2019). Essentially, contract management directs the effort of the teams through agreements both at the organizational and project levels (COBIM, 2011). BIM, however, has changed construction planning due to its collaborative environment (Arshad et al., 2019). Consequently, these new emerging services, responsibilities and legal issues need to be defined (Abdirad, 2015). BIM is incompatible with traditional documents prepared for the participants' relations, and due to lack of experience in BIM, there is no common contract strategy and law (Eschenbruch and Bodden, 2018).

As with all contracts, it is important for all parties to clearly understand their roles and responsibilities, and also to define a responsible BIM manager for all BIM tasks such as creation, implementation, and use (Howard and Ciliberto, 2016). From a contractual point of view, it is necessary to pay particular attention to the technical, industrial and practical standards required for the use of BIM when preparing an addendum or master

contract (Kuiper and Dominik, 2013). From the owner's perspective, the agreement should include at least BIM goals, success criteria, and hierarchies of the participants (Howard and Ciliberto, 2016). In addition, the creation of contractual arrangements that promote the collaborative working environment, which defines the regulations regarding the information processing and management of the participants, contributes to the management of the BIM model and reduces the problems caused by the participants' deficiencies and errors (Liu et al., 2013). It can be beneficial to establish the BEP that includes the checklist and guidelines required for the successful implementation of BIM (Chong et al., 2017). In common practice, however, BEP is not usually created as part of the contract (Hardin and McCool, 2015). Conversely, for the successful integration of BIM projects, the definitions and processes of BIM tasks and the BIM model must be included in the contract as legally binding agreements (Borrmann et al., 2018). After defining the liabilities and obligations of the participants, the standard of care should be specified, in which the tasks required to be fulfilled by the participants according to their titles or assignments (Chong et al., 2017).

BIM has brought along various concerns related to both the technology itself and the way that technology is used (Ashcraft, 2008). In this aspect, BIM technology may have issues about model accuracy, management, maintenance, ownerships of informations, and collaboration of parties (Sardroud et al., 2018). Nevertheless, using BIM as a collaborative tool to improve project quality is incompatible with risk allocations in traditional contracts (Pandey et al., 2016). The lack of interoperability between different software systems, and various legal barriers to collaborative BIM processes, affects BIM adaptation (Succar, 2010). Additionally, it should be considered that who will be responsible for the accuracy and risks of data shared among stakeholders throughout the project life cycle (Ghaffarianhoseini et al., 2017). Moreover, the legal protection of copyrights of the information can assure the designers as well as improve the quality of the project (Manderson et al., 2015).

According to Kupier and Dominik (2013), Potential risks and required legal regulations can be determined by analysing BIM implementation commercially. Likewise, it can be seen that the legal concerns that come with BIM are not inherently new, but should be considered from a different perspective (Kuiper and Dominik, 2013). From this point of view, the use of BIM planning technologies, which seems to

be a risky venture, can be promoted with fit-for-purpose construction contracts (Eschenbruch and Bodden, 2018). On the one hand, Porwal and Hewage (2013) stated that BIM Partnering Procurement Agreements are one of the most effective solutions to prevent contractual and legal problems that can arise in BIM integration. This structure supports the collaborative environment of BIM, improves participants' adaptation to new processes and facilitates the compliance of BIM with governmental standards (Barakeh and Almarri, 2017). Eschenbruch and Bodden (2018), on the other hand, emphasized that BIM can also be integrated into traditional contracts when the obligations arising from multiple contracts and different hierarchy levels are properly divided.

2.2.1 Claims and disputes in the construction projects

Construction projects have a complex structure consisting of many participants. This complexity has increased further due to developments in technology and changing demands. Claims are more likely to occur with increasing size and complexity of projects (Mishmish and El-Sayegh 2016). The claim, which is defined as an extra time or cost request, may turn into a dispute if it is not resolved in a compromising manner (Jervis and Levin, 1988). Disputes in construction projects are increasing and they affect the sector negatively in various ways (NBS, 2013). According to the research, from 2010 to 2015, the global average cost of disputes increased from 35.1 million to 46 million US Dollars, and the global average resolution time of disputes expanded from 9.1 months to 15.5 months (Arcadis, 2016). In the Report of National Research Council, annual transactional costs of disputes in construction projects vary between 4 billion and 12 billion USD (NRC, 2009). As can be seen in the reports (NRC, 2009) and as stated by Shahhosseini and Hajarolasvadi (2018), the disputes experienced in construction projects cause cost overruns by wasting project resources. Moreover, the resolution processes of disputes delay the implementation of the project, causing timeouts or even the project being suspended in the pessimistic scenarios (Acharya et al., 2006). Consequently, construction projects can be realized on time and at the estimated cost, as long as disputes arising in the project process are minimized or eliminated (Dougherty, 2015).

In the process of implementing complex construction projects, disputes seem to be inevitable due to cost, expectation and goal-related problems among the participants.

(Charehzehi et al., 2017). These problematic issues can trigger disputes, thus damaging the project process and causing costly lawsuits (Cheung and Yiu, 2006). In a study conducted in 2016, the following are identified as the most common causes of disputes in construction projects globally (Arcadis, 2016): problematic contract management, unfair risk allocation and inaccurate contract documents. These issues may also be the most important points to be considered to prevent disputes (Arcadis, 2016). Unlike many approaches that can be implemented after the dispute occurs, proper management of conflicts at their initial stages can resolve the dispute with minimal time and money loss (Charehzehi et al., 2017).

The relationships between the participants (Responsibilities, obligations, compensatory payments and risk allocation) in the construction projects are mostly determined through contracts (Stamatiou et al., 2019). Nevertheless, construction contracts generally have a long and complex structure, hence claims and disputes can arise from the contract terms (Shahhosseini and Hajarolasvadi, 2018). Although there are provisions on specific issues, contracts cannot be sufficiently comprehensive due to different limitations (Stamatiou et al., 2019). When one of the parties thinks that their contractual rights are not met, they can submit a claim to make a monetary or time coverage (Semple et al., 1994). Shahhosseini and Hajarolasvadi (2018) stated that once a claim is submitted, the evaluation process begins according to the terms and conditions of the contract. Evaluation of claims is a time-consuming process since it is necessary to compare the information of the proponent party with the terms of the contract based on the comprehensive and strict rules (Shahhosseini and Hajarolasvadi, 2018).

The widespread use of BIM in the CI brought new concerns over claims and disputes (Dougherty, 2015). The multi-participatory and common environment of BIM can affect the existing legal and contractual status by mixing the relationships between the participants (Gibbs et al., 2017). Although BIM brings technological innovations to the industry, there are relatively few studies on conflict management intended to minimize disputes in BIM-based constructions (Charehzehi et al., 2017).

Causes of disputes in the construction projects

The CI is constantly getting complicated both in terms of construction techniques and stakeholders (Papadonikolaki et al., 2019). Especially in large projects, many

stakeholders from different regions may participate in the project. Consequently, the contract, which determines the relationships between stakeholders, becomes increasingly more important (Stamatiou et al., 2019). Most of the current construction contracts can lead to claims and disputes between stakeholders due to unpredictable and uncertain factors (Abdul-Malak and Abdulhai, 2017). In order to survive in the highly competitive market, contractors have to bid on risky projects with minimal profit, hence smooth implementation of the project is compromised (Bakhary et al., 2017). Moreover, as a characteristic of the CI, verbal instructions and improperly archived information can often lead to claims (Bakhary et al. 2015). Despite measurements and arrangements, it is almost impossible to avoid disputes in complex projects, disputes can only be minimized (Haugen and Singh, 2015). Arcadis the Global Construction Disputes Report (2019) identified the top three of the causes of construction disputes in 2018 as follows:

- Stakeholders whose contractual obligations are not understood and/or met,
- Improper contract documents, and
- Poor contract management.

As seen in the report (Arcadis, 2019), the common cause of disputes in the CI is contractual-related issues. Additionally, there are some other important causes for disputes. Liu et al. (2013) stated that most of the problems and disputes arise from the organizational interface. For this reason, they suggested that a total information structure should be created to ensure the availability, accessibility and reliability of the information (Liu et al., 2013). Gardezi et al. (2013) emphasized cost/financial issues and timely decision-making problems as the causes for client-related disputes. Furthermore, contractor-related reasons include non-realistic construction scheduling and poor construction management (Charehzehi et al., 2017). Moreover, variations during construction process, change of scope and payment delays caused by the owner lead to disputes (Çakmak and Irlayıcı Çakmak, 2014). The most common disputes experienced by countries stated in the Table 2.4 are consistent with the literature.

Table 2.4 : The most common disputes experienced by countries.

Country	The Most Common Disputes
Australia	Variations to the scope, Interpretation of scope (Waldron, 2006).
Canada	Delays, Scheduling, Variations to the scope (Semple et al., 1994).
China	Payment delay, Variation orders, Time extension, Quality of works (Chan and Suen, 2005).
Ghana	Payment Delay, Poor communication (Narh et al., 2015).
Norway	Payments, Low priced contracts, Variations (Sabrı et al., 2019).
Pakistan	Payment Delay, Poor communication, Differing site conditions, Lack of funds (Khahro and Ali, 2014).
Saudi Arabia	Variations, Variations in quantities, Delays, Design errors or omissions, Inconsistent drawings (Assaf et al., 2018).
Thailand	Inconsistent drawings, Contract violation (Ayudhya, 2011).
Turkey	Variations, Instructions of the employer, Inadequate/incomplete technical and contractual documentation (Ilter, 2012). Unit prices, Time extension, Contractual matters, Variations, Contract documents, Payments (Irlayıcı Çakmak, 2016). Contract documents (Çevikbaş and Köksal, 2018).
USA	Design errors or omissions (Diekmann and Nelson, 1985).

As can be seen in the Table 2.4, most of the disputes arising in the CI are contract-related issues. Other common causes are the problems regarding construction management and payments. Whatever the cause, stakeholders should always be claim-aware and identify the claim before it turns into conflict for a successful claim management (Bakhary et al., 2017). It is crucial that contract management, stakeholder management and documentation are carried out effectively to reduce the disputes that can arise in the project (Hayati et al., 2019). If dispute has become inevitable, the best solution is to solve it effectively with minimal impact on projects and stakeholders (Parikh et al., 2019).

BIM requires a number of stakeholders, such as architects, engineers, contractors, and related supply chain members, to work in harmony to transform the data into a 3D virtual model (Papadonikolaki et al., 2019). Due to the fact that traditional construction

contracts are mostly bilateral documents, various legal problems may arise during this collaborative operation (SBEnrcBIM, 2017). According to Ussing et al. (2016), legal uncertainties during project process may cause stakeholders to turn to traditional methods. Consequently, BIM may not be efficiently integrated into the project by stakeholders and it may result in failure to achieve BIM goals (Ussing et al., 2016). Legal issues related to BIM are mainly ownership of the model, risk allocation, intellectual properties and interoperability between the stakeholders (Jo et al., 2018). Additionally, responsibility of the used data, responsibility of quantities, clash detection, professional reliability and third parties related to BIM can cause the legal problems (Ussing et al., 2016). Although BIM is equipped with various tools for documentation, unclassified and/or non-prioritized documents are also important causes of conflict (Charehzehi et al., 2017).

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

Although conflicts are likely to occur in large and complex projects, minimizing the quantities of disputes is important for efficient and effective implementation of the project (Abdul-Malak and Abdulhai, 2017). With the integration of BIM into the project, both the increase in the number of stakeholders and digital data can pose various risks (Liu et al., 2017). With the collaborative and communication assisted structure of BIM, disputes that may occur during the project process can be prevented (Ghaffarianhoseini et al., 2017). Conversely, due to some deficiencies in the contract phase, various disputes can occur in the BIM-based construction projects (Dougherty, 2015). Preparation of an effective and comprehensive contract may reduce disputes (Sardroud et al., 2018). The causes of disputes occurring in the life cycle of BIM-based projects can be categorized under four main headings (Arensman and Ozbek, 2012; Ashcraft, 2008; Ashworth et al.,2019; Dougherty, 2015; Huzaimi Abd Jamil and Fathi, 2019; Kuiper and Dominik, 2013): Allocation of risks and responsibilities, IPR, interoperability, data security and documentation.

2.2.2.1 Allocation of risks and responsibilities

Contracts are legal tools that determine the scope of a work, methods, responsibilities and obligations (Kuiper and Dominik, 2013). BIM-based contracts should consider equality between parties like any other contracts (Semple et al., 1994). The current legal system based on the concept of distinct responsibility, so each party should know

what they are responsible for (Arensman and Ozbek, 2012). The collaborative and integrated system of BIM, however, mixes the levels of responsibility among different stakeholders (Azhar et al., 2012). Further, Schapke et al. (2018) stated that in paper-based traditional systems, responsible parties can be identified through the latest stamp or signature of documents. Nevertheless, it is more difficult to determine who is responsible for the BIM-based system that requires simultaneous operation on the integrated model (Schapke et al., 2018). Disputes are likely to occur if the responsibilities specified in the contract are incompatible with the relationships between teams in the BIM project process. Furthermore, the risks should be distributed to the parties relatively to their ability to control the risk in order to effectively implement the project with minimum conflict and dispute (Ashcraft, 2008). Conversely, it is common for disputes related to risk allocation to occur, since contractors set a contract price without making a risk assessment of the project (Hsu et al., 2015). In addition, contractors may be taking a risk by keeping their bid prices as low as possible to compete in the construction market (Bakhary et al., 2017). According to Oviedo-Haito et al. (2014), general contractors transfer this risk to contractors through contracts, but subcontractors usually do not have sufficient resources to manage these risks, and the accomplishment of the project is compromised. It should be noted that in the case of suspension or termination of the project, there is a risk that none of the parties can get their expected benefits (Oviedo-Haito et al., 2014).

BIM-based projects have several unique risks due to their collaborative nature. Manderson et al. (2015) stated that one of these risks is the use of the digital model produced by the architect as a base for construction. This requires the architect to be precise when creating the model (Manderson et al., 2015). Another risk factor is that the BIM model is open to intervention on a common platform (Huzaimi Abd Jamil and Fathi, 2019). Thus, defective productions prepared by the project participants may be considered as accurate (Dougherty, 2015). Additionally, when collecting or extracting data from the BIM model, erroneous information can be transferred unintentionally, therefore, additional measures should be taken to the existing standard contract (Greenwood et al., 2010).

In BIM-based projects, the fair and clear allocation of risk and responsibilities in a contractual manner can protect the motivation of the participants by reducing the risk

of emergence of the conflicts and disputes that can occur throughout the process (Manderson et al., 2015). According to Eschenbruch and Bodden (2018), there are two approaches in this regard. First, the integration of BIM in the project does not change the individual responsibilities, so each participant is responsible for their own contributions (Eschenbruch and Bodden, 2018). Second, arranging limitations on liabilities to merge as many participants as possible, thereby distributing risks and responsibilities to large groups with reduced interfaces (Eschenbruch and Bodden, 2018). Furthermore, to address concerns about BIM responsibilities and obligations, Azhar et al. (2012) recommend creating additional forms or protocols that will make the main contract convenient to BIM to protect teams that are directly or indirectly affected by the BIM system. In some cases, although the contract is clear and appropriate, the owner may hire a BIM manager to reduce the responsibility-related risks from BIM tasks (Hsu et al., 2015). In this case, the BIM manager should control and monitor the accuracy of the data, model access and coordination of the parties (Azhar et al., 2011).

2.2.2.2 Intellectual property rights

Due to the collaborative nature of BIM, it is possible for many stakeholders to generate, share and change the data on the same model or platform (Charehzehi et al., 2017). According to Solihin and Eastman (2015), this collaborative environment means exposure and sharing of valuable data for stakeholders themselves. Therefore, IPR is one of the most important issues of BIM implementation due to the documents open to extracting, sharing and copying (Solihin and Eastman, 2015). IPR generally includes ownership rights, patents, copyrights, trademarks and design rights (Hsu et al., 2015). Traditionally, designers want to protect the rights of their designs (Eadie et al., 2015). Similarly, since the owner also wants to have the model for later use during the operation, it can create conflicts for the ownership of the model and the data produced (Arensman & Ozbek, 2012). The protection of intellectual property on a platform that is accessible to all participants is important for company secrets and confidential information (Keeley, 2017). In addition, it is necessary to protect the IPR of design and data to maintain the confidence of the designer throughout the process (Manderson et al., 2015). It is necessary to pay considerable attention to construction materials and techniques, file format and data in the integrated system, private information and trade secrets to determine the information that will constitute IP in the

model (McAdam, 2010). According to the AIA E202 (2008), ownership rights of the digital data are not conveyed with the transmission of the data. Ownership rights are determined by the governing agreements (AIA, 2008). Similarly; using, modifying and transmitting of the received data is limited (AIA, 2013). According to Hsu et al. (2015), the following factors should be considered when determining these limitations:

- Whether the intended use is commercial or educational,
- The essence of the work subject to copyright,
- The amount and importance of the used part of the copyrighted work,
- The value of the copyrighted work and its impact on the market.

If there is a special condition related to ownership, it should be specified in the contract so that the conditions of the usage right will be determined (Ashcraft, 2008). In some cases, contradiction may occur if the BIM protocol defines IPR in more detail and inclusive than the main contract (Udom, 2012). Consequently, the IPR of the model and embedded data in the integrated or combined system must be defined and compromised in any event that can arise to reduce the disputes (Kuiper and Dominik, 2013). Moreover, it should be determined contractually whether the model is part of the contract or is a project tool and/or deliverable (McAdam, 2010). Although the IPR of the parties are protected by the contract, the status of the produced information should be determined in case of early termination of the contract (Hsu et al., 2015). From the owner's perspective, in such a case, the produced data during the project life cycle must be unrestrictedly accessible to effective implementation of the project (Eschenbruch and Bodden, 2018). Some contractual measures should be taken for effective and efficient management of the facility after the accomplishment of the project (Eschenbruch and Bodden, 2018). Therefore, information that is changed or transferred during the project construction phase should be secured contractually within the scope of facility management (Eschenbruch and Bodden, 2018).

2.2.2.3 Interoperability

According to Samuelson and Björk (2014), one of the most important benefits of BIM especially in large and complex projects is that it enables collaborative design. Several stakeholders need to work together in cooperation to use this advantage (Ghaffarianhoseini et al., 2017). Stakeholders such as owner, architect, engineer,

contractor, outsourcing service provider and consultants need to be managed properly for an effective collaborative environment (Dougherty, 2015). Compatible information systems are important to exchange information between various actors and can be used for the integration of the design and construction phase (Dulaimi et al., 2002). BIM software provides a better understanding of the concept of design with light and shadow analysis over the 3D model and improves communication between teams (Ashcraft, 2008). Furthermore, BIM tools that can run with the 3D model simplify cost estimations for quantity surveyors and contractors (Azhar, 2011). While structural elements traditionally overlapping each other can only be detected during construction or afterward, different interdisciplinary overlap problems can be simulated through the combined model and design flaws can be eliminated (Li et al., 2017). For effective and proper interoperability in BIM-based projects, standards should be established for producing, changing and sharing the information (Eastman et al., 2010). Industry Foundation Classes (IFC) data exchange standards produced by buildingSMART have been developed to allow full collaboration among users of BIM tools (Hietanen, 2006).

According to Kenley et al. (2016), the transformation of 2D CAD drawings into object-based integrated 3D models with BIM, although advantageous, has brought some problems. The development of the CI at a slow pace compared to digital transformation and not reaching sufficient capacity may be the main cause of these problems (Kenley et al., 2016). BIM aims to provide data flow to all project participants from a common platform, therefore it requires significant coordination at IT level in terms of planning and control (Rahman et al. 2016). Data exchanges via different software for specific design goals can become a challenge for project stakeholders (Bynum et al. 2013). The model elements or information must be in the same software language to avoid incompatibility problems during the merging process (Ashcraft, 2008). Additionally, the data files in the multi-purpose unified model are larger and more comprehensive than individual models of disciplines, which can adversely affect data transfer processes (Lai et al., 2019). Nevertheless, the issues of communication and direct data exchange between the parties without the use of manual tools or data converters have not yet been fully resolved (Samuelson and Björk 2014).

The measures to be taken to prevent problems based on model-based interoperability can vary according to the size of the project organization and the complexity of the project (Dougherty, 2015). Digital provisions can be taken for concerns about

interoperability, such as communication of software at import/export of data and the up-to-date/compatibility versions of software (McAdam, 2010). Since the project process is a highly interactive and non-stationary process, it is important for the project management that the 3D common model is on a platform that can be controlled, marked and interpreted (Lai et al., 2019). In summary, according to Schapke et al. (2018), the following sections should be noted for a collaborative environment that can enable effective interoperability:

- Communication and cooperation between participants with contractual relationship,
- When to integrate synchronously generated information,
- Who is responsible for the produced information and access/usage rights,
- Procedures for updating or changing information,
- The process of approving and publishing information.

Furthermore, the procedures for the distribution, sharing and documenting of the generated data must be specified in the governing agreement (Siemens, 2017). By specifying the procedures and restrictions clearly in the contract, conflicts and disputes that may arise during the interoperability process can be reduced (Ussing et al., 2016).

2.2.2.4 Data security and documentation

Due to the inovative nature of BIM, the digitalization of traditional hardcopy documents has affected the BIM implementation process (Charehzehi et al., 2017). With BIM Level 2, instead of paper documents, project stakeholders are expected to digitally generate and share information, and the 3D unified model is mandatory (Gibbs et al., 2015). Digital documents can be transmitted and reproduced at much less cost and effort than paper documents (Eschenbruch and Bodden, 2018). The main problems of digital information transformation are ownership and data security issues of BIM deliverables (Solihin and Eastman, 2015). Olatunji (2011) stated that unlike traditional methods, BIM-based projects contain a large amount of digital information. This information is required to be protected against losses, corruption or even theft (Olatunji, 2011).

Although the software industry is developed, they are not secure enough (Sardroud et al., 2018). Besides the external risks, there can be various distortions due to the fact

that the information is electronic (Eschenbruch and Bodden, 2018). The accessibility of electronic data by all stakeholders, raises concerns about unauthorized online access and ownership violations (Chien et al., 2014). According to Dougherty (2015), in case of software or data error, most of the risks that will occur will be compensated by the owner. Most of the time, however, as the problems are human-caused, the party who made the mistake undertakes the responsibility (Dougherty, 2015). Project stakeholders may need to be informed of the potential risks of any changes in the data, as the information is kept in a transparent common platform (Mosey, 2014). Alternatively, the rights to use and transmit data can only be granted to the required degree for the construction practice (Eschenbruch and Bodden, 2018). Data with limited access and modification can also reduce construction errors by reducing disorganised information (Schapke et al., 2018). Provisions can be made in the contract for data transfer and security to reduce the confidential concerns of the participants who will be involved in the project (Eschenbruch and Bodden, 2018). Furthermore, insurance can be a solution to reduce financial losses from data security breaches (Manderson et al., 2015). Finally, contractual standards on data security and access control can minimize the risk of transferring important data to unauthorized parties (Eschenbruch and Bodden, 2018).

2.2.3 Critical points of BIM-based CPM

Within the scope of this dissertation, international standard contracts and protocols, and international guidelines are analysed to determine the critical points of BIM-based construction project management. In total, 6 international standard contracts (AIA E203, CDOC301, CIC BIM, CIOB, JCT, NEC4) and protocols, 13 international guidelines (BBIM, BSI, CANBIM, COBIM, DASBIM, NATSPEC, NBGO, NBIM, PSUBIM, SBEnrcBIM, SBIM, USCBIM, USFBIM) and 36 articles were examined. In these reviewed articles and documents, there are imperatives, recommendations and warnings for the critical points. As a result of the examination, 49 critical points have been identified. The critical points of BIM based CPM are shown in Table 2.5. In the Table 2.5, documents that strongly mention the critical points are shown in dark gray, and weakly mentioned documents in light gray.

Table 2.5 : The critical points of BIM-based CPM.

Critical Points	Standard Contracts and Protocols						International 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 (2017)	NATSPEC (2016)	BBIM (2015)	DASBIM (2015)	CANBIM (2014)	SBIM (2013)	NBIM (2013)	COBIM (2012)	USCBIM (2012)	
BIM Execution Plan	■	■	■	■			■	■	■	■	■	■		■		■		■	■	(Abdirad,2015; Chong et al., 2017; Eschenbruch and Bodden, 2018; Lin et al., 2016)
Sustainability Analysis							■	■	■	■		■	■	■	■	■	■	■	■	
Time and Cost Analysis						■	■	■	■	■	■	■	■	■	■	■	■	■	■	(Azhar et al., 2012)
Pre-Qualifications							■	■				■			■			■		(Oviedo-Haito et al. 2014)
BIM Process Responsible	■	■	■	■	■	■	■	■		■	■	■	■		■	■	■	■	■	(Borrmann et al., 2018; Holzer, 2016; Hsu et al., 2015)
BIM Discipline Responsible									■					■						(Azhar et al., 2011; Borrmann et al., 2018)
BIM Consultant							■	■					■						■	(Tulke and Schumann, 2018; Ussing et al., 2016)
Protocol for Obligations	■	■	■	■	■	■	■	■		■	■	■	■		■	■		■		(Arensman and Ozbek, 2012; Ussing et al., 2016)
BIM Requirements of Owner							■	■		■		■	■		■	■		■	■	(Howard and Ciliberto, 2016)
BIM Requirements of Other Parties								■		■			■			■		■	■	
BIM Requirements Through Project Stages			■			■	■	■		■	■	■	■		■	■		■		(Abdirad,2015; Kuiper and Dominik, 2013)
BIM Deliverables Through Project Stages			■			■	■	■		■	■	■	■		■	■		■		(Kuiper and Dominik, 2013; Lin et al., 2016; Papadonikolaki et al., 2019)
Definition of BIM Roles and Responsibilities	■	■		■	■	■	■	■	■	■	■	■	■	■		■		■	■	(Arensman and Ozbek, 2012; Bosch-Sijtsema et al., 2017; Ussing et al., 2016)
Definition of BIM Tasks							■	■	■	■	■	■	■	■	■	■	■	■	■	(Abdirad, 2015; Borrmann et al., 2018; Bosch-Sijtsema et al., 2017)
Contractual Status of Model					■	■		■	■			■	■		■	■				(Azhar et al., 2012; Borrmann et al., 2018; McAdam, 2010)
Contractual Status of Protocols	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	(Azhar et al., 2011; Hardin and McCool, 2015; BESA, 2017)
As-Built Model Procedures								■								■	■	■		
Organization-related Decisions							■	■									■	■		(Ashworth et al., 2019)
Asset-related Decisions								■									■	■		(Ashworth et al., 2019)
Project-related Decisions							■	■	■	■	■	■	■	■	■	■	■	■	■	(Ashworth et al., 2019)
Confidentiality of Information	■			■	■	■	■	■		■	■	■	■		■	■		■		(Arshad et al., 2019; Manderson et al., 2015)
Protocol for Information			■	■	■	■	■	■	■	■		■	■		■		■	■	■	(Charehzehi et al., 2017; Dougherty, 2015; Eschenbruch and Bodden, 2018; Ghaffarianhoseini et al., 2017)
Authority to Share	■			■	■	■	■	■	■	■		■	■	■	■		■	■	■	(Charehzehi et al., 2017; Eastman et al., 2010; Solihin and Eastman, 2015)
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)
Electronic Stamps															■		■			

Critical Points	Standard Contracts and Protocols						International 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 (2017)	NATSPEC (2016)	BBIM (2015)	DASBIM (2015)	CANBIM (2014)	SBIM (2013)	NBIM (2013)	COBIM (2012)	USCBIM (2012)	
Authority to Change	■			■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	(Charehzehi et al., 2017; Schapke et al., 2018; Solihin and Eastman, 2015)
Native Data Format	■					■		■							■					(Bynum et al. 2013)
Software	■			■		■	■	■	■	■	■	■	■	■	■	■	■	■	■	(Bynum et al. 2013; McAdam, 2010; Succar, 2010)
Modes of Collaboration					■		■	■				■	■		■	■	■	■		
Clash Detection					■		■	■	■	■	■	■	■	■	■	■	■	■	■	(Li et al., 2017; Ussing et al., 2016)
Change Order Procedures				■		■	■	■	■	■	■	■		■	■	■		■	■	
Level of Development					■		■	■	■	■	■	■	■	■	■	■	■	■	■	(Ashcraft, 2008; Lin et al., 2016)
Contact List of Authorized Users				■			■	■	■		■	■	■	■		■		■	■	
Extracting 2D Drawings From 3D Model				■					■					■	■					
BIM Meetings					■		■	■	■	■		■	■	■	■	■		■	■	
Centralized File System		■			■		■	■	■	■	■	■	■		■		■	■	■	(Mosey, 2014)
Encrypted Filing				■										■						
Data Insurance				■																(Manderson et al., 2015)
Authority to Access	■			■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	(Charehzehi et al., 2017; Schapke et al., 2018; Solihin and Eastman, 2015)
Digital Data Storage					■		■	■		■		■	■		■	■	■			(Lai et al., 2019)
Digital Data Archiving					■		■	■	■	■		■	■		■		■	■	■	(Bakhary et al. 2015)
Access from Unknown Server						■														(Chien et al., 2014)
Back-up Procedures				■																(Olatunji, 2011)
Restore Procedures				■																
Data Security for Loss, Corruption and Virus				■		■	■	■		■		■	■		■	■		■		(Chien et al., 2014; Dougherty., 2015; Eschenbruch and Bodden, 2018)
Maintenance Manuals							■	■	■	■	■							■	■	
Handing Over of Model							■	■	■	■	■	■	■			■	■	■	■	(Eschenbruch and Bodden, 2018)

As can be seen in the Table 2.5, CDOC301 BIM Addendum is the most comprehensive document covering 20 critical points in standard contracts and protocols. CIOB and AIA E203 are documents following CDOC with close numbers. Conversely, NEC4 and JCT have been identified as documents covering relatively less critical points. Details of the documents have been given in Table 2.6.

Table 2.6 : Contents of standard contracts and protocols.

Standard contracts and protocols	The number of critical points covered
CDOC301 (2015)	20
AIA E203 (2013)	18
CIOB (2013)	18
CIC BIM (2018)	13
JCT (2016)	7
NEC4 (2017)	7

As shown in Table 2.6, 2 ISO and 6 PAS documents belonging to BSI Standards Publications are the most comprehensive documents among the international guidelines examined by referring to 40 critical points. DASBIM is in the last place compared to the others as it covers 11 critical points. Details of the documents have been provided in Table 2.7.

Table 2.7 : Contents of international BIM guidelines.

International BIM guidelines	The number of critical points covered
BSI (2018)	40
COBIM (2012)	33
CANBIM (2014)	31
NBGO (2017)	31
NATSPEC (2016)	30
PSUBIM (2019)	30
BBIM (2015)	27
SBIM (2013)	25
USCBIM (2012)	23
USFBIM (2018)	22
NBIM (2013)	19
SBEnrcBIM (2017)	16
DASBIM (2015)	11

While 12 critical points in Table 2.5 are covered by many documents and articles, 11 critical points are mentioned by very few sources. The critical points covered by the vast majority of documents, and by minority of sources are shown in Table 2.8.

Table 2.8 : The critical points covered by majority and minority of the documents.

Covered by Majority	Covered by Minority
BIM Execution Plan	Pre-Qualifications
BIM Process Responsible	BIM Consultant
Protocol for Obligations	As-Built Model Procedures
Definition of BIM Roles and Responsibilities	Organization-related Decisions
Contractual Status of Protocols	Asset-related Decisions
Confidentiality of Information	Term of Usage Letter
Protocol for Information	Electronic Stamps
Authority to Share	Extracting 2D Drawings From 3D Model
Copyrights of Produced Data	Encrypted Filing
Authority to Change	Data Insurance
Software	Access from Unknown Server
Authority to Access	Back-up Procedures
	Restore Procedures

The critical points covered in most of the standard contracts and protocols are also frequently covered in the international guidelines examined. There are, however, some critical points emphasized by guidelines, which have not been fully addressed by contracts and protocols. These critical points have been shown in Table 2.9.

Table 2.9 : The critical points emphasized by international guidelines.

Critical Points
Sustainability Analysis
Time and Cost Analysis
BIM Requirements Through Project Stages
BIM Deliverables Through Project Stages
Definition of BIM Tasks
Modes of Collaboration
Clash Detection
Change Order Procedures
Level of Development
BIM Meetings
Centralized File System
Digital Data Storage
Digital Data Archiving
Data Security for Loss, Corruption and Virus
Handing Over of Model

3. RESEARCH METHODS

The aim of the research is to improve the contract preparation phase of the BIM-based construction projects through a preliminary checklist template proposal which can be considered as a potential input in the contract preparation phase of these projects. (Table 1.1). With this aim, the objectives of this research are as follows:

- **Objective 1:** To review the BIM guidelines, standard contracts and protocols.
- **Objective 2:** To determine the critical aspects and issues to be considered in the BIM-based construction contracts.
- **Objective 3:** To propose a preliminary checklist template which can be considered as a potential input in the contract preparation phase of the BIM-based construction projects.

To achieve these objectives, first, a comprehensive literature review has been carried out. In the literature review section, 13 BIM guidelines (BBIM, BSI, CANBIM, COBIM, DASBIM, NATSPEC, NBGO, NBIM, PSUBIM, SBEnrcBIM, SBIM, USCBIM, USFBIM) from different countries and institutions have been examined and compared. Guidelines have been selected based on their content, level of detail, and the latest version. In addition, 6 international standard (AIA E203, CDOC301, CIC BIM, CIOB, JCT, NEC4) have been examined and compared. Standard documents have been selected based on their content, level of detail, and the latest version.

Following the literature review, litigation awards and case laws involving BIM-related disputes in construction projects have been examined through local and international databases. The Lexis-Nexis database, which includes case laws from 13 countries worldwide, and the Kazancı database, which includes case laws from Turkey have been investigated. Moreover, interviews were conducted. Within the scope of these interviews, professionals having expertise and experience in BIM projects have been interviewed. Furthermore, an online questionnaire has been applied to professionals experienced in BIM-based projects. These sample has been accessed online via

LinkedIn and e-mail. Finally, the preliminary checklist template proposal was esthablished and a verification study was carried out with the second stage interviews. The flowchart diagram of the research carried out within the scope of this dissertation is shown in Figure 3.1.

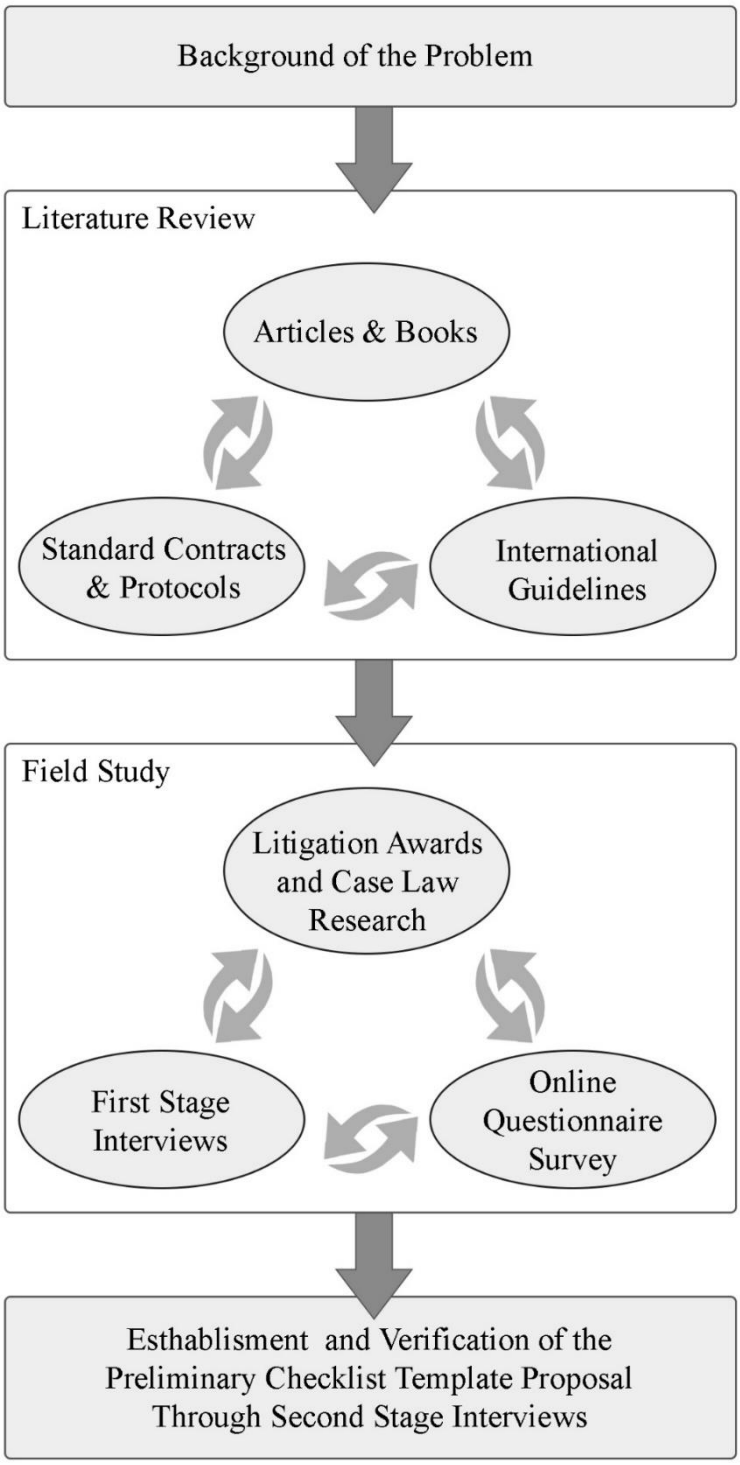

Figure 3.1 : Flowchart diagram of the research.

3.1 Litigation Awards and Case Law Research

Within the scope of this dissertation, case laws containing BIM-related disputes emerging in construction projects have been investigated via local and international databases. The Lexis-Nexis database, which includes case laws from 13 countries worldwide, and the Kazancı database, which includes litigation awards from Turkey have been examined. The research has been carried out by searching BIM and Building information modelling keywords, and their Turkish versions. Among the search results, those related to BIM and BIM processes have been selected.

3.2 First Stage Interviews

Interviews were conducted with 5 professionals to achieve the objectives (Table 1.1). Interview questions have been prepared based on the information obtained from the literature review in line with the objectives of the study. Interviews have been performed with 5 professionals actively using BIM technology. All participants are from different companies and head or authorized persons in their department. 2 of the participants are architects and 3 of them are civil engineers. The participants have been coded with letters as shown in Table 3.1. to ensure the confidentiality of the participants.

Table 3.1 : Interviewed professionals (First Stage).

Code	Profession	Experience	BIM Experience	Role in the Project
A	Architect	20 Years	10 Years	BIM Designer and consultant on the design party
B	Architect	16 Years	7 Years	BIM Manager and chief designer on the design party
C	Civil Engineer	26 Years	13 Years	BIM Director at the employer party
D	Civil Engineer	8 Years	6 Years	BIM Coordinator on the engineering party
E	Civil Engineer	25 Years	10 Years	Founding partner of the engineering firm

Interviews were conducted with the participants by asking open-ended questions about the process and asking them to interpret the scale questions. While making face-to-face interviews with professionals, notes have been taken with their permission. Each interview took approximately 45 minutes on average. Summarized findings obtained from the notes have been provided under the "4.2 Data obtained through first stage interviews" subheading. The interview consists of the introductory part with personal information and 15 questions. Interview questions have been provided in the Appendix. In question 1, the reasons for the preference of BIM integration into the project, level of BIM used, and the results of this integration have been asked. In question 2, the BIM integration process has been asked. In question 3, the level of detail used in the project has been asked. In question 4, problems and recommendations regarding the supply chain during the BIM integration process have been asked. In question 5, the difficulties experienced in the integration of BIM into the contract, the protocols used, and the recommendations have been asked. In Question 6, participants have been asked to evaluate Turkish and international standard contracts in terms of compliance with BIM. In question 7, BIM's innovations, difficulties, and contractual recommendations have been asked for various headings at the pre-construction, construction, and post-construction stages of the project. In question 8, how the BIM-based project management can affect the performance of various titles has been asked in the Likert scale. In question 9, the appropriateness of BIM integration according to the type of project has been asked in the Likert scale. In question 10, the main issues to be considered when preparing the contract in BIM-based projects have been asked. In question 11, the points to be considered while preparing various BIM Documents have been asked. In the 12^{th} and 13^{th} questions, interviewees have been asked in which areas the contracts made in BIM-based projects can reduce and increase the disputes respectively. In question 14, the participants have been asked about the skills that contract managers in BIM-based projects should have. Finally, in question 15, the participants have been asked about other issues they wanted to address.

3.3 Online Questionnaire Survey

Following the interviews, an online questionnaire survey has been conducted to meet the objectives (Table 1.1). The questionnaire has been corrected and finalized according to the feedbacks of the pilot survey before being sent to the participants. The online questionnaire survey has been provided in the Appendix. This online questionnaire survey has been conducted via LinkedIn and e-mails to professionals who are actively involved in the industry and whose job titles are BIM Manager, BIM Specialist, BIM Consultant, BIM Engineer, BIM Architect, BIM Modeller, BIM Director, and BIM Coordinator. An online questionnaire has been sent to 433 people and 69 people returned. The online survey form was open for 6 months on www.veti.itu.edu.tr.

The survey questions have been prepared in line with the objectives according to the literature review, litigation awards and case law rearch, and interviews. The online questionnaire survey consists of 6 sections and 16 questions. In the first section, the first 4 questions have asked about the professions of the participants, the duration of their professional experience, the duration of the BIM experience, and their roles in the project. In question 5, the relationship between standard contracts and BIM integration has been asked on the Likert scale. In question 6, the level of difficulties in various phases and topics during BIM integration has been asked in the Likert scale. In question 7 in the second section, the performance effectiveness of BIM-based project management according to various headings has been asked in the Likert scale. In question 8 in the third section, the challenges that the participants faced in various headings during BIM integration have been asked. In question 9 in the fourth section, their recommendations for the same headings have been asked. In question 10 in the fifth section, the points to be considered while preparing various BIM documents have been asked. In question 11 in the sixth section, the appropriateness of BIM integration according to the type of project has been asked in the Likert scale. In question 12, the main issues to be considered when preparing the contract in BIM-based projects have been asked. In the 13^{th} and 14^{th} questions, respondents have been asked in which areas the contracts made in BIM-based projects can reduce and increase the disputes respectively. In question 15, the participants have been asked about the skills that contract managers in BIM-based projects should have. Finally, in question 16, the most serious problem faced by the participants during their experiences and how they came

over have been asked. The answers given by the participants to the open-ended survey questions have been first grouped according to the related topics, and then ranked according to the frequency of the participants who have provided the same statements.

3.4 Second Stage Interviews

Second stage interviews have been performed to further improve and verify the preliminary checklist template proposal. These interviews have been carried out with 10 professionals working on BIM and specialized in BIM. 7 participants are civil engineers whereas 3 participants are architects and all professionals work in different companies. The created preliminary checklist template proposal has been interpreted by professionals in terms of design, clarity and content. Following the interviews, the preliminary checklist templete proposal has been updated and verified. Information of the participants is shown in Table 3.2.

Table 3.2 : Interviewed professionals (Second Stage).

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

As second stage interviews could not be held face-to-face due to the pandemic period, and they were performed through online meetings. Online meetings took an average of 45 minutes. The responses given by the participants were first grouped according to the related topics, and then ranked according to the frequency of the participants who stated the same statements and emphasised the same topics.

4. RESULTS

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 (US), United Kingdom (UK) and Canada. In Turkey, however, no litigation awards have been found containing BIM-related disputes. The case laws found in the research conducted in the Lexis-Nexis database are shown in Table 4.1.

Table 4.1 : Case laws containing BIM-related disputes.

Country / Year	Case No	Parties (Plaintiff / Defendant)	Core Terms
US / 2019	88641	Subcontractor / Main Contractor	Failure to provide BIM model to subcontractor by Main Contractor
Canada / 2019	O.J. No. 1284	Owner / Main Contractor	(Ownership of the model) Delay and design deficiency caused by the main contractor blocking the owner's access to the model.
Canada / 2019	S.J. No. 254	Main Contractor / Subcontractor	Financial dispute between main contractor and subcontractor arising from improper distribution of responsibilities and failure to control change orders.
US / 2018	131299	BIM Consultant / Main Contractor	Financial dispute between BIM consultant and main contractor
UK / 2017	HT-2017-000164	Main Contractor / Subcontractor	IPR & Ownership of the model
US / 2017	1267	Subcontractor / Main Contractor	Conflict of model definition, Scope of work
US / 2017	70779	Main Contractor / Subcontractor	IPR
US / 2017	4320	Subcontractor / Main Contractor	Dispute due to delay in adaptation of the main contractor to BIM.

Country / Year	Case No	Parties (Plaintiff / Defendant)	Core Terms
US / 2017	171299	BIM Support Firm / Main Contractor	Financial dispute between BIM support firm and main contractor
US / 2017	7805	Subcontractor / Main Contractor	Financial dispute between the subcontractor and the main contractor arising from the as-built drawings
US / 2015	125136	Subcontractor / Main Contractor	Difference between 2D drawings and 3D model, Clash detection caused by not including subcontractors in the BIM process.
Canada / 2014	O.I.P.C. No. 179	Tender Participant / University serving as an expert	IPR & Ownership of the model

Considering international case laws and researches in the literature, it is seen that the main causes of disputes in BIM-based constructions are contractual problems. To summarize, dispute causes can be categorized under four main headings (Arensman and Ozbek, 2012; Ashcraft, 2008; Ashworth et al.,2019; Dougherty, 2015; Huzaimi Abd Jamil and Fathi, 2019; Kuiper and Dominik, 2013):

- Allocation of time/financial risks and responsibilities that will arise during the project process,
- IPR regarding ownership and use right of the model and data produced,
- Interoperability problems of traditional and new participants emerging with BIM while working in a collaborative environment,
- Data security and documentation covering the updating, omissions, errors, cyber security and archiving issues related to digital data in BIM,

Comparison of the cases found by case law research with the critical points of BIM-based CPM (Table 2.5) according to their core terms is shown in Table 4.2. The critical points causing disputes in the cases are shown in gray in Table 4.2.

Table 4.2 : Critical points in case laws.

Critical Points	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)
Pre-Qualifications										■		
BIM Consultant		■				■						
Protocol for Obligations	■									■		
BIM Requirements of Owner			■									
BIM Requirements Through Project Stages	■				■							
BIM Deliverables Through Project Stages	■				■							
Definition of BIM Roles and Responsibilities	■									■		
As-Built Model Procedures							■					
Confidentiality of Information				■					■		■	■
Authority to Share											■	
Ownership of Model				■					■		■	■
Copyrights of Produced Data				■					■		■	■
Authority to Change											■	
Clash Detection								■				
Change Order Procedures										■		
Extracting 2D Drawings From 3D Model								■				
Authority to Access											■	

When Table 4.2 is analysed, critical points such as pre-qualification (BSI, CANBIM, COBIM, NATSPEC and PSUBIM), BIM consultant (BSI, BBIM, PSUBIM and USCBIM), as-built model procedures (BSI, COBIM, NBIM and SBIM) and extracting 2D drawings form 3D model (CANBIM, CDOC and USFBIM) mentioned in the minority of documents in Table 2.8 were encountered in case laws. Additionally, critical points such as BIM requirements and deliverables through project stages (BBIM, BSI, CANBIM, CDOC, CIOB, COBIM, NATSPEC, NBGO, PSUBIM, SBEnrcBIM, SBIM), clash detection (AIA, BBIM, BSI, CANBIM, COBIM, DASBIM, NATSPEC, NBGO, NBIM, PSUBIM, SBEnrcBIM, SBIM, USCBIM, USFBIM) and change order procedures , highlighted (AIA, BSI, CANBIM, CDOC, CIOB, COBIM, DASBIM, NATSPEC, NBGO, PSUBIM, SBEnrcBIM, SBIM, USCBIM, USFBIM) by international guidelines, have been identified in case laws.

4.2 Data Obtained Through First Stage Interviews

In this part of the study, the results of the interviews with 5 people actively working on BIM-based projects to investigate their experiences. Participants A and B have integrated BIM into the project to make the project easier due to the complex structures of the projects. Participant C also integrated BIM into the contract at the request of the employer to increase interdisciplinary communication. As the participant D is on the engineering side of the same project, they are included in the BIM processes as an engineering company. Participant E is the founding partner of the engineering firm and is doing his PhD on dispute resolution boards. While BIM was integrated into the projects, a document was not used directly, it was adapted from various standard documents (BSI PAS, FIDIC and PSUBIM) and a project-specific contract was created. The answers given by the participants to the questions about the projects and the legal aspects of BIM are given below.

The results of the first part of interview questions, where personal information of professionals are answered, are given in Table 3.1. For the interview questions, Person A answered the questions regarding an airport project, Person B answered regarding a TV&Radio tower complex, and Person C and Person D answered regarding a metro project. Finally, participant E answered on the basis of his experience and expertise.

Question 1 - The reasons for the preference of BIM integration into the project, BIM level of the project, and the results:

A: As a company, we chose BIM since we tried to make integrated designs in every project.

B: The employer did not request a BIM, we insisted. We said that due to the complex structure of the project, it cannot be done without BIM. BIM somehow got involved in the project, but not in the specification. Along with our design team, static, electrical and facade teams are also included in the BIM model. Our expectation was to include all disciplines, but there was 60 percent participation. Telecommunications and fire parties could take place more actively.

C: We chose BIM to manage the project easily and correctly. In addition to time, quality and cost, we preferred BIM to deal with workplace safety. We thought that BIM would provide us advantages at implementing the contract more accurately. Moreover, BIM reduced uncertainties before the bidding in terms of both owner and

contractor. BIM was particularly helpful in explaining design concepts to decision-makers (employer, manager). During construction, we used various software to check the current construction status. With laser technology, we have scanned the constructed works and tested their accuracy with the project.

D: The major reason we do the project with BIM is BIM in its technical specifications and contract. We have determined the level in line with the specific requirements in the technical specification according to the disciplines. The reason for choosing BIM in the project is to make project coordination better, to resolve conflicts digitally, and thus to provide cost benefit to the contractor.

E: In order to minimize the organization and coordination problems that arise in the project process in the national and international level in general.

Question 2 - The BIM integration process:

A: Over the years, we have provided integration within the team with trainings. We have never used 2D programs, we have been trying to deploy the BIM system from the very beginning. We observe construction progress in the field through point cloud and make as-built model and compare it.

B: We could not create a BEP for this project, but we carried out the process thanks to our team's know-how. Further, we received BIM consultancy in the context of relations with other teams in the project.

C: At first, we had a lot of trouble because the companies were reluctant to integrating BIM. They mentioned the lack of trained staff but later they adapted to BIM easily.

D: We created an inclusive BEP considering the stakeholders in accordance with the technical specifications.

Question 3 - The level of detail of the project:

A: We used levels that vary according to need. We usually use the LOD 300-350 level.

B: We used LOD ranging from 200 to 300 depending on the needs.

C: We haven't determined a level like this from the beginning of the process. The level was then self-determined according to project requirements which is more important.

D: No LOD was specified in the technical specification, instead discipline-based requirements were specified.

Question 4 - Problems and recommendations regarding the supply chain during the BIM integration process:

A: We did not have any problems in terms of supply chain, but on the contrary, our work got easier. First, we modelled the product we wanted, then sent it to the suppliers and received a price accordingly. Thus, we did not experience any price changes or product changes during the project process.

B: Unfortunately, the supply chain could not be included in the process as BIM was not integrated into the project contract. Manufacturers were already unconscious about BIM.

C: We wanted the 3-D models of the products from the suppliers we worked with, and they provided it somehow. We tested these models in our BIM model. It was a very difficult request for them at first, but they got used to it.

D: While the designer and engineer can easily integrate to BIM, the supplier at the production stage has difficulty in adapting. Especially in Turkey, we have difficulty in finding suppliers that can be integrated and could open the BIM model.

E: Supply chain cannot be integrated effectively and efficiently as the construction industry focuses more on the design phase of the project.

Question 5 - The difficulties experienced in the integration of BIM into the contract, the protocols they use, and the recommendations:

A: We use FIDIC Short Form of Contract and define Swiss law, since it is more understandable and protective especially in international projects. We add the articles we want about design or construction to this contract. But contractors and employers in Turkey do not accept the FIDIC contracts because they do not want to evenly distribute the responsibilities and risks.

B: Unfortunately, in the project, BIM could not be integrated into the contract, but in my experience, BIM integrated contracts are very undefined. There should be protocols that can be customized for the project, otherwise, missing or excessive requirements can be defined.

C: We didn't use any protocol directly, but we were inspired by some specifications, especially from BSI PAS documents. We adopted our specification according to Turkey’s condition.

D: In fact, the administration has more problems, they want to put BIM in specifications, but they don't know how to add it. They look to the international guidelines on this issue but can lead to incompatibilities in Turkey. First, the guidelines can be adapted to Turkey by translate. We are preparing our own BEP by adapting PSUBIM.

E: I do not think Turkish standard contracts are incompatible with BIM. If BIM is to be used in the real sense, however, it should be stated in the contract that BIM's input and outputs are legally binding and the parties agree to this.

Question 6 - Evaluation of Turkish and international standard contracts in terms of compliance with BIM:

A: International agreements may be appropriate to BIM integration, but contracts in Turkey is not compatible with BIM. There are no standard definitions for intermediate processes. Therefore, contractors can often put all responsibilities on subcontractors. Subcontractors are delaying works and losing money because they cannot manage risk, which actually increases project costs. I have never seen that the completed construction price and the tender price announced are the same, project is always completed with more costs. Contracts in Turkey based on the strong/weak side logic, therefore incompatible with the operation of BIM.

B: I think that the tender conditions should be updated in public tenders, and I realize that the authorities are also aware of this issue.

C: We could not find any standard contract in Turkey. We have examined international agreements, and we have prepared a specification according to Turkey's conditions. We pioneered other cities in a sense, and now we saw that they used our specifications. In addition, companies have gained knowledge.

D: Unfortunately, Turkey doesn't have a contract that meets the uncertain definition of responsibilities due to the collaborative environment of BIM.

E: I do not think Turkish standard contracts are incompatible with BIM. However, if BIM is to be used in the real sense, it should be stated in the contract that BIM's input and outputs are legally binding and the parties agree to this.

Question 7 - BIM's innovations, difficulties, and contractual recommendations:

A: There are points in BIM that need to be redefined for intellectual property. In models shared between teams, there is a risk of accidentally violating the IPR of another team. Some employers do not want to work as BIM's collaborative structure transparently shares information between all teams.

The site schedule produced over the BIM model can be used to ensure that the two teams making their production at the same time do not overlap. You can decide who is right by checking the model in the dispute.

In terms of contract, we have defined some additional terms in FIDIC. For instance, we will receive a construction work on the model first, then shop drawing models will be approved, then an as built model will be made. We have created a rating system to reduce the mistakes and omissions made by the teams. For some construction applications that may be dangerous for health and safety at work, we process the relevant information and follow up on the model in the related phase.

B: Since you think in 3D with BIM, it helps to detect the mistakes made during construction in advance. I hope that 2D submissions will be removed soon and we will not have to print out. In the pre-construction phase, we have had difficulties in communicating with employers who do not know the BIM system. As a suggestion, I think there should be a representative of the employer's team who knows the BIM system. Also, the versions of the programs to be used, the working methods, the change order procedures must be included in the BEP and of course the contract.

I am trying to establish a team with professionals who can keep up with this system while starting the project. Intellectual property is very undefined within the BIM system. There are cases when the ownership rights of BIM files differ according to the level of detail. Data protection is a big problem because all information about the project needs to be protected in one place. While unspecified parts benefit some teams in traditional projects, the transparent structure of BIM changes these relationships. Overlapping construction practices have been significantly reduced because the facade of the project was very important and other teams had to follow the BIM model. In the post-construction phase, since the operation and maintenance teams did not have a model demand, we did not transfer the model to them. In fact, we would like to include them in the BIM process.

C: At the pre-construction stage, to ensure the use of BIM by adding an additional clause in the tender specifications. This clause is “Contractor shall ensure interdisciplinary coordination in all the projects and deliver it to the employer with a 3D model in accordance with the work program.” We have prepared a detailed specification of BIM. We have identified the program and documentation processes to be used in this specification. We define a BIM manager in the specifications but could not find one in Turkey. Since the concept of Intellectual Property is not developed enough in Turkey, we did not experience any problem in this regard. We have added a clause to the specification that no data can be shared or distributed without permission. The 3D model and information provided by BIM were useful in the understanding of the situation and resolving disputes.

At the construction phase, we could not provide many benefits related to interoperability because the concept of BIM is not understood by subcontractors in Turkey. Nevertheless, we have increased communication by identifying all delivery formats and software to be used. Using the BIM 360 program, we have provided a collaborative environment for all team members to work together. BIM was particularly useful in clash detection and provided us the opportunity to take measures, therefore, minimizes the variation orders.

At the post-construction phase, we have included the operator in the whole construction process, and we will transfer all of our knowledge to them after the end of construction.

D: We had some concerns to be able to adapt to the technical specification. The working structure of our design team has changed. Interdisciplinary coordination became important, so we held BIM meetings at regular intervals. Thanks to the meetings, the quality of the construction has increased. Responsibility definitions gained more importance. With the 3D model, storage, archiving and protection have become important due to the increasing data sizes. We offered to store in cloud systems but the employer did not accept.

Since the communication between the design and construction team has increased, the accuracy and quality of the construction has increased. It was also very useful in clash detection. 3D model has been very useful in optimization studies. Viewing, assigning and controlling change orders has become easier with BIM.

E: In the Preconstruction phase, I think that investors did not pay enough attention to the design dimension of BIM before the construction of the project started. BIM must be understood by all stakeholders and exercises of information sharing must be done. Sufficient time and cost should be given to this stage. Arrangements for intellectual property and dispute resolution must be made at the contract stage. Information access, use and sharing of stakeholders should be authorized regarding data security. I think the benefits of BIM will be seen in the construction phase if the planning and arrangements are well done in the previous stages.

Question 8 - Effects of BIM-based project management on project performance:

A: I think BIM-based project management will increase the performance of all given headings.

B: BIM based project management strongly enhances the performance of all titles. However, it is necessary to regulate the viewing, accessing, sharing and interpreting permissions of the information for intellectual property. If the produced data is shared with certain protocols, it also increases the performance of data security.

D: I think it does not affect performance in tender and contract phases and in data usage, dispute resolution and occupational health and safety. In terms of intellectual property, I think it reduces performance due to new risks. It improves performance in other titles.

E: BIM does not affect IP, interoperability, risk management, and health and safety performances. It definitely strongly improves other headings.

Question 9 - The appropriateness of BIM integration according to the type of project:

A: BIM is strongly suitable for all project types, and I think projects should not be made without using BIM anymore.

B: BIM is strongly suitable for complex, large-scale and infrastructure projects. Small projects will also be strongly suitable, with some costs related to BIM system reduced in the future. Other projects are also suitable for BIM integration.

D: I think, BIM is not strongly suitable for small-scale and infrastructure projects due to the limits on costs and software, still it is strongly suitable for other project types.

E: BIM is not suitable for small scale projects and neither suitable nor not suitable for national projects. It varies according to the project size in infrasutructure and public projects. BIM is strongly suitable in other project types.

Question 10 - The main issues to be considered when preparing the contract in BIM-based projects:

A: Firstly, an appropriate BEP should be prepared, the processes and the scope should be well defined, then it is very important that the requirements of the BIM model and the responsible people are determined and specified in the contract.

B: A comprehensive BEP should be prepared and included in the contract. BEP should include, programs to be used, LOD levels according to disciplines, data usage and sharing rights, and allocation of responsibilities.

D: Responsibilities and rights of stakeholders and disciplines should be well defined.

E: It is necessary to divide it into two as design contract and construction contract. The design contract is much more important, it is necessary to create standard contracts. For construction contracts, the BIM implementation system and procedures should be added to the contract, and the contractual status of BIM deliverables should be determined.

Question 11 - The points to be considered while preparing various BIM Documents:

A: While preparing the BEP, the design and construction must be clearly defined. With the proper preparation of the BEP, the cost, time and quality requirements of the project can be determined more realistically.

D: It is necessary to prepare the BEP for each project made with BIM. In addition, stakeholders need to know that BEP is a living document and see it as a reference book. In addition, every stakeholder should be included in the process of forming the BEP, such as supplier, subcontractor, infrastructure, mechanic and electricity team.

Question 12 - Issues where contracts in BIM-based projects will reduce disputes:

A: In addition, with the integration of BIM, preventing future problems by measuring the competency of suppliers, reducing overlapping construction practices.

E: In large and complex projects involving many participants, BIM reduces disputes if implemented correctly.

Question 13 - Issues where contracts in BIM-based projects will increase disputes:

A: Reducing the cost of the subcontractors by optimizing their work may cause the main contractors to think that they have given too much money, thus causing disputes.

B: I do not think that there is an issue where BIM increases disputes compared to other projects not done with BIM.

E: In large and complex projects involving many participants, BIM increases disputes if implemented incorrectly.

Question 14 - Skills that contract managers in BIM-based projects should have:

A: He/she must have full knowledge of the project's BEP, BIM processes, and tools.

B: The contract manager is a very important position of the project in a legal sense. First of all, a good manager should know about national and international law. He/she should be able to think multiple and know each stage of the building from the pre-design phase to demolish more or less. The contract manager should allocate the rights and responsibilities of every stakeholder involved in this process fairly.

D: The contract manager of our design team is consult me as a BIM coordinator, on issues related to BIM. Generally, the contract manager must look at the duties of each discipline and specify it in the contract.

E: Since BIM cannot be correctly matched by professionals, its orientation needs to be done effectively. Contract managers from all parties should be involved in the BIM process. The contract manager needs to know BIM very well, monitor and use them.

Question 15 - Other issues they wanted to address:

D: The inclusion of the supply chain in the BIM system.

4.3 Data Obtained Through Questionnaire Survey

In this part of the dissertation, the results of the online questionnaire survey are proivded. 69 professionals experienced or having expertise in BIM-based projects have answers the questionnaire. As a result of the Reliability analysis (Cronbach's Alpha Test), the alpha value of Q5, Q6 and Q11 asked in accordance with the 5-point Likert scale is 0.749, and it is acceptable according to the reliability test. Moreover, the alpha value of Q7 asked in accordance with the 3-point Likert scale is 0.825, and

it is good according to the reliability test. Other questions in the online questionnaire survey are open-ended.

Question 1 - Professions of the participants:

The professions of the 69 participants are shown in Figure 4.1 according to the number of answers.

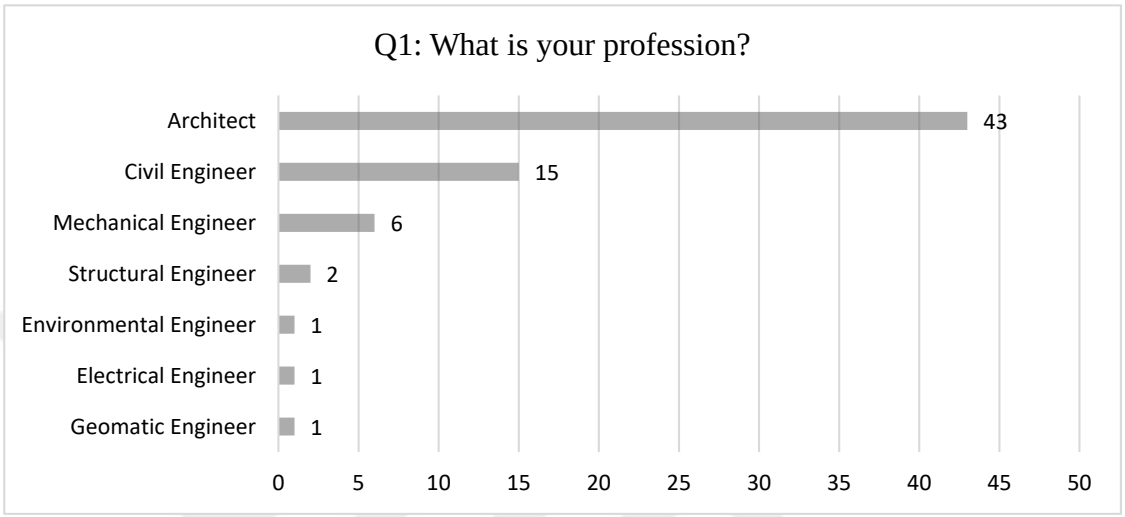

Figure 4.1 : Professions of the participants.

Question 2 - Roles of the participants in the project:

The roles of the 69 participants in the project are shown in Figure 4.2. There is a note under question 2 that "If you are not working on a specific project, please indicate your area of expertise".

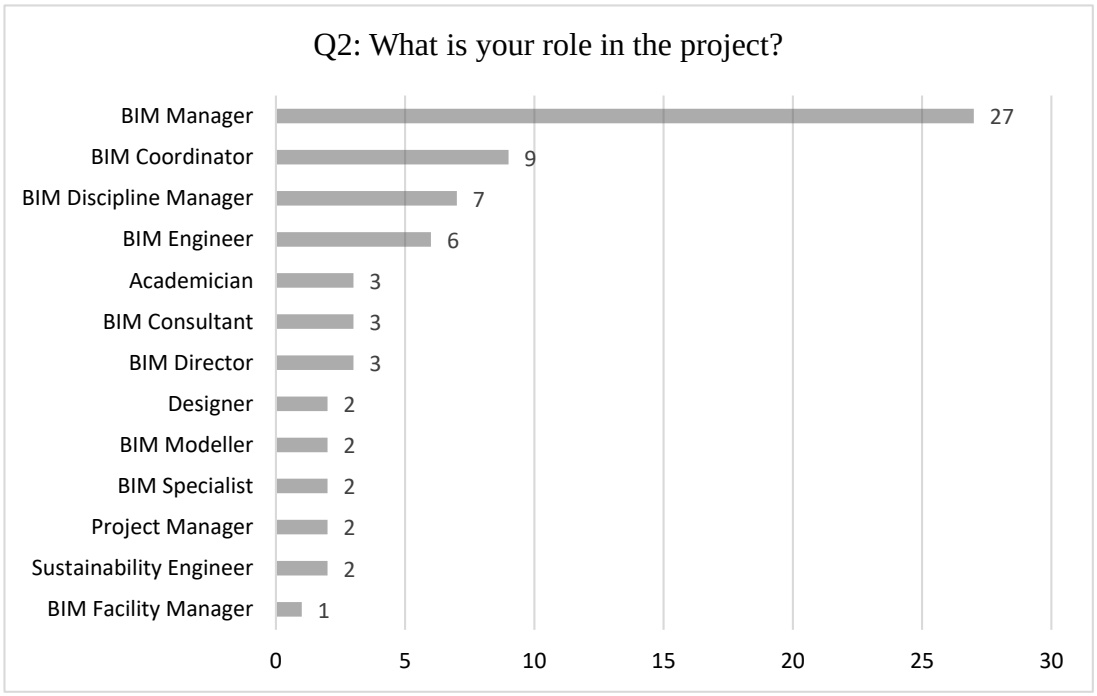

Figure 4.2 : Roles of the participants in the project.

Question 3 - The professional experience of the participants:

The professional experiences of 69 participants are shown in Figure 4.3.

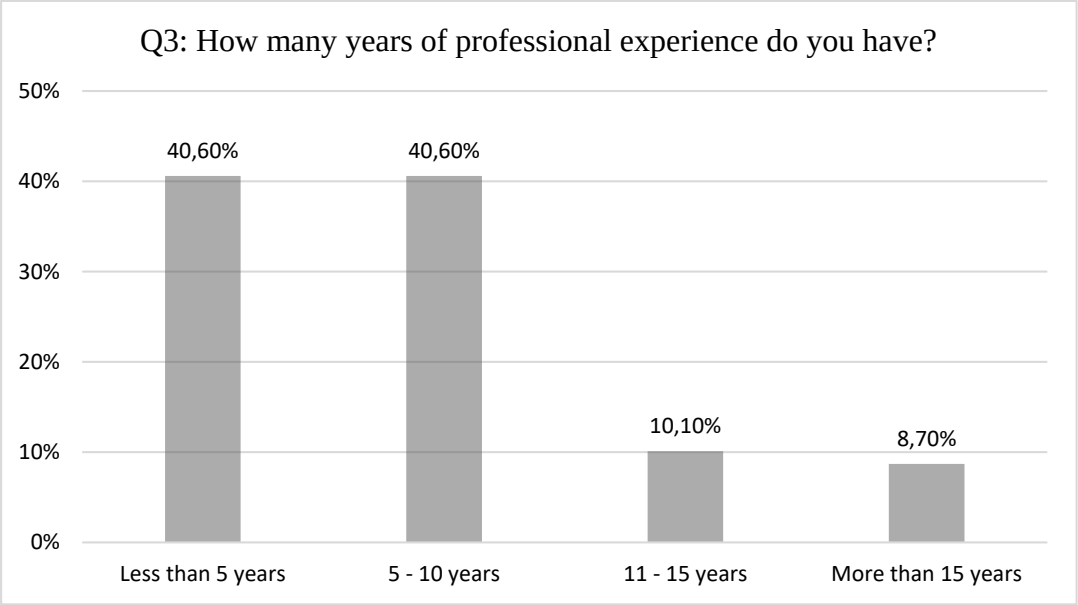

Figure 4.3 : The professional experience of the participants.

Question 4 - The BIM experience of the participants:

The BIM experiences of 69 participants are shown in Figure 4.4.

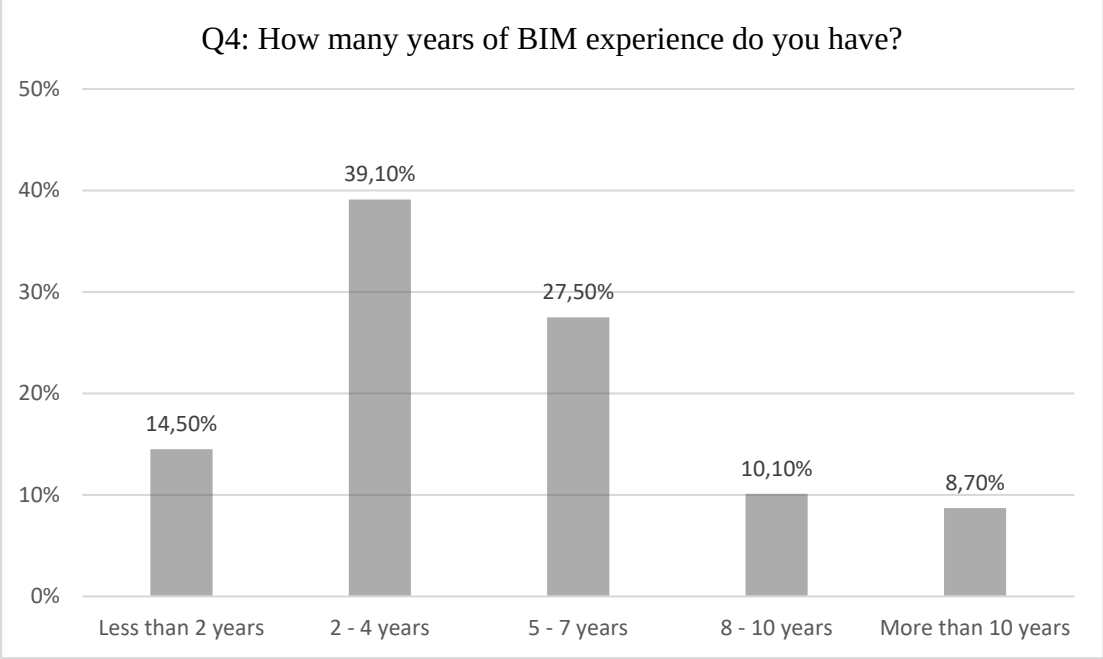

Figure 4.4 : The BIM experience of the participants.

Question 5 - The relationship between standard contracts and BIM integration:

The mean values of the answers provided by the participants are shown in Figure 4.5.

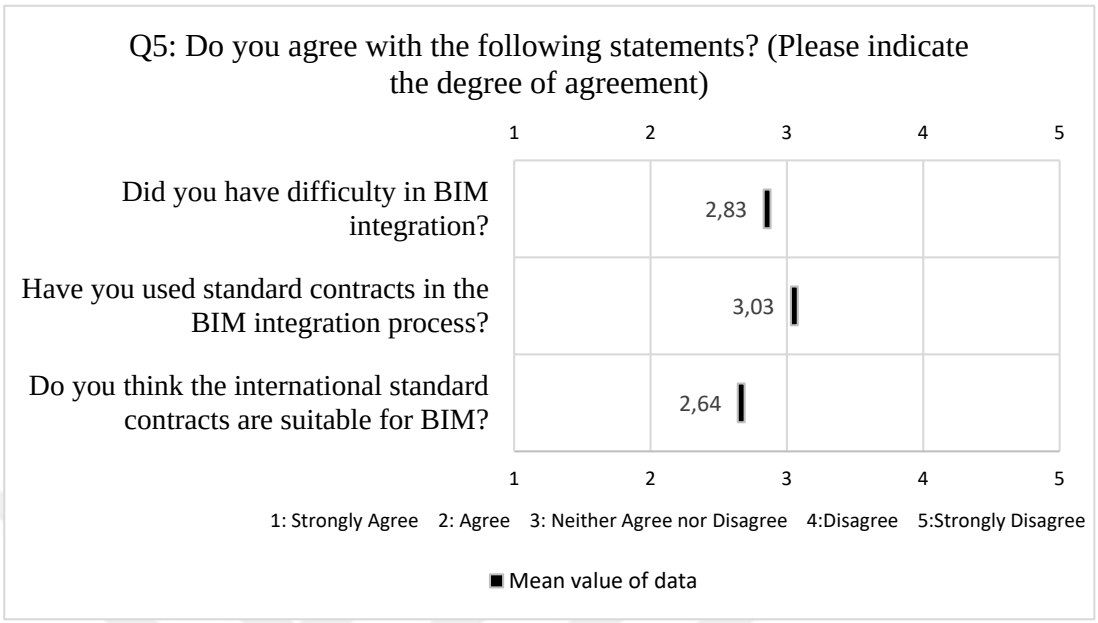

Figure 4.5 : The relationship between standard contracts and BIM integration.

Question 6 - The level of difficulties during BIM integration:

The mean values of answers given by participants to the difficulties experienced during BIM integration for various topics are shown in Figure 4.6.

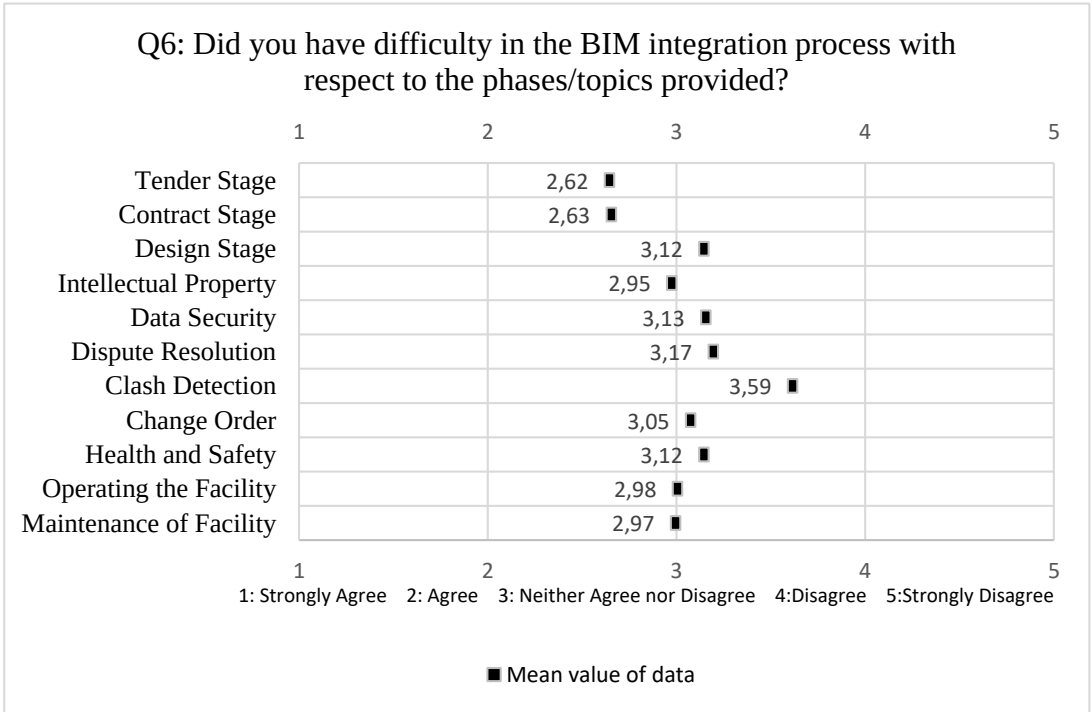

Figure 4.6 : The level of difficulties during BIM integration.

Question 7 - The performance effectiveness of BIM-based project management:
The mean values of answers given by participants to the impact of BIM-based project management on the performance of various topics are shown in Figure 4.7.

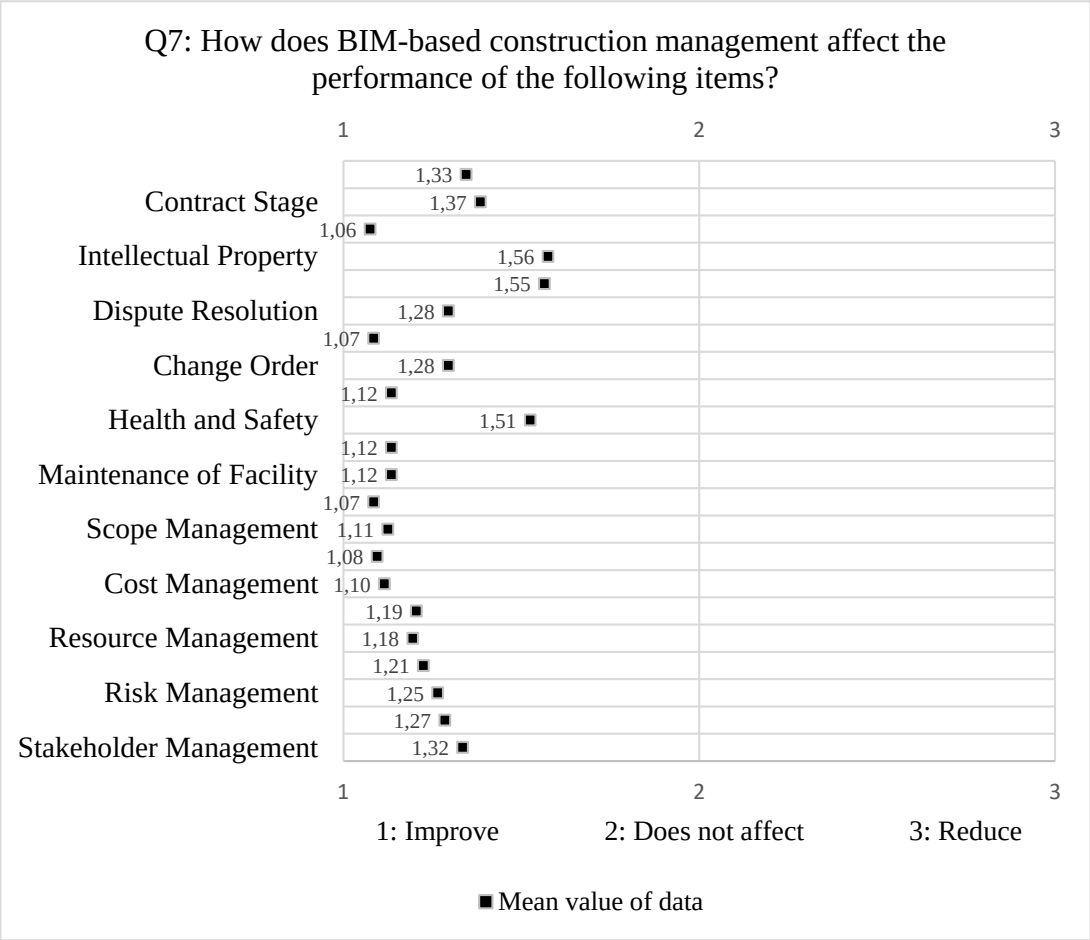

Figure 4.7 : The performance effectiveness of BIM-based project management.

Questions 8 and 9 - Main challenges during BIM integration and recommendations to overcome these challenges:

The main challenges during the BIM integration for 15 topics and recommendations to these challenges have been shown in sequence. The items have been listed from the highest to the lowest frequency. At the end of each item, frequencies of participants similar statements have been indicated.

Challenges during tender stage:

- Lack of knowledge and experience of BIM at the national level, of the public entities and private sector. (7 Participants)

- Errors in the process of extracting bill of quantities (BOQ) from the model. (5 Participants)
- Lack of definitions of the owner's BIM requirements. (4 Participants)
- Finding appropriate model families from qualified suppliers, and miscommunication between suppliers. (3 Participants)
- Due to the length of the BIM model creation process, the model is mostly incomplete until the tender process. (3 Participants)
- Since BIM will provide transparency, it may be problematic to know the cost data beforehand. (2 Participants)

Recommendations:

- Definitions of the owner's BIM requirements. (3 Participants)
- Legal regulations and guides. (3 Participants)
- Tender process that is more interactive and compatible with technology. (2 Participants)
- The BIM Model needs to be completed before the tender stage, thus Bill of Quantities will be precise. (2 Participants)
- Pre-qualification of BIM to the participants during the tender process. (1 Participant)

Challenges during contract stage:

- Lack of definitions of process, scope and responsibilities in the contract and its addendums. (8 Participants)
- Conflicts between the main contract and its addendums and/or technical specifications. (2 Participants)

Recommendations:

- Ensure that the subcontractor is legally bounded by the project requirements via the contract. Clearly define roles and responsibilities as well as the consequences of not complying with the requirements. (4 Participants)

- Specific requirements about the level of BIM (practices, program, purpose etc.) that will be used within the Project. (4 Participants)
- Consultancy from the BIM expert when preparing the project contract. (4 Participants)
- Legal regulations and guides. (2 Participants)

Challenges during design stage:

- Lack of knowledge of BIM concepts. At the beginning of the project, design teams should be aware of the project requirements and contract clauses. BEP's are needed to be prepared completely and designers should consider the liabilities during the design phase. (5 Participants)
- The fact that all participants in the design team do not work on BIM modelling in an integrated way. Due to the inability of participants to work collaboratively through the BIM model and inadequate cooperation, many clashes occur in the model. (4 Participants)
- Difficulties in the integration of difficult geometries into the BIM model and the scarcity of professionals with knowledge in this regard. (3 Participants)
- Lack of definitions of model requirements. (3 Participants)
- Not enough time for the BIM model before the construction phase. (3 Participants)
- Lack of knowledge in the concept of smart object. (1 Participant)

Recommendations:

- Ensure that all design elements need to be integrated due to project requirements are available in the final design. (8 Participants)
- Ensure that BIM is being effectively used by all design teams to be able to use this platform for monitoring, checking, reporting and updating etc. (6 Participants)
- BIM model must be completed before the construction phase. (3 Participants)
- Particular emphasis should be placed on applied BIM trainings for professionals such as civil engineers and architects. (3 Participants)

- There should be legal definitions about LOD's. (2 Participants)

Challenges in intellectual property:

- Lack of provisions about intellectual property in the contract. (3 Participants)
- Risk of third parties getting confidential information since databases are collaborative. (3 Participants)
- Contractor's desire to take ownership rights of the design information produced in the project. (1 Participant)
- Stakeholders generally do not want to share their commercial information. (1 Participant)

Recommendations:

- Definition of intellectual property in contract documents. (3 Participants)
- Authorization of information in the BIM model for access, viewing and sharing. (2 Participants)

Challenges in data security:

- The lack of tools to ensure data security in BIM. (4 Participants)
- Increasing cloud-based information sharing environments, making the data more open to cyber-attacks. (2 Participants)

Recommendations:

- Use security access strategies based on roles to the data in the common BIM model. (5 Participants)
- Using worldwide data sharing standards. (1 Participant)
- Firewalls should be developed against possible cyber-attacks. (1 Participant)

Challenges in dispute resolution:

- Communication problem caused by not following the procedures. (2 Participants)

Recommendations:

- Communication and clear understanding of the conflicts by parties. (2 Participants)

Challenges in clash detection:

- Clashes cannot be detected at the design stage, and occur during implementation due to fact that not all disciplines work on a common BIM model. (2 Participants)
- Incompatibility between BIM software can cause clashes in construction applications. (1 Participant)
- Lack of knowledge about BIM software from some of collaborators. (1 Participant)

Recommendations:

- BIM modelling will play an active role in conflict management. Therefore, especially the design team should be competent in BIM modelling, and clash detection check should be done before the construction phase. (4 Participants)
- Clash tracking should be done by a single authority and should be managed from a single centre. (1 Participant)

Challenges in change order:

- Many errors and clashes arise during construction as an integrated design and construction process cannot be managed. Decrease in efficiency with increasing time and cost due to changes orders. (4 Participants)

Recommendations:

- Even though the change orders will decrease with BIM, with the help of simulation technology, simultaneous communication with between design and construction team will detect possible faults that may occur within the site and provide solution support at that time. (2 Participants)
- Define a change management process so that the change is reviewed and approved before it gets implemented in the model. (2 Participants)

Challenges in interoperability:

- All the stakeholders do not have enough knowledge about using BIM and sharing information in all the phases. (4 Participants)

- The lack of technology that can be used for the production and sharing of large-size models affects coordination and collaboration. (3 Participants)
- The parties' failure to comply with the BEP. (2 Participants)

Recommendations:

- Making sure of every party is well educated and aware of advantages of using BIM. (4 Participants)
- Establishing a protocol for information sharing and software. The data should be shared in native or open format. (2 Participants)
- BEP should be prepared and described correctly at the beginning of the process, and meetings should be held at regular intervals for interoperability. (1 Participant)
- Use of electronic signature or stamp. (1 Participant)

Challenges in health and safety (HS):

- Due to the complexity of the interface of BIM-based HS standards, there is a difficulty in using on construction sites. (2 Participants)
- Preparation of CPM based on cost, time and quality by ignoring health and safety requirements. (1 Participant)
- Unqualified sub-contractors. (1 Participant)

Recommendations:

- Using the BIM model, hazard areas on the job site can be identified. By detecting the location of the employees with sensors, possible work accidents can be prevented. (1 Participant)
- The interface of BIM 360 services, which is one of the software for construction management, should be more available and language support should be available for every employee on the job site. More HS issues should be developed in BIM 360 services rather than documents. (1 Participant)

Challenges during operation and maintenance (O&M) of the facility:

- O&M team not being effectively involved in the BIM process. (4 Participants)

- Lack of information due to the fact that the BIM Model was not created considering the operation and maintenance phase. (3 Participants)

Recommendations:

- Ensure that monitoring system developed for the operation phase is compatible with the specific BIM software being used in the Project. (1 Participant)
- Ensure that facility management company carrying out the operation tasks has sufficient capacity to use BIM practices. (1 Participant)

Challenges during pre-construction phase:

- Definition and coordination of work packages. (3 Participants)
- Lack of communication and roadmap, as initial meetings are not held with all stakeholders in accordance with the BEP. (2 Participants)

Recommendations:

- In the design process, working of different disciplines on the common model will minimize errors. In addition, design and material decisions will be made more accurately by making simulations such as energy and daylight. (1 Participant)
- Preparation of a comprehensive BEP that defines the requirements and responsibilities of all stakeholders. (1 Participant)

Challenges during construction phase:

- Increased waste of material, energy and time due to high errors and repetitions in applications and inadequate communication between teams. Consequently, the emergence of an inefficient and low-quality process. (4 Participants)
- Delays in construction implementations. (2 Participants)

Recommendations:

- Using BIM models for project control, delay analysis, organizing progress payments. (3 Participants)
- Ensure effective implementation of the project requirements. (2 Participants)
- Maintaining effective communication and coordination between different construction teams. (2 Participants)

Challenges during post-construction phase:

- Due to many faulty productions in the construction process, many renovation needs arise during the operation process. (1 Participant)
- Low predictability as there is no common data platform in operation and maintenance. (1 Participant)

Recommendations:

- Compare the as-built model with a point cloud model of the real asset and make sure everything is in place. (1 Participant)
- With a proper BIM model, any defects or malfunctions that may occur in the post-construction and operational processes can be detected and precautions can be taken. (1 Participant)

Other recommendations:

- Investment cost calculation can be further improved. Although the current list of equipment used in the building phase of the building can be created automatically in the software, it still cannot accurately reflect the correct data in terms of cost. (1 Participant)
- Investment costs of sustainable technologies to be made in the BIM model should be comparable and payback times should be calculated. (1 Participant)
- Existing software with BIM integration should be developed for carbon and water footprint rates originating from buildings, which is one of the most important issues triggering climate change. (1 Participant)

Question 10 - The points to be considered while preparing various BIM documents:

Critical points to be considered when preparing various BIM documents have been listed. The items have been listed from the highest to the lowest frequency. At the end of each item, frequencies of participants' similar statements have been indicated.

BIM Execution Plan (BEP):

- The BEP should cover many topics, from the scope, goals and milestones of the Project to descriptions of works, intellectual property, product standards, as-built model requirements, file naming and sharing procedures. (6 Participants)

- BEP should be created in line with the requirements of the owner at meetings where all stakeholders can express their opinions openly. (5 Participants)
- Responsibility and liability definitions according to the project's stages. (2 Participants)

Organisational Information Requirements (OIR):

- Understanding organisation and stakeholders. (1 Participant)

Project Information Requirements (PIR):

- The requirements of the project and the owner must be determined correctly. (2 Participants)

Exchange Information Requirements (EIR):

- Defining the roles and responsibilities of key stakeholders. (1 Participant)
- Model change and transmission procedures should be clearly defined. (1 Participant)

Supply Chain Assessment Form (SCAM):

- Assessment criteria for suppliers should be established by identifying key performance indicators. (1 Participant)

Task Information Delivery Plan (TIDP):

- Understanding and clear definition of task, task orders and method of statements. (1 Participant)

Question 11 - The appropriateness of BIM integration according to the type of project:

The mean values of answers given by participants to the compliance of project types to BIM integration have been shown in Figure 4.8.

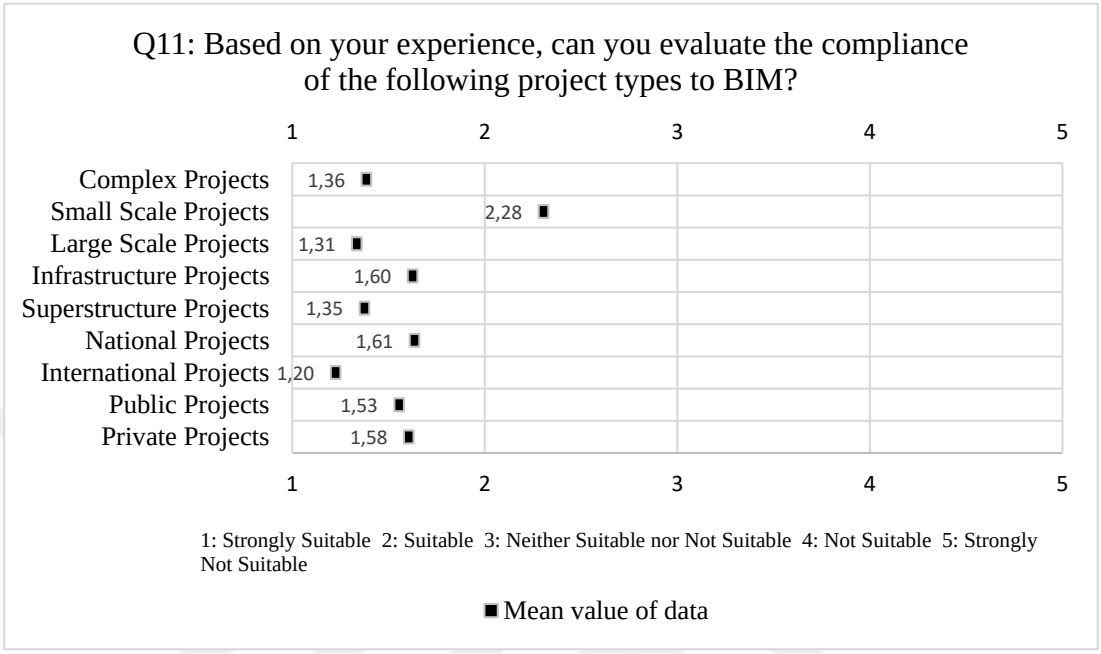

Figure 4.8 : The appropriateness of BIM integration.

Question 12 - The main issues to be considered when preparing the contract in BIM-based projects:

The main issues to be considered when preparing the contract in BIM-based projects have been listed. The items have been listed from the highest to the lowest frequency. At the end of each item, frequencies of participants' similar statements have been indicated.

- Requirements and scope of the model, payment schedules, data security and intellectual property should be included in the BEP. (4 Participants)
- LOD levels should be selected carefully to provide the owner with enough level of information. (3 Participants)
- BIM execution plan should be in line with the main contract, and make sure no contradiction in standards, methods and procedures. (2 Participants)
- The distribution of responsibilities and role definitions of the participants should be clearly stated, the BIM representative should be determined and periodic control processes should be defined. (1 Participant)

- A special contract should be prepared with the awareness that each project is unique. (1 Participant)

Question 13 - Issues where contracts in BIM-based projects will reduce disputes:

The main issues that BIM-based projects can reduce disputes will be listed. The items have been listed from the highest to the lowest frequency. At the end of each item, frequencies of participants' similar statements have been indicated.

- Since the contractor has to stick to the prepared BEP, his construction practices can be monitored continuously. Thus, change orders can be minimized. (3 Participants)
- BIM integration reduces conflicts and disputes as it strengthens communication between direct and indirect collaborators. (3 Participants)

Question 14 - Issues where contracts in BIM-based projects will increase disputes:

The main issues that BIM-based projects can increase disputes have been listed. The items have been listed from the highest to the lowest frequency. At the end of each item, frequencies of participants' similar statements have been indicated.

- If the task and responsibility definitions of the parties are not made clear in the contracts, there will be conflict at every stage of the process. (3 Participants)
- Due to the rapidly developing technologies, there may be situations that are not covered by the contract over time. (2 Participants)

Question 15 - Skills that contract managers in BIM-based projects should have:

The main issues that BIM-based projects can increase disputes have been listed. The items have been listed from the highest to the lowest frequency. At the end of each item, frequencies of participants' similar statements have been indicated.

- The contract manager must be in contact with all stakeholders of the construction and have the ability to coordinate, understand and manage their work. (4 Participants)
- Experience in actual BIM model creation, should have experience from bottom up. Too many people in those positions who have no understanding that BIM also has a technical component and issues dependent on the software used. (3 Participants)

- The contract manager should have knowledge of BIM's workflows, software, outputs, and documents. (3 Participants)

Question 16 - The most serious problem faced by the participants during the project:

The most serious problem and solution methods encountered by the participants during the project have been listed.

- Problems arising from the inclusion of unqualified participants in the BIM-based construction process in terms of their technological infrastructure and technical knowledge. Giving various seminars and trainings to project participants.
- Conflicts in approved static and architectural projects and software problems with defining materials for some building elements.
- Construction laws, permits not aligned and contradicting with BIM requirements. Issues with tendering, design and construction are dividing into separate tenders, BIM is more suitable for design and build, rather than design bid build.

Suppliers which does not respond or update the models during construction phase. The models updates must be follow by construction and not the opposite.

4.4 Data Obtained Through Second Stage Interviews

The verification study of the preliminary checklist template proposal created within the scope of the dissertation was carried out with 10 professionals who were asked to evaluate the preliminary checklist template proposal created. They assessed the preliminary checklist template proposal in terms of design, clarity and content. All interviewees have approved the proposed preliminary checklist template developed within the scope of this dissertation. They have indicated that this proposed template is sufficient and useful. The preliminary checklist template has been further improved based on the following comments of the interviewees:

Section 1: Critical points of administrative decisions.

- For stakeholders working in complex and large projects, the organizational decision phase of BIM should be a “must have” feature. (1 Participant)

- This should be stated if BIM needs internal departments as an organizational decision. (1 Participant)
- Each company should set their own BIM specifications on why they prefer BIM and how they will implement it. (1 Participant)
- It should be determined whether BIM process management will be done by the company or whether it will be outsourced to third parties. (1 Participant)

Section 2: Critical points of analysis.

- The analyses should be planned considering the entire building life cycle. (3 Participants)
- Supply chain analysis for materials and human resources should be done by considering the geography where the project will be made. (2 Participants)
- In the time and cost analysis section, the analyzes should be compared according to different alternatives of the project design. (1 Participant)
- Quality analysis should be added. (1 Participant)
- Time and cost analyses should also include the marketing of the project. (1 Participant)

Section 3: Critical points of legal issues.

- The contract and BEP should be compatible with each other and there should be no contradictions. (3 Participants)
- Millestones of the project should also be specified in BEP. (1 Participant)

Section 4: Critical points of allocation risks and responsibilities.

- Changes that occur during BIM meetings should be revised to the BIM model immediately. (1 Participant)

Section 5: Critical points of intellectual property rights.

- The definition of confidential information should also be specified. (1 Participant)
- Ownership of the model can switch between the parties depending on the stages of the project. (1 Participant)

Section 6: Critical points of data security.

- Databases used internally and among stakeholders should be organized in different ways. (1 Participant)

Section 7: Critical points of information management.

- Industry Foundation Classes (IFC) can be added to native data format part as an example. (3 Participants)
- Update procedures should also be added to the software type and version part. (1 Participant)
- In the information protocol, an information process map containing all information produced and shared according to the stages of the project should be created. (1 Participant)

Section 8: Critical points of interoperability.

- The software to be used in relation to the change order part and the platform used should also be specified. (1 Participant)
- Change order transmittals in the project need to be archived to ensure that stakeholders notice the changes and take responsibility. (1 Participant)

Section 9: Critical points of operation phase.

- In the as-built model part, the layouts should be updated regularly during the construction phase of the project. (1 Participant)

5. DISCUSSION

The findings obtained from the literature review, litigation awards and case law research, interviews and online questionnaire survey conducted within the scope of the dissertation are discussed in line with the objectives of the research (Table 1.1).

5.1 Review of BIM Guidelines, Standard Contracts and Protocols

In order to identify the legal concerns that arise in BIM-based construction projects, the processes, stakeholders, and documents of BIM-based project management have been investigated. For this purpose, a literature review has been conducted, international guidelines (Table 2.1), and standard contracts and protocols (Table 2.3) have been examined. These documents have been discussed in comparitive ways among themselves and the literature.

It is stated in the literature that BIM is suitable for construction projects with various advantages (Bryde et al., 2013; Fountain and Langar, 2018). BIM-based projects, however, contain various administrative, technical, and legal risks (Chien et al., 2014). Today's traditional legal structure based on individual rights and responsibilities (Pandey et al., 2016). Therefore, in BIM's multi-participant and collaborative structure, it has become difficult to protect the rights and responsibilities of stakeholders (Azhar et al., 2012).

Various guides, standard contracts, and protocols have been published by universities and institutions to ensure efficient and effective integration of BIM-based construction projects. All reviewed guidelines (BBIM, BSI, CANBIM, COBIM, DASBIM, NATSPEC, NBGO, NBIM, PSUBIM, SBEnrcBIM, SBIM, USCBIM, USFBIM) have information that they are not a legal document but are published only as supportive documents. CIOB, JCT, and NEC4 are contract documents and either contain or refer to BIM, while AIA, CDOC, and CIC protocols state that they will not replace the main contract, but are an addendum to the main contract.

In most of the reviewed guidelines (BBIM, CANBIM, DASBIM, NATSPEC, NBGO, PSUBIM, SBEnrcBIM, SBIM, USCBIM, USFBIM), the process started with the initial project stage and ended with the close-out and handover, while BSI, NBIM, and COBIM define the process from the organizational and asset-related decision stages to the demolishing of the building. Conversely, the standard contracts and protocols have described the process through legal provisions. The mentioned issues by the majority and minority of guidelines, contracts, and protocols are shown in Table 2.8. In general, the guidelines describe more issues, as they are published to support the BIM integration process. The issues not addressed by contracts and protocols but highlighted by guidelines are shown in Table 2.9. These issues can be summarized as follows: Sustainability, time and cost analysis; definitions of BIM tasks, requirements, deliverables and LOD levels; procedures for meetings, collaboration, clash detection and change order; data systems, storage, archiving and security; and handing over procedures of model.

Borrmann et al. (2018), Hsu et al. (2015), Holzer, (2016), and the reviewed documents stated that someone responsible for BIM processes should be identified. In addition, all reviewed documents (AIA E203, 2013; BBIM, 2015; BSI ISO1, 2018; CANBIM, 2014; CDOC301, 2015; CIC BIM, 2018; CIOB, 2013; COBIM, 2012; DASBIM, 2015; JCT, 2016; NATSPEC, 2016; NBGO, 2017; NBIM, 2013; NEC4, 2017; PSUBIM, 2019; SBEnrcBIM, 2017; SBIM, 2013; USCBIM, 2012; USFBIM, 2018) underline the BEP, which includes BIM's requirements, processes, and responsibilities. Similarly, In the literature, BEP was deemed necessary for effective BIM integration (Abdirad, 2015; Chong et al., 2017; Eschenbruch and Bodden, 2018; Lin et al., 2016).

As a result of the surveys and interviews conducted with professionals actively involved in BIM projects, the participants stated that BIM is suitable for many types of projects (Figure 4.8) and that BIM positively affects performance (Figure 4.7) at different phases of the project. On the one hand, online questionnaire survey participants were, on average, undecided about the compatibility of international standard contracts and protocols with BIM (Figure 4.5). On the other hand, interviewees stated that they used the FIDIC, BSI PAS, and PSUBIM documents by adapting them while preparing the contract or technical specifications.

In Question 8, the participants of the questionnaire indicated that the main challenge they experienced in all processes was the inadequate definitions of the needs, processes, and responsibilities. In Question 9, similar to the literature, they recommended the creation of a clear and comprehensive BEP by taking the ideas of all project stakeholders in line with the needs of the owner. They also noted that BEP should clearly define many issues such as the scope, objectives, milestones, responsibilities, obligations, production standards, LOD level, as-built model requirements, file sharing, and naming procedures and IPR of the BIM.

5.2 Determination of the Critical Aspects and Issues in BIM-Based Contracts

BIM's collaborative working environment has changed the relationships between stakeholders identified in traditional contracts (Eschenbruch and Bodden, 2018). Consequently, the legal arrangements that regulate the integration of BIM into the project are seen as challenges (Kuiper and Dominik, 2013). In the literature, issues that will lead to claims and conflicts during BIM integration have been investigated. According to Archadis (2019) and as illustrated in Table 2.4, the main cause of conflicts and disputes occurring in the CI are contract-related issues. With the integration of BIM, the clarity of responsibilities and obligations among stakeholders decreased and new legal problems emerged (Azhar et al., 2012). Legal issues related to BIM integration are mainly ownership of the model, risk allocation, intellectual properties, and interoperability between the stakeholders (Jo et al., 2018), the responsibility of the data, the responsibility of quantities, clash detection and professional reliability of third parties (Ussing et al., 2016), documentation, unclassified and/or non-prioritized documents (Charehzehi et al., 2017). These legal issues are examined under 4 main headings: Allocation of risks and responsibilities, IPR, interoperability, data security and documentation.

Allocation of risks and responsibilities:

According to Arensman and Ozbek (2012), the current legal system is based on definite roles and responsibilities. These roles and responsibilities, however, have become difficult to determine, due to BIM's collaborative and simultaneous working system on the integrated model (Schapke et al., 2018). In the documents reviewed (BSI, CANBIM, COBIM, NATSPEC, PSUBIM), it was emphasized that a protocol

should be created for obligations in BIM-based projects. Similarly, it is stated in the literature that responsible persons and obligations should be determined according to BIM tasks (Arensman and Ozbek, 2012; Azhar et. Al., 2012; Bosch-Sijtsema et al., 2017; Ussing et al., 2016). Although it is not included in the contracts and protocols, it is emphasized in the guidelines (BBIM, CANBIM, NATSPEC, SBIM, USFBIM) and literature by McAdam (2010), Azhar et al. (2012) and Borrmann et al. (2018) that the contractual status of the model should be determined in case of any conflict or dispute.

The guidelines and literature specified that the requirements and deliverables should be determined in the contract according to BIM stages (Abdirad,2015; Papadonikolaki et al., 2019; Lin et al., 2016; Kuiper and Dominik, 2013). As a result of the litigation award and case law research, it was determined that there were disputes related to the definitions of requirements and deliverables in 2 cases (Table 4.2). In question 8, questionnaire participants stated that they had a challenge in tender and contract stages due to a lack of definitions regarding the owner's requirements, scope, and responsibilities.

PSU, BSI, CANBIM, COBIM, and Oviedo-Haito et al. (2014) indicated that there should be a pre-qualification procedure regarding BIM in the selection of the supply chain. Nevertheless, supply chain regulations were not found in standard contracts and protocols. Unlike contracts and protocols, PSU, BSI, BBIM, and USCBIM emphasize the BIM consultant procedures. Moreover, BSI, SBIM, NBIM, and COBIM address detailed regulations regarding the as-build model procedures. Although not much addressed by the documents, disputes related to pre-qualifications, BIM consultant, and as-built model procedures were identified in the case law research (Table 4.2).

IPR:

The ability of all participants to transparently produce, change, and share the data on the common information model are some of the benefits provided by BIM. Since the valuable data for stakeholders, however, are exposed to the same platform, IPR is one of the most important concerns in BIM integration (Solihin and Eastman, 2015). Traditionally, designers want ownership rights for the model or information they produce (Eadie et al., 2015). At the same time, since the owner wants to have the same

model to be used during the operation, there is a possibility of conflict between the parties (Arensman and Ozbek, 2012).

There are regulations and recommendations regarding IPR in the literature (Arensman and Ozbek, 2012; Arshad et al., 2019; Manderson et al., 2015; Solihin and Eastman, 2015) and reviewed documents (AIA E203, 2013; BBIM, 2015; BSI ISO1, 2018; CANBIM, 2014; CDOC301, 2015; CIC BIM, 2018; CIOB, 2013; COBIM, 2012; DASBIM, 2015; JCT, 2016; NATSPEC, 2016; NBGO, 2017; NBIM, 2013; NEC4, 2017; PSUBIM, 2019; SBEnrcBIM, 2017; SBIM, 2013; USCBIM, 2012; USFBIM, 2018). The most stressed topics, in general, are protocol for information, the confidentiality of information, copyrights of produced data, and authority to share. In the litigation award and case law research, disputes originating from authority to share and confidentiality of information were determined regarding IPR (Table 4.2). The online questionnaire survey and interview participants mentioned that the arrangements regarding IPR are insufficient in the contracts. Questionnaire survey participants defined databases open to 3rd parties as challenges. They also stated that contractors' requests for ownership of the design information are an IPR violation. In question 9, similar to the literature (Manderson et al., 2015; Solihin and Eastman, 2015), participants suggested that IPR definitions should be included in the contract, and access to the common BIM model should be authorized. Regarding the protection of IPR, Eschenbruch and Bodden (2018), CIC, AIA, and CANBIM have recommended that a term of usage letter be signed to the recipient party regarding ownership and user rights before the information generated is shared.

Interoperability:

The number of stakeholders involved in the project has increased due to the size of the construction projects and the complexity of the construction methods. With the BIM integration, various conflicts and disputes occur between stakeholders who have to work together throughout the entire project life cycle (Dougherty, 2015; Ghaffarianhoseini et al., 2017; Li et al., 2017). Therefore, the relationships of stakeholders communicating via the 3D BIM model and common information systems need to be regulated (Rahman et al. 2016; Eastman et al., 2010). Charehzehi et al. (2017), Solihin and Eastman (2015), Schapke et al. (2018), and the majority of documents (AIA E203, 2013; BBIM, 2015; BSI ISO1, 2018; CANBIM, 2014;

CDOC301, 2015; CIC BIM, 2018; CIOB, 2013; COBIM, 2012; DASBIM, 2015; NATSPEC, 2016; NBGO, 2017; NBIM, 2013; PSUBIM, 2019; SBEnrcBIM, 2017; SBIM, 2013; USCBIM, 2012; USFBIM, 2018) emphasized the need to grant access by authorizing the data in the common model or the information system. In the litigation awards and case law research, a case with a dispute caused by unauthorized sharing was determined (Table 4.2). Additionally, Succar (2010), Bynum et al. (2013), McAdam (2010), and all reviewed documents (AIA E203, 2013; BBIM, 2015; BSI ISO1, 2018; CANBIM, 2014; CDOC301, 2015; CIC BIM, 2018; CIOB, 2013; COBIM, 2012; DASBIM, 2015; JCT, 2016; NATSPEC, 2016; NBGO, 2017; NBIM, 2013; NEC4, 2017; PSUBIM, 2019; SBEnrcBIM, 2017; SBIM, 2013; USCBIM, 2012; USFBIM, 2018) paid attention to the software issue to be used throughout the process. In questions 8 and 9, the survey participants stated that a protocol should be established for information sharing and software. In question 10, they also mentioned that this protocol should be included in the BEP.

Topics not mentioned in standard contracts and protocols but highlighted by the majority of guidelines (BBIM, BSI, CANBIM, COBIM, DASBIM, NATSPEC, NBGO, NBIM, PSUBIM, SBEnrcBIM, SBIM, USCBIM, USFBIM) are modes of collaboration, clash detection, change order procedures, centralized file system, and BIM meetings. Ussing et al. (2016) and Li et al. (2017) emphasized that procedures should be determined for the change order. Likewise, Mosey (2014) recommended regulations for the centralized file system. In the litigation award and case law research, 2 cases containing disputes caused by a lack of description of clash detection and change order procedures were detected (Table 4.2). In question 7, the interview participants stated that they did not have much trouble with clash detection and change order during the project, since interdisciplinary meetings were held with the integration of BIM. Survey participants stated in question 8 that all disciplines do not have sufficient BIM knowledge and therefore have difficulty in coordinated works.

Unlike standard contracts and protocols, the level of development (LOD) is emphasized by all of the guidelines (BBIM, BSI, CANBIM, COBIM, DASBIM, NATSPEC, NBGO, NBIM, PSUBIM, SBEnrcBIM, SBIM, USCBIM, USFBIM). Lin et al. (2016) and Ashcraft (2008) indicated that the LOD level should be determined according to the project stages from the start of the BIM-based project. In question 3, interview participants stated that LOD requirements are not specified in the contracts

of the projects they are involved in but are determined according to the needs. In question 9, the participants of the survey recommended the LOD levels to be used at different stages of the project should be determined according to the needs of the project and added to the BEP. They noted that legal LOD definitions should be made within the national framework.

Electronic stamps and extraction of 2D drawings issues are not emphasized much in the literature, standard contracts, protocols, and guidelines. CANBIM and NBIM recommend the use of electronic stamps or signs for the tracking and control of the responsible person of the shared document on the common platform in an interdisciplinary manner. CDOC, USFBIM, and CANBIM indicate that all 2D drawings to be used in the project process should be extracted from the common 3D model through certain procedures. In question 7, interview participants stated that all shop drawings should be interconnected with the common 3D model to reduce overlapping construction practices. In the litigation award and case law research, a dispute was identified due to the contradiction of the 2D drawings and the 3D model (Table 4.2).

Data security and documentations:

In general, as in all industries, digitization is being rapidly widespreading in the CI. With BIM Level 2, project stakeholders are expected to digitally generate and share the information (Gibbs et al., 2015). Unlike traditional methods, BIM-based projects contain a lot of information. All this information should be protected against corruption, theft, and loss (Olatunji, 2011).

Sardroud et al. (2018) stated that despite the developments in software technology, it is still not secure enough. In question 8, questionnaire survey participants mentioned the lack of tools to provide data security in BIM. They also noted that the documents stored in cloud-based databases are open to cyber-attacks. In question 7, interview participants stated that keeping all information about the project in one place is a big problem. Charehzehi et al. (2017), Solihin and Eastman (2015), Schapke et al. (2018), and in the majority of the reviewed documents (AIA E203, 2013; BBIM, 2015; BSI ISO1, 2018; CANBIM, 2014; CDOC301, 2015; CIC BIM, 2018; CIOB, 2013; COBIM, 2012; DASBIM, 2015; NATSPEC, 2016; NBGO, 2017; NBIM, 2013; PSUBIM, 2019; SBEnrcBIM, 2017; SBIM, 2013; USCBIM, 2012; USFBIM, 2018)

highlighted authorized access for data protection. In question 9, survey participants suggested that security access strategies should be developed. They also noted the use of firewalls to prevent cyber-attacks and viruses. In the case law research, a case with a dispute due to un-authorized access was detected (Table 4.2).

Issues not mentioned in standard contracts and protocols but highlighted by the majority of guidelines (BBIM, BSI, CANBIM, COBIM, NATSPEC, NBGO, NBIM, PSUBIM, SBEnrcBIM, SBIM, USCBIM, USFBIM) are digital data storage, digital data archiving, and data security protocol. In the literature, data storage (Lai et al., 2019), data archiving (Bakhary et al. 2015), and data security (Chien et al., 2014; Dougherty., 2015; Eschenbruch and Bodden, 2018) are emphasized. In question 7, interview participants indicated that they made cloud-based storage in the project or stored in the database in their offices.

Another issue highlighted by Eschenbruch and Bodden (2018), and the majority of guides (BBIM, BSI, COBIM, NATSPEC, NBGO, NBIM, PSUBIM, SBEnrcBIM, SBIM, USCBIM, USFBIM) are procedures of handing over the BIM model. In question 7, some of the interviewees stated that they would transfer all information and model of the project directly to the operator at the end of the project, while others stated that the operator did not have such a request. In question 8, the questionnaire survey participants mentioned that the operation and maintenance team not being effectively involved in the BIM process, therefore, the model was not prepared for the operation of the facility. In question 9, the participants suggested that the tasks and software to be used during the operation should be compatible with the project.

There are various issues that the literature and the examined documents do not emphasize much. CDOC and Mosey (2014) recommended encrypted filing systems for data security. CIOB and Chien et al. (2014) suggested that project stakeholders' access to the common platform from unknown servers should be regulated. CDOC and Olatunji (2011) gave importance to back-up and restore procedures for any deterioration and loss problems that may occur in the model. CDOC recommends data insurance against financial loss due to data loss or security. Establishment of the preliminary checklist template proposal

5.3 Establishment of the Preliminary Checklist Template Proposal

The proposed preliminary checklist template can assist the contract preparation phase of BIM-based construction projects. Additions, corrections or removals can be made in the contract of BIM-based construction projects by considering the project-specific requirements and constraints using the proposed preliminary checklist.

With the information obtained as a result of the literature review and field studies, the necessary points for the preliminary checklist template proposal to be used in BIM-based construction projects contracts have been determined. For this purpose, 25 main topics and 32 subtopics under 9 categories have been determined to be considered while preparing the contract. These nine main categories are shown in Table 5.1.

Table 5.1 : The nine main categories of the preliminary checklist template proposal.

Categories of the Preliminary Checklist Template Proposal
1. Critical points of administrative decisions.
2. Critical points of analysis.
3. Critical points of legal issues.
4. Critical points of allocation risks and responsibilities.
5. Critical points of intellectual property rights.
6. Critical points of information management
7. Critical points of interoperability.
8. Critical points of data security.
9. Critical points of operation phase.

The nine main categories of the preliminary checklist template proposal and their relation to the knowledge areas and BSI PAS 1 project stages have been interpreted and provided in Table 5.2.

Table 5.2 : The nine main categories of the preliminary checklist template proposal and their relation to the PMI knowledge areas and BSI PAS 1 project stages.

Corresponding PMI knowledge areas (PMBOK, 2017)	Categories of the Preliminary Checklist Template Proposal	Project Stages according to BSI PAS 1 (2015)							
		Strategy	Brief	Concept	Definition	Design	Built and Commission	Handoover and Closeout	Operation and End of Life
Scope and Resource Management	1. Critical points of administrative decisions.								
Schedule, Cost, Quality and Procurement Management	2. Critical points of analysis.								
Scope and Risk Management	3. Critical points of legal issues.								
Risk and Stakeholder Management	4. Critical points of allocation risks and responsibilities.								
Risk Management	5. Critical points of intellectual property rights.								
Communications Management	6. Critical points of information management								
Integration and Stakeholder Management	7. Critical points of interoperability.								
Risk Management	8. Critical points of data security.								
Stakeholder Management	9. Critical points of operation phase.								

The categorized tables of the preliminary checklist template categorised under different headings are given in the successive tables (Tables 5.3, 5.4, 5.5, 5.6, 5.7, 5.8, 5.9, 5.10, and 5.11). In these tables, LACLR stands for litigation awards and case-law research, IS stands for interview surveys, QS stands for questionnaire survey, and IS2 stands for second stage interview surveys.

Table 5.3 : Critical points of administrative decisions.

Critical Points	References
☐ Organization-related Decisions 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**	(Ashworth et al., 2019; BSI ISO1, 2018; COBIM, 2012; NBIM, 2013; PSUBIM, 2019)
☐ Asset-related Decisions Determine the production methods and procedures as well as the managerial and commercial decisions regarding the asset.	(Ashworth et al., 2019; BSI ISO1, 2018; COBIM, 2012; NBIM, 2013)
☐ Project-related Decisions Measure and monitor that organizational decisions are supported in a particular project.	(Ashworth et al., 2019; BBIM, 2015; BSI ISO1, 2018; CANBIM, 2014; COBIM, 2012; DASBIM, 2015; NATSPEC, 2016; NBGO, 2017; NBIM, 2013; PSUBIM, 2019; SBEnrcBIM, 2017; SBIM, 2013; USCBIM, 2012; USFBIM, 2018) **IS, QS**

Table 5.4 : Critical points of analysis.

Critical Points	References
The analysis should be planned considering the entire building life cycle. **IS2**	
☐ Sustainability Analysis Identify the analyses and their procedures to be performed to measure the environmental impact and efficiency of the project.	(BBIM, 2015; BSI PAS1, 2015; CANBIM, 2014; COBIM, 2012; DASBIM, 2015; NATSPEC, 2016; NBGO, 2017; NBIM, 2013; PSUBIM, 2019; SBEnrcBIM, 2017; SBIM, 2013; USCBIM, 2012; USFBIM, 2018) **QS**
☐ Time and Cost Analysis 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**	(Azhar et al., 2012; BBIM, 2015; BSI PAS1, 2015; CANBIM, 2014; CIOB, 2013;COBIM, 2012; DASBIM, 2015; NATSPEC, 2016; NBGO, 2017; NBIM, 2013; PSUBIM, 2019; SBEnrcBIM, 2017; SBIM, 2013; USCBIM, 2012; USFBIM, 2018) **IS, QS**
☐ 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**	

Table 5.5 : Critical points of legal issues.

Critical Points	References
☐ BIM Execution Plan 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** Millestones of the project should also be specified in BEP. **IS2**	(Abdirad,2015; BBIM, 2015; BSI ISO2, 2018; CANBIM, 2014; CDOC301, 2015; Chong et al., 2017; CIC BIM, 2018; COBIM, 2012; DASBIM, 2015; Eschenbruch and Bodden, 2018; JCT, 2016; Lin et al., 2016; NATSPEC, 2016; NBGO, 2017; NBIM, 2013; NEC4, 2017; PSUBIM, 2019; SBEnrcBIM, 2017; SBIM, 2013; USCBIM, 2012; USFBIM, 2018) **IS, QS**
☐ Contractual Status of Documents Determine the contractual and legally binding status of the documents (protocol, guideline and/or standard) used in case of dispute.	(AIA E203, 2013; Azhar et al., 2011; BBIM, 2015; BESA, 2017; BSI ISO1, 2018; CANBIM, 2014; CDOC301, 2015; CIC BIM, 2018; CIOB, 2013; COBIM, 2012; DASBIM, 2015; Hardin and McCool, 2015; JCT, 2016; NATSPEC, 2016; NBGO, 2017; NBIM, 2013; NEC4, 2017; PSUBIM, 2019; SBEnrcBIM, 2017; SBIM, 2013; USCBIM, 2012; USFBIM, 2018)
☐ Contractual Status of Model Determine the contractual and legally-binding status of the common BIM model and the information it contains in case of Dispute.	(AIA E203, 2013; Azhar et al., 2012; BBIM, 2015; Borrmann et al., 2018; CANBIM, 2014; CIOB, 2013; McAdam, 2010; NATSPEC, 2016; SBIM, 2013; USFBIM, 2018)

Table 5.6 : Critical points of allocation risks and responsibilities.

Critical Points	References
☐ BIM Meetings 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**	(BBIM, 2015; BSI ISO1, 2018; COBIM, 2012; DASBIM, 2015; NATSPEC, 2016; NBGO, 2017; PSUBIM, 2019; SBIM, 2013; USCBIM, 2012; USFBIM, 2018) **IS, QS**
☐ Pre-Qualifications Prepare a comprehensive pre-qualification in terms of BIM competency and risk management capacity of suppliers before being included in the project.	(BSI ISO1, 2018; CANBIM, 2014; COBIM, 2012; NATSPEC, 2016; Oviedo-Haito et al., 2014; PSUBIM, 2019) **LACLR, IS, QS**
☐ Protocol for Obligations Identify the obligation and liability issues of each party in relation to allocation of risk and responsibility.	(AIA E203, 2013; Arensman and Ozbek, 2012; BBIM, 2015; BSI ISO1, 2018; CANBIM, 2014; CDOC301, 2015; CIC BIM, 2018; CIOB, 2013; COBIM, 2012; JCT, 2016; NATSPEC, 2016; NBGO, 2017; NEC4, 2017; PSUBIM, 2019; SBEnrcBIM, 2017; SBIM, 2013; Ussing et al., 2016) **LACLR, QS**

☐ Responsible Persons for BIM Processes Identify who is responsible according to BIM processes o BIM Process Responsible (Manager) - Responsible for whole BIM process. - Coordinates all updates. - Developing, publishing and coordinating all protocols required during information integration. - Monitoring the compliance of the parties to the BEP during the project. o BIM Main Discipline Responsible (Coordinator) Design Responsible: -Integration of all 3D models into a single model. - Clash detection control after integration - define model analysis and responsible disciplines. Construction Responsible: - To evaluate the model in terms of constructability and scheduling at all stages of the design. - Coordinating subcontractors. - Using the model for coordination and control during construction. o BIM Sub-Discipline Responsible (Discipline Lead) - Delivering the BIM model as clash-free. - Developing and managing model change methods. - Take responsibility for BIM of their own disciplines. o BIM Consultant Identification of the responsible person giving consultancy to the employer or other stakeholders in BIM processes. o BIM Information Technology Manager Identification of the person responsible for the management of the common model and the information it contains.	(AIA E203, 2013; Azhar et al., 2011; BBIM, 2015; Borrmann et al., 2018; Borrmann et al., 2018; BSI PAS2, 2013; CANBIM, 2014; CDOC301, 2015; CIC BIM, 2018; CIOB, 2013; COBIM, 2012; DASBIM, 2015; Holzer, 2016; Hsu et al., 2015; JCT, 2016; NATSPEC, 2016; NBGO, 2017; NBIM, 2013; NEC4, 2017; PSUBIM, 2019; SBEnrcBIM, 2017; SBIM, 2013; Tulke and Schumann, 2018; USCBIM, 2012; USFBIM, 2018; Ussing et al., 2016) **IS, QS** (BSI PAS2, 2013; BBIM, 2015; PSUBIM, 2019; USCBIM, 2012) **LACLR, IS** (BSI PAS2, 2013; USCBIM, 2012)
☐ BIM Requirements Determine the requirements throughout project stages for effective BIM integration.	(Abdirad,2015; BBIM, 2015; BSI ISO1, 2018; BSI ISO2, 2018; CANBIM, 2014; CIOB, 2013; COBIM, 2012; Howard and Ciliberto, 2016; Kuiper and Dominik, 2013; NATSPEC, 2016; NBGO, 2017; PSUBIM,

○ For Owner Define the information, procedures, sustainability and economic goals that is determined by the project owner and that the client must meet in the handover of the project. ○ For Other Parties Determine the needs of other stakeholders according to the project delivery method.	2019; SBIM, 2013; USCBIM, 2012; JCT, 2016) **LACLR, IS, QS**
☐ BIM Model Requirements and Deliverables Determine the objectives, requirements and outcomes of the common BIM model according to the project stages.	(BBIM, 2015; BSI ISO1, 2018; BSI ISO2, 2018; CANBIM, 2014; CIOB, 2013; COBIM, 2012; JCT, 2016; Kuiper and Dominik, 2013; Lin et al., 2016; NATSPEC, 2016; NBGO, 2017; Papadonikolaki et al., 2019; PSUBIM, 2019; SBIM, 2013; USCBIM, 2012) **LACLR, IS, QS**
☐ Definition of BIM Tasks Identify the tasks required to achieve the objectives, requirements and outcomes of the common BIM model determined according to the project stages.	(Abdirad, 2015; BBIM, 2015; Borrmann et al., 2018; Bosch-Sijtsema et al., 2017; BSI ISO1, 2018; BSI ISO2, 2018; CANBIM, 2014; COBIM, 2012; DASBIM, 2015; NATSPEC, 2016; NBGO, 2017; NBIM, 2013; PSUBIM, 2019; SBEnrcBIM, 2017; SBIM, 2013; USCBIM, 2012; USFBIM, 2018) **LACLR, IS, QS**
☐ Definition of BIM Responsibilities According to the Tasks 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.	(AIA E203, 2013; Arensman and Ozbek, 2012; BBIM, 2015; Bosch-Sijtsema et al., 2017; BSI ISO1, 2018; BSI ISO2, 2018; CANBIM, 2014; CDOC301, 2015; CIC BIM, 2018; CIOB, 2013; COBIM, 2012; DASBIM, 2015; JCT, 2016; NATSPEC, 2016; NBGO, 2017; NBIM, 2013; NEC4, 2017; PSUBIM, 2019; SBEnrcBIM, 2017; SBIM, 2013; USCBIM, 2012; USFBIM, 2018; Ussing et al., 2016) **LACLR, QS**

Table 5.7 : Critical points of intellectual property rights.

Critical Points	References
☐ Confidentiality of Information 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**	(AIA E203, 2013; Arshad et al., 2019; BBIM, 2015; BSI PAS2, 2013; CANBIM, 2014; CDOC301, 2015; CIC BIM, 2018; CIOB, 2013; COBIM, 2012; Manderson et al., 2015; NATSPEC, 2016; NBGO, 2017; PSUBIM, 2019; SBEnrcBIM, 2017; SBIM, 2013) **LACLR, IS, QS**
○ Ownership of Model 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**	(Arensman and Ozbek, 2012; BBIM, 2015; BSI PAS2, 2013; CANBIM, 2014; COBIM, 2012; NATSPEC, 2016; NBGO, 2017; PSUBIM, 2019; SBEnrcBIM, 2017; SBIM, 2013; Solihin and Eastman, 2015) **LACLR, IS, QS**
○ Copyrights of Produced Data Identify copyrights of information produced by all disciplines in line with project goals throughout the process.	(AIA E203, 2013; BBIM, 2015; BSI PAS2, 2013; CANBIM, 2014; CDOC301, 2015; CIC BIM, 2018; COBIM, 2012; Manderson et al., 2015; NATSPEC, 2016; NBGO, 2017; NEC4, 2017; PSUBIM, 2019; SBEnrcBIM, 2017; SBIM, 2013; Solihin and Eastman, 2015) **LACLR, IS, QS**
○ Term of Usage Letter Establish the Term of Usage Letter, where the usage and sharing rights will be specified before the stakeholders share information.	(AIA E203, 2013; CANBIM, 2014; CIC BIM, 2018; Eschenbruch and Bodden, 2018) **QS**

Table 5.8 : Critical points of information management.

Critical Points	References
☐ Protocol for Information 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	(AIA E203, 2013; BBIM, 2015; BSI PAS2, 2013; CANBIM, 2014; CDOC301, 2015; Charehzehi et al., 2017; CIC BIM, 2018; COBIM, 2012; DASBIM, 2015; Dougherty, 2015; Eschenbruch and Bodden, 2018; Ghaffarianhoseini et al., 2017; JCT, 2016; NATSPEC, 2016; NBGO, 2017; NBIM, 2013; PSUBIM, 2019; SBEnrcBIM, 2017; SBIM, 2013; USCBIM, 2012; USFBIM, 2018) **QS**
○ Centralized File System Set up a centralized file system where documents are shared, stored and archived for effective information management throughout the project process.	(AIA E203, 2013; BBIM, 2015; BSI PAS2, 2013; CANBIM, 2014; COBIM, 2012; Mosey, 2014; NATSPEC, 2016; NBGO, 2017; NBIM, 2013; PSUBIM, 2019; USCBIM, 2012; USFBIM, 2018) **QS**
○ Level of Development 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.	(AIA E203, 2013; Ashcraft, 2008; BBIM, 2015; BSI PAS1, 2015; CANBIM, 2014; COBIM, 2012; DASBIM, 2015; Lin et al., 2016; NATSPEC, 2016; NBGO, 2017; NBIM, 2013; PSUBIM, 2019; SBEnrcBIM, 2017; SBIM, 2013; USCBIM, 2012; USFBIM, 2018) **IS, QS**
○ Software These are the software that the common BIM model will be created and used during information exchange between stakeholders.	
○ Type and Version of Software 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**	(BBIM, 2015; BSI PAS2, 2013; Bynum et al. 2013; CANBIM, 2014; CDOC301, 2015; CIC BIM, 2018; CIOB, 2013; COBIM, 2012; DASBIM, 2015; McAdam, 2010; NATSPEC, 2016; NBGO, 2017; NBIM, 2013; PSUBIM, 2019; SBEnrcBIM, 2017; SBIM, 2013; Succar, 2010; USCBIM, 2012; USFBIM, 2018) **QS**
○ Native Data Format 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**	, (BSI PAS2, 2013; Bynum et al. 2013; CANBIM, 2014; CIC BIM, 2018; CIOB, 2013) **QS**
○ Authority to Access	(AIA E203, 2013; BBIM, 2015; BSI PAS2, 2013; CANBIM, 2014; CDOC301, 2015; Charehzehi et al., 2017; CIC BIM, 2018; CIOB, 2013; COBIM, 2012; DASBIM, 2015; NATSPEC, 2016; NBGO, 2017; NBIM, 2013;

Provide authorized access to data in the common model to prevent data corruption, loss and errors.	PSUBIM, 2019; SBEnrcBIM, 2017; SBIM, 2013; Schapke et al., 2018; Solihin and Eastman, 2015; USCBIM, 2012; USFBIM, 2018) **LACLR, QS**
○ Contact List of Authorized Users Identify the contact information of authorized users to monitor changes and revisions in the common model, and to resolve potential problems quickly.	(BBIM, 2015; BSI PAS2, 2013; CDOC301, 2015; DASBIM, 2015; NATSPEC, 2016; NBIM, 2013; PSUBIM, 2019; USCBIM, 2012; USFBIM, 2018)
○ Authority to Change Provide authorized modification permissions to the data in the model to prevent conflict caused by changing data without controlling.	(AIA E203, 2013; BBIM, 2015; BSI PAS2, 2013; CANBIM, 2014; CDOC301, 2015; Charehzehi et al., 2017; CIC BIM, 2018; CIOB, 2013; COBIM, 2012; DASBIM, 2015; NATSPEC, 2016; NBGO, 2017; NBIM, 2013; PSUBIM, 2019; SBEnrcBIM, 2017; SBIM, 2013; Schapke et al., 2018; Solihin and Eastman, 2015; USCBIM, 2012; USFBIM, 2018) **LACLR, IS, QS**
○ Electronic Stamps 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.	(CANBIM, 2014; NBIM, 2013) **QS**
○ Authority to Share Provide authorized sharing of data in the common model to prevent data from being shared to unauthorized 3rd parties.	(AIA E203, 2013; BBIM, 2015; BSI PAS2, 2013; CANBIM, 2014; CDOC301, 2015; Charehzehi et al., 2017; CIC BIM, 2018; CIOB, 2013; COBIM, 2012; DASBIM, 2015; Eastman et al., 2010; NATSPEC, 2016; NBGO, 2017; NBIM, 2013; PSUBIM, 2019; SBEnrcBIM, 2017; SBIM, 2013; Solihin and Eastman, 2015; USCBIM, 2012; USFBIM, 2018) **LACLR, QS**
○ Term of Usage Letter 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.	(AIA E203, 2013; CANBIM, 2014; CIC BIM, 2018; Eschenbruch and Bodden, 2018) **QS**
○ 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 Determine the procedures for storing all data of the project and the BIM model during the project process.	(AIA E203, 2013; BBIM, 2015; BSI PAS2, 2013; CANBIM, 2014; Lai et al., 2019; NATSPEC, 2016; NBGO, 2017; NBIM, 2013; PSUBIM, 2019; SBIM, 2013) **IS, QS**
○ Digital Data Archiving Determine the archiving procedures of all data of the project and the BIM model after the close-out phase of the project.	(AIA E203, 2013; Bakhary et al., 2015; BBIM, 2015; BSI PAS2, 2013; CANBIM, 2014; COBIM, 2012; NATSPEC, 2016; NBGO, 2017; NBIM, 2013; PSUBIM, 2019; USCBIM, 2012; USFBIM, 2018)

○ Back-up and Restore Procedures of Data Set backup and restore procedures for Deterioration and loss problems that may occur in the 3D common model.	(CDOC301, 2015; OLATUNJİ, 2011)

Table 5.9 : Critical points of interoperability.

Critical Points	References
☐ Modes of Collaboration Identify procedures, priorities and critical points for the collaboration of different disciplines in the common model.	(AIA E203, 2013; BBIM, 2015; BSI PAS2, 2013; CANBIM, 2014; COBIM, 2012; NATSPEC, 2016; NBIM, 2013; PSUBIM, 2019; SBIM, 2013) **IS, QS**
○ Clash Detection 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.	(AIA E203, 2013; BBIM, 2015; BSI PAS1, 2015; CANBIM, 2014; COBIM, 2012; DASBIM, 2015; Li et al., 2017; NATSPEC, 2016; NBGO, 2017; NBIM, 2013; PSUBIM, 2019; SBEnrcBIM, 2017; SBIM, 2013; USCBIM, 2012; USFBIM, 2018; Ussing et al., 2016) **LACLR, IS, QS**
○ Extracting 2D Drawings from 3D Model 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.	(CANBIM, 2014; CDOC301, 2015; USFBIM, 2018) **LACLR, IS, QS**
☐ Change Order Procedures 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**	(BSI ISO1, 2018; CANBIM, 2014; CDOC301, 2015; CIOB, 2013; COBIM, 2012; DASBIM, 2015; NATSPEC, 2016; NBGO, 2017; PSUBIM, 2019; SBEnrcBIM, 2017; SBIM, 2013; USCBIM, 2012; USFBIM, 2018) **LACLR, IS, QS**

Table 5.10 : Critical points of data security.

Critical Points	References
☐ Data Security Protocol for Loss, Corruption and Virus 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**	(BBIM, 2015; BSI PAS5, 2015; CANBIM, 2014; CDOC301, 2015; Chien et al., 2014; CIOB, 2013; COBIM, 2012; Dougherty, 2015; Eschenbruch and Bodden, 2018; NATSPEC, 2016; NBGO, 2017; PSUBIM, 2019; SBIM, 2013) **IS, QS**
○ Encrypted Filing Identify encrypted filing systems and system procedures for data security.	(CDOC301, 2015)
○ Access from Unknown Server Identify procedures for accessing unknown servers to protect data from viruses or theft.	(CIOB, 2013; Chien et al., 2014) **QS**
○ Data Insurance Use data insurance to cover financial losses that will arise from any problems with data security.	(CDOC301, 2015; Manderson et al., 2015)

Table 5.11 : Critical points of operation phase.

Critical Points	References
☐ As-Built Model Procedures 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**	(BSI PAS2, 2013; COBIM, 2012; NBIM, 2013; SBIM, 2013) **LACLR, IS, QS**
☐ 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 Specify the necessary regulations regarding the models that will be transferred to the operator following the realization of the project.	(BBIM, 2015; BSI PAS3, 2014; COBIM, 2012; Eschenbruch and Bodden, 2018; NATSPEC, 2016; NBGO, 2017; NBIM, 2013; PSUBIM, 2019; SBEnrcBIM, 2017; SBIM, 2013; USCBIM, 2012; USFBIM, 2018) **IS, QS**
○ Maintenance Manuals Indicate the necessary procedures for the transfer of maintenance manuals related to construction materials and technical equipment used in the project to the operator.	(BSI PAS3, 2014; COBIM, 2012; NBGO, 2017; PSUBIM, 2019; SBEnrcBIM, 2017; USCBIM, 2012; USFBIM, 2018)

6. CONCLUSIONS AND RECOMMENDATIONS

This research aims to improve the contract preparation phase of the BIM-based construction projects through preliminary checklist template proposal which can be considered as a potential input in the contract preparation phase of these projects. To achieve this aim, the following objectives have been achieved (Table 1.1.): (1) To review the BIM guidelines, standard contracts and protocols; (2) To determine the critical aspects and issues to be considered in the BIM-based construction contracts; and (3) To propose a preliminary checklist template which can be considered as a potential input in the contract preparation phase of the BIM-based construction projects. With this aim and objectives, firstly the literature review has been performed and various international guidelines, standard contracts and protocols have been examined, and processes, stakeholders and documents related to BIM-based project management have been investigated. Then, a literature research was conducted to determine the causes for the claims and disputes in BIM-based construction projects. Moreover, litigation awards and case laws due to BIM-related disputes in BIM-based construction projects have been investigated through local and international databases. In line with the objectives, interviews were carried out. An online questionnaire survey was conducted to professionals having expertise and/or experience in BIM-based projects. In line with the data obtained as a result of the literature review and field research, a suggestion for the preliminary checklist template has been created that indicates the issues to be considered when preparing BIM-based construction project contracts. Second stage interviews were made with professionals for the verification study of the created preliminary checklist template proposal.

The main findings obtained as a result of the literature review, litigation award and case law research, interviews with professionals, and questionnaire survey study are summarized below:

Review of existing BIM guidelines, standard contracts, and protocols:

- According to the results of the interviews and questionnaire survey, BIM integration has several challenges, but BIM is suitable to be integrated into all

types of projects and provides a variety of performance improvements at all stages of the project.

- It was determined that international guidelines described BIM processes more comprehensively than standard contracts and protocols.
- The use of protocols and guidelines only as supportive documents or addenda, not as the main contract, can create contradictions in some cases. If the contractual status of the document to be referred to in the main agreement is not clearly determined, it may cause disputes. In addition, since the majority of the guidelines are created in the form of recommendations rather than legal provisions regarding the BIM process, it has been determined that they may cause disputes if they are not integrated into the contract with legal counseling.
- Each of the examined guidelines and protocols has its weaknesses and strengths in covering issues that may lead to claim and dispute. As every project is unique in various subjects such as size, complexity, and cost, it has been determined that there is no standard document that can be used directly in all types of projects. Project-specific arrangements, additions or inferences should be made in the document used to avoid problems during the project process.
- Documents generally describe the process from the beginning of the project to the completion of the construction. Very few documents (BSI ISO1, 2018; NBIM, 2013; COBIM, 2012) covered the project process, from the organizational and asset decision phase to the demolition of the building. Contractual arrangements for an efficient and effective BIM integration should cover the process from organizational decision stages to the demolition of projects, including the operation and maintenance phase.
- The appointment of a BIM manager responsible for the BIM process of the project can reduce the problems that can arise during BIM integration. The responsibility of BIM processes can be assigned to a single person or to representatives of the main construction disciplines.
- It is determined that the most important document regarding BIM processes is the BEP. BEP should be created comprehensively with the contribution of all

project participants in line with the requirements of the owner, specific to the project.

Identification of the causes of claims and disputes in BIM-based projects and determination of the issues to be considered in the contracts:

- Conflicts and disputes are often contractual issues in the BIM integration process, as rights and responsibilities between stakeholders change with BIM.

Allocation of risks and responsibilities:

- Inadequate definition of BIM-related processes, tasks, requirements, rights, and responsibilities in the BIM-based contract causes conflicts and disputes. Furthermore, in any dispute that may arise, the contractual status of the 3D BIM model and/or the information it contains must be specified in the contract.
- Qualification of BIM competencies of suppliers and subcontractors, which are important stakeholders of the construction project, can reduce problems.
- It has been determined that conflict and dispute may occur due to the lack of responsibility arrangements regarding third-party consultancy.

IPR:

- IPRs of stakeholders can be violated voluntarily or involuntarily due to the collaborative work of the BIM integration process on the common model. Therefore, the regulations regarding the ownership rights of the produced, shared, or transferred information or model should be clearly stated in the contract.
- The fact that the common BIM model is open to access by unauthorized third parties, and that stakeholders' valuable information can be shared without permission has been identified as a challenge in IPR. Regulations on authorized access, sharing, and use of information on the common platform in the contract may reduce disputes arising from this issue.

Interoperability:

- With the increase in the size and complexity of construction projects, the number of stakeholders has also increased. When all stakeholders work together with the BIM system, various problems may arise when changing relationships are not regulated. For this reason, starting from the beginning of the project, BIM meetings should be held regularly, including all stakeholders, and the expectations and duties of the parties should be determined.

- Access to the common BIM model should be authorized to reduce conflicts and problems that may arise, and an electronic stamp or signature should be used to control changes made by the teams. In addition, arrangements should be made to reduce problems in interdisciplinary information exchanges and mergers.

- Conflicts may occur when the types or versions of software used by teams working together are different. Consequently, the software to be used according to the project stages should be determined and the information should be shared in native format.

- With the integration of BIM into the project, the overlapping construction practices experienced during the construction process decreased. Nevertheless, there are overlapping construction practices due to the lack of competence of stakeholders in BIM and the problems that occur during the use of the model. In order to reduce the conflicts and disputes that can arise, the processes and responsibilities for clash detection on the model should be determined. In addition, regulations regarding change orders should also be included in the contract.

- Uncertain LOD levels can lead to conflict and disputes. Therefore, national or international LOD levels should be defined. LOD levels and requirements should be specified in the contract, according to the BIM stages.

- The design of the project in a common BIM model, but the implementation of the construction on 2D drawings produced in different environments, can cause contradictions between design and construction and conflicts between different construction applications. For this reason, all 2D drawings to be used in

construction applications should be extracted from the 3D common BIM model.

Data security and documentations:

- The fact that digital data on the common BIM platform is vulnerable to corruption, loss, and theft raises concerns about data security. For this reason, a protocol should be created regarding digital data storage, archiving, and security.

- Cloud-based or traditional database systems must be protected against physical or software threats. Firewall systems can be used for viruses and cyber-attacks. Project stakeholders' access to the common platform from unknown servers should also be regulated. Encrypted filing systems can also improve data security.

- In the event of loss or corruption of data, conflicts and disputes can occur. Back-up and restored procedures should be determined for such problems. Data can be insured to compensate for financial losses caused by data security issues.

- Transferring the model to the facility manager during the project's closeout phase reduces the problems that may arise during the operation. Arrangements regarding the as-built model and maintenance manuals to be transferred to the operator should be specified in the contract.

Proposal of a preliminary checklist template which can be considered as a potential input in the contract preparation phase:

For the aim of this study, critical points have been determined based on the results obtained from the literature review and field research. Based on these critical points, a preliminary checklist template proposal was prepared to be used as potential input to be considered in the contract preparation phase of BIM-based construction projects.

Experiences and expertise from BIM-based construction projects can enhance the proposed preliminary checklist template. Likewise, this preliminary checklist template can be updated with the developments in the CI in the future.

Within the scope of the dissertation, BIM-based construction project contracts were examined in terms of legal aspects and a suggestion for the preliminary checklist template has been prepared. The proposed preliminary checklist can be used by employers, contractors, architects, and engineers in the CI who want to create a BIM-based project contract. Since the preliminary checklist template has been created as a suggestion, it may need to be customized according to the conditions of the project to be used. This dissertation is useful for all construction stakeholders involved in BIM-based projects and who have legal concerns. Furthermore, it can be a resource for students and academics interested in the subject. In addition, this research can be beneficial to lawmakers and public entities engaged in legal regulations concerning the construction practices.

REFERENCES

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

Abdul-Malak, M.-A. U., & Abdulhai, T. A. (2017). Conceptualization of the Contractor's Project Management Group Dynamics in Claims Initiation and Documentation Evolution. *Journal of Legal Affairs and Dispute Resolution in Engineering and Construction*, *9*(3), 04517014. doi: 10.1061/(asce)la.1943-4170.0000229

Acharya, N. K., Lee, Y. D., & Im, H. M. (2006). Conflicting factors in construction projects: Korean perspective. *Engineering, Construction and Architectural Management*, *13*(6), 543–566. doi: 10.1108/09699980610712364

Akintola, A., Venkatachalam, S., & Root, D. (2017). New BIM Roles' Legitimacy and Changing Power Dynamics on BIM-Enabled Projects. *Journal of Construction Engineering and Management*, *143*(9), 04017066. doi: 10.1061/(asce)co.1943-7862.0001366

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. Procs 30th Annual ARCOM Conference, *Association of Researchers in Construction Management*, pp. 623-632.

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

Arcadis Consulting Company. (2016). *Global Construction Disputes Record 2016*. 17. Retrieved from https://www.arcadis.com/media/3/E/7/%7B3E7BDCDC-0434-4237-924F-739240965A90%7DGlobal Construction Disputes Report 2016.pdf

Arcadis Consulting Company. (2019). *Global Construction Disputes Record 2019*. Retrieved from https://images.arcadis.com/media/5/D/1/%7B5D16141D-B883-4398-BB35-218023E1F4F6%7DRP_GCDR_AL20190620_Final.pdf

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

Arshad, M. F., Thaheem, M. J., Nasir, A. R., & Malik, M. S. A. (2019). Contractual Risks of Building Information Modeling: Toward a

Standardized Legal Framework for Design-Bid-Build Projects. *Journal of Construction Engineering and Management*, *145*(4), 1–13. https://doi.org/10.1061/(ASCE)CO.1943-7862.0001617

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

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

Assaf, S., Hassanain, M. A., Abdallah, A., Sayed, A. M. Z., & Alshahrani, A. (2019). Significant causes of claims and disputes in construction projects in Saudi Arabia. *Built Environment Project and Asset Management*, *9*(5), 597–615. https://doi.org/10.1108/BEPAM-09-2018-0113

Australian Government Productivity Commission. (2014). *Public Infrastructure Productivity Commission Inquiry Report: Volume 1* (Vol. 1). Retrieved from http://www.pc.gov.au/__data/assets/pdf_file/0003/137280/infrastructure-volume1.pdf

Ayudhya, B. I. N. (2011). Common disputes related to public work projects in Thailand, *Songklanakarin Journal of Science and Technology*, Vol. 33 No. 5, pp. 565-573.

Azhar, S. (2011). Building Information Modeling (BIM): Trends, Benefits, Risks, and Challenges for the AEC Industry. *Leadership and Management in Engineering*, *11*(3), 241–252. doi: 10.1061/(asce)lm.1943-5630.0000127

Azhar, S., Hein, M., Sketo, B. (2011). Building Informtion Modeling benefits, risks and challenges. Auburn, Alabama: Auburn University

Azhar, S., Khalfan, M., & Maqsood, T. (2015). Building information modelling (BIM): now and beyond. *Construction Economics and Building*, *12*(4), 15–28. doi: 10.5130/ajceb.v12i4.3032

Bach, M. (2014). The Project Coach: The New Role of the Project Manager for the Future Due to the News Tools Like Building Information Modelling, Integrated Project Delivery, Last Planner and Others. In C. Llinares-Millán, I. Fernández-Plazaola, F. Hidalgo-Delgado, M. M. Martínez-Valenzuela, F. J. Medina-Ramón, I. Oliver-Faubel, I. Rodríguez-Abad, A. Salandin, R. Sánchez-Grandia, I. Tort-Ausina (Eds.), *Construction and Building Research*. London: Springer. doi: 10.1007/978-94-007-7790-3

Bailey, J., Turrini, M., Robottom, L., & Duncan, C. (2019). *06.01.2019 NEC4 su te of standard form contracts to be released in June | White & Case LLP International Law Firm, Global Law Practice 03*. (May 2017), 2017–2019.

Bakhary, N. A., Adnan, H., & Ibrahim, A. (2015). A Study of Construction Claim Management Problems in Malaysia. *Procedia Economics and Finance*, *23*, 63–70. doi: 10.1016/s2212-5671(15)00327-5

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

Barakeh, K., & Almarri, K. (2013). Management of the Organizational and Contractual Risks of BIM Projects in the Architecture, *Engineering and Construction Industry (AEC), Proceedings of 3rd International Sustainable Buildings Symposium*, 2017. Springer.

Becerik-Gerber, B., Jazizadeh, F., Li, N., & Calis, G. (2012). Application areas and data requirements for BIM-enabled facilities management. *Journal of Construction Engineering and Management*, *138*(3), 431–442. https://doi.org/10.1061/(ASCE)CO.1943-7862.0000433

Belgian Guide for the construction Industry – BIM. (2015). The guide to Building Information Modelling Version 1.0. Belgium.

Borrmann, A., König, M., Koch, C., & Beetz J. (2018). Building Information Modeling: Why?What? How? In A. Borrmann, M. König, C. Koch, J Beetz (Eds.) *Building Information Modeling: Technology Foundations and Industry Practice* (pp. 1-21). Switzerland: Springer. https://doi.org/10.1007/978-3-319-92862-3

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

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

Building Engineering Services Association (BESA). (2017). *First steps to BIM competence: A guide for specialist contractors.* Retrieved from https://www.thebesa.com/media/2899/bim-competence-final.pdf

Bynum, P., Issa, R. R. A., & Olbina, S. (2013). Building Information Modeling in Support of Sustainable Design and Construction. *Journal of Construction Engineering and Management*, *139*(1), 24–34. doi: 10.1061/(asce)co.1943-7862.0000560

Cakmak, E., & Cakmak, P. I. (2014). An Analysis of Causes of Disputes in the Construction Industry Using Analytical Network Process. *Procedia - Social and Behavioral Sciences*, *109*, 183–187. https://doi.org/10.1016/j.sbspro.2013.12.441

Canada BIM Protocol. (2014). AEC(CAN) BIM Protocol. AEC(Can)BIM.

Chan, E. H., & Suen, H. C. (2005). Dispute resolution management for international construction projects in China. *Management Decision*, *43*(4), 589–602. doi: 10.1108/00251740510593576

Charehzehi, A., Chai, C. S., Md Yusof, A., Chong, H. Y., & Loo, S. C. (2017). Building information modeling in construction conflict management.

International Journal of Engineering Business Management, *9*, 1–18. https://doi.org/10.1177/1847979017746257

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

Cheung, S. O., & Yiu, T. W. (2006). Are construction disputes inevitable? *IEEE Transactions on Engineering Management*, *53*(3), 456–470. https://doi.org/10.1109/TEM.2006.877445

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

Chong, H. Y., Fan, S. L., Sutrisna, M., Hsieh, S. H., & Tsai, C. M. (2017). Preliminary contractual framework for BIM-enabled projects. *Journal of Construction Engineering and Management*, *143*(7). https://doi.org/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). ConsensusDocs301 Building Information Modeling (BIM) Addendum - 2008, Revised 2015.

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

Çevikbaş, M., & Köksal, A. (2018). An investigation of litigation process in construction industry in Turkey. *Teknik Dergi/Technical Journal of Turkish Chamber of Civil Engineers*, *29*(6), 8715–8729. https://doi.org/10.18400/tekderg.389757

Davies, K., Mcmeel, D., Wilkinson, S. (2015). Soft skill requirements in a BIM project team. In Beetz, J., Van Berlo, L., Hartmann, T., Amor, R. (Eds.), *CIB W78 Information Technology for Construction Conference (CIB W78)*, 32nd vol. 2015. Eindhoven, Netherlands, pp. 108–117.

Demian, P., & Walters, D. (2013). The advantages of information management through building information modelling. *Construction Management and Economics*, *32*(12), 1153–1165. doi: 10.1080/01446193.2013.777754

Department of Administrative Services (DAS). BIM Guidelines. (2015). BIM Guidelines CT DAS 0420 Rev. 11.09.15. United States.

Diekmann, J. E., & Nelson, M. C. (1985). Construction Claims: Frequency and Severity. *Journal of Construction Engineering and Management*, *111*(1), 74–81. doi: 10.1061/(asce)0733-9364(1985)111:1(74)

Division of Capital Asset Management and Maintenance (DCAMM). (2015). *BIM guidelines for design and construction.* Retrieved from https://www.mass.gov/doc/bim-guidelines-for-design-and-construction/download

Dougherty, J. M. (2015). Claims, disputes and litigation involving BIM. In *Claims,*

Disputes and Litigation Involving BIM. https://doi.org/10.4324/9781315689012

Dulaimi, M. F., Y.ling, F. Y., Ofori, G., & Silva, N. D. (2002). Enhancing integration and innovation in construction. *Building Research & Information*, *30*(4), 237–247. doi: 10.1080/09613210110115207

Eadie, R., McLernon, T., Patton, A. (2015). An Investigation Into the Legal Issues Relating to Building Information Modelling (BIM), The Construction, Building and Real Estate Research Conference of the Royal Institution of Chartered Surveyors, Australia, 8 -10 July 2015. London: Royal Institution of Chartered Surveyors.

Eastman, C. M., Jeong, Y. S., Sacks, R., & Kaner, I. (2010). Exchange Model and Exchange Object Concepts for Implementation of National BIM Standards. *Journal of Computing in Civil Engineering*, *24*(1), 25–34. doi: 10.1061/(asce)0887-3801(2010)24:1(25)

Eastman, C. M., Teicholz, P. M., Sacks, R., & Lee, G. (2018). *Bim handbook: a guide to building information modeling for owners, managers, designers, engineers and contractors*. Hoboken, NJ: Wiley.

Eschenbruch, K., & Bodden, J. L. (2018). Integrating BIM in construction contracts. In A. Borrmann, M. König, C. Koch, J Beetz (Eds.) *Building Information Modeling: Technology Foundations and Industry Practice* (pp. 1-21). Switzerland: Springer. https://doi.org/10.1007/978-3-319-92862-3

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

FERMILAB: Facilities Engineering Services Section. (2015). *Building Information Modeling (BIM) Guide.* Retrieved from https://web.fnal.gov/organization/fess/Shared%20Documents/BIM_Guide.pdf

Fountain, J., & Langar, S. (2018). Building Information Modeling (BIM) outsourcing among general contractors. *Automation in Construction*, *95*(August), 107–117. https://doi.org/10.1016/j.autcon.2018.06.009

Ganah, A., & John, G. A. (2015). Integrating Building Information Modeling and Health and Safety for Onsite Construction. *Safety and Health at Work*, *6*(1), 39–45. doi: 10.1016/j.shaw.2014.10.002

Gardezi, S. S., Shafiq, N., & Khamidi, M. F. (2013). Prospects of Building Information Modeling (BIM) in Malaysian construction industry as conflict resolution tool. *Journal of Energy Technologies and Policy*, 3(11): 346–350.

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

https://doi.org/10.1016/j.rser.2016.11.083

Gibbs, D. J., Emmitt, S., Lord, W., & Ruikar, K. (2007). BIM and Construction Contracts CPC 2013's Approach. *Proceedings of ICE - Management, Procurement & Law.*, *4304*(Level 0).

Greenwood, D., Lewis, S., Lockley, S. (2010). Contractual Issues in the Total Use of Building Information Modelling, *Special Track 18th CIB World Building Congress (W-113)*, United Kingdom, 10-13 May 2010.

Hafeez, M. A., Chahrour, R., Vukovic, V., Dawood, N., & Kassem, M. (2016). Investigating the Potential of Delivering Employer Information Requirements in BIM Enabled Construction Projects in Qatar. *Product Lifecycle Management in the Era of Internet of Things IFIP Advances in Information and Communication Technology*, 159–172. doi: 10.1007/978-3-319-33111-9_15

Hardin, B. (2015). *Bim and construction management: proven tools, methods, and workflows*. Indianapolis, IN: Wiley.

Haugen, T., & Singh, A. (2015). Dispute Resolution Strategy Selection. *Journal of Legal Affairs and Dispute Resolution in Engineering and Construction*, *7*(3), 05014004. doi: 10.1061/(asce)la.1943-4170.0000160

Hayati, K., Latief, Y., & Rarasati, A. D. (2019). Causes and Problem Identification in Construction Claim Management. *IOP Conference Series: Materials Science and Engineering*, *469*(1). https://doi.org/10.1088/1757-899X/469/1/012082

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

Hendrickson, C. & Au, T. (2000). Project Management for Construction, Fundamental Concepts for Owners, Engineers, Architects and Builder. Pittsburgh, United States: Carnegie Mellon University, PA.

Hietanen, J. (2006). IFC model view definition format. *International Alliance for Interoperability*. Retrieved from https://www.buildingsmartsingapore.org/news/news-docs/20060410_IFC_MVD_Format.pdf

Holzer, D. (2016). *The Bim managers handbook: guidance for professionals in architecture, engineering, and construction*. Chichester, West Sussex: John Wiley & Sons.

Howard, J., & Ciliberto, C. (2016). Why BIM, and Appropriate BIM Contracts, are Critical to Project Success. *Design Cost & Data*, *60*(1), 16. Retrieved from 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., & 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), 127–133. https://doi.org/10.1680/feng.14.00005

Huzaimi Abd Jamil, A., & 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). https://doi.org/10.1088/1757-899X/513/1/012035

Ilter, D. (2012). Identification of the relations between dispute factors and dispute categories in construction projects. *International Journal of Law in the Built Environment*, *4*(1), 45–59. doi: 10.1108/17561451211211732

Irlayici Çakmak, P. (2016). Causes of disputes in the turkish construction industry: Case of public sector projects. *A/Z ITU Journal of the Faculty of Architecture*, *13*(3), 109–118. https://doi.org/10.5505/itujfa.2016.69885

Islam, M. S., & Trigunarsyah, B. (2017). Construction Delays in Developing Countries: A Review. *Journal of Construction Engineering and Project Management*, *7*(1), 1–12. doi: 10.6106/jcepm.2017.3.30.001

Jaradat, S., Whyte, J., & Luck, R. (2013). Professionalism in digitally mediated project work. *Building Research & Information*, *41*(1), 51–59. doi: 10.1080/09613218.2013.743398

Jervis, B. M., & Levin, P. (1988). *Construction law, principles and practice*. New York: McGraw-Hill.

Jo, T. M., Ishak, S. S. M., & 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*. https://doi.org/10.1051/matecconf/201820302011

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

Keeley, A. (2017). BIM: Legal Issues. Retrieved June 7, 2020, from https://www.charlesrussellspeechlys.com/en/news-and-insights/insights/constuction-engineering-and-projects/2017/bim-legal-issues/

Kenley, R., Harfield, T., & Behnam, A. (2016). BIM Interoperability Limitations: Australian and Malaysian Rail Projects. *MATEC Web of Conferences*, *66*, 4–8. https://doi.org/10.1051/matecconf/20166600102

Khahro, S. H., & Ali, T. H. (2014). Causes leading to conflicts in construction projects: a viewpoint of Pakistani construction industry, *Proceedings of the International Conference on Challenges in IT, Engineering and Technology*, Phuket, July 17–18, pp. 116-121.

Kuiper, I., & 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), 1–17. https://doi.org/10.5130/ajceb.v13i4.3630

Lai, H., Deng, X., & Chang, T. Y. P. (2019). BIM-Based Platform for Collaborative Building Design and Project Management. *Journal of*

Computing in Civil Engineering, *33*(3), 1–15. https://doi.org/10.1061/(ASCE)CP.1943-5487.0000830

Li, X., Xu, J., & Zhang, Q. (2017). Research on Construction Schedule Management Based on BIM Technology. *Procedia Engineering*, *174*, 657–667. https://doi.org/10.1016/j.proeng.2017.01.214

Lin, Y. C., Chen, Y. P., Huang, W. T., & Hong, C. C. (2016). Development of BIM execution plan for BIM model management during the pre-operation phase: A case study. *Buildings*, *6*(1). https://doi.org/10.3390/buildings6010008

Liu, H. L., Wang, G. Bin, & Zhang, L. (2013). Research on BIM-based construction project organization interface management. *Applied Mechanics and Materials*, *357–360*, 2781–2784. https://doi.org/10.4028/www.scientific.net/AMM.357-360.2781

Liu, Y., van Nederveen, S., & Hertogh, M. (2017). Understanding effects of BIM on collaborative design and constructionAn empirical study in China. *International Journal of Project Management*, *35*(4), 686–698. https://doi.org/10.1016/j.ijproman.2016.06.007

Manderson, A., Jefferies, M., & Brewer, G. (2015). Building information modelling and standardised construction contracts: A content analysis of the GC21 contract. *Construction Economics and Building*, *15*(3), 72–84. https://doi.org/10.5130/AJCEB.v15i3.4608

Mcadam, B. (2010). Building information modelling: the UK legal context. *International Journal of Law in the Built Environment*, *2*(3), 246–259. doi: 10.1108/17561451011087337

McGraw Hill. (2014). *The Business Value of BIM for Construction in Major Global Markets: How Contractors around the World are Driving Innovation with Building Information Modeling*. McGraw Hill, Bedford, MA, USA, SmartMarket Report. Retrieved from https://www.icn-solutions.nl/pdf/bim_construction.pdf

McCombe, V. (2018). We need a standard approach to BIM and building contracts. Retrieved June 10, 2020, from https://www.bimplus.co.uk/people/we-need-standard-approach-bim-and-building-contrac/

Mishmish, M., & El-Sayegh, S. M. (2016). Causes of claims in road construction projects in the UAE. *International Journal of Construction Management*, *18*(1), 26–33. doi: 10.1080/15623599.2016.1230959

Mosey, D. (2014). BIM and Related Revolutions: A Review of the Cookham Wood Trial Project. *Society of Construction Law*, Hinckley, UK, D171.

Narh, O. C., Owusu, E. E., Oduro-Apeatu, K. & Narh, T.W.J. (2015). An exploratory study of professional conflicts and disputes within the construction industry, *International Journal of Managerial Studies and Research*, Vol. 3 No. 12, pp. 44-65.

National BIM Guide for Owners. (2017). National Institute of Building Sciences. USA: National Institute of Building Sciences.

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

Centre. Australia.

National Building Specification (NBS) (2013). National Construction Contracts and Law Survey 2013. RIBA, Newcastle Upon Tyne, UK.

National Building Specification. (2016). What is BIM? Retrieved from https://www.thenbs.com/knowledge/what-is-building-information-modelling-bim.

National Building Specifications, National BIM Guide. (2016). NATSPEC National BIM Guide. Australia: Construction Information Systems Limited.

National Research Council (NCR). (2009). Advancing the competitiveness and efficiency of the U.S. construction industry. Washington, D.C.: National Academies Press.

New Engineering Contract 4 (NEC4). (2017). Engineering and Construction Contract. Great Britain: Bell & Bain Limited, Galsgow,UK.

Norway BIM Manual. (2013). Statsbygg Building Information Modelling Manual Version 1.2.1

Olatunji, O. A. (2011). A preliminary review on the legal implications of BIM and model ownership. *Electronic Journal of Information Technology in Construction*, *16*(August 2010), 687–696.

Olatunji, O. A. (2016). Constructing Dispute Scenarios in Building Information Modeling. *Journal of Legal Affairs and Dispute Resolution in Engineering and Construction*, *8*(1). doi: 10.1061/(asce)la.1943-4170.0000165

Olawumi, T. O., & Chan, D. W. M. (2018). Building information modelling and project information management framework for construction projects. *Journal of Civil Engineering and Management*, *25*(1), 53–75. https://doi.org/10.3846/jcem.2019.7841

Olsen, D., & Mark Taylor, J. (2010). Building Information Models as contract documents: Common practice for the U.S. construction industry - A preliminary report. *COBRA 2010 - Construction, Building and Real Estate Research Conference of the Royal Institution of Chartered Surveyors*, 364–373.

Oviedo-Haito, R. J., Jiménez, J., Cardoso, F. F., & Pellicer, E. (2014). Survival Factors for Subcontractors in Economic Downturns. *Journal of Construction Engineering and Management*, *140*(3), 04013056. doi: 10.1061/(asce)co.1943-7862.0000811

Pandey, A., Shahbodaghlou, F., & Burger, J. (2016). *Legal and Contractual Challenges of Building Information Modeling—Designers' Perspectives*. Construction Research Congress 2016. doi: 10.1061/9780784479827.053

Papadonikolaki, E., van Oel, C., & Kagioglou, M. (2019). Organising and Managing boundaries: A structurational view of collaboration with Building Information Modelling (BIM). *International Journal of Project Management*, *37*(3), 378–394. https://doi.org/10.1016/j.ijproman.2019.01.010

Papadonikolaki, E., Vrijhoef, R., & Wamelink, H. (2016). The interdependences of BIM and supply chain partnering: empirical explorations. *Architectural Engineering and Design Management*, *12*(6), 476–494. doi: 10.1080/17452007.2016.1212693

Parikh, D., Joshi, G. J., & Patel, D. A. (2019). Development of Prediction Models for Claim Cause Analyses in Highway Projects. *Journal of Legal Affairs and Dispute Resolution in Engineering and Construction*, *11*(4), 1–11. https://doi.org/10.1061/(ASCE)LA.1943-4170.0000303

Pennsylvania State University. (2019). BIM Project Execution Planning Guide - Version 2.2. Computer Integrated Construction Research Program, United States: Penn State University Park, Pa.

Porwal, A., & Hewage, K. N. (2013). Building Information Modeling (BIM) partnering framework for public construction projects. *Automation in Construction*, 31, 204-214. doi:10.1016/j.autcon.2012.12.004

Project Management Body of Knowledge (PMBOK). (2017). A guide to the project management body of knowledge (PMBOK guide) Sixth edition. USA: Project Management Institute, Inc.

Rahman, R. A., Alsafouri, S., Tang, P., & Ayer, S. K. (2016). Comparing Building Information Modeling Skills of Project Managers and BIM Managers Based on Social Media Analysis. *Procedia Engineering*, *145*, 812–819. doi: 10.1016/j.proeng.2016.04.106

Rokooei, S. (2015). Building Information Modeling in Project Management: Necessities, Challenges and Outcomes. *Procedia - Social and Behavioral Sciences*, *210*, 87–95. https://doi.org/10.1016/j.sbspro.2015.11.332

Sabri, O. K., Lædre, O., & Bruland, A. (2019). Why conflicts occur in roads and tunnels projects in Norway. *Journal of Civil Engineering and Management*, *25*(3), 252–264. https://doi.org/10.3846/jcem.2019.8566

Samuelson, O., and Björk, B. C. (2014). A longitudinal study of the adoption of IT technology in the Swedish building sector. Automation in Construction, 37 (1), 182–190. https://doi.org/10.1016/j.autcon.2013.10.006.

Sardroud, J. M., Mehdizadehtavasani, M., Khorramabadi, A., & Ranjbardar, A. (2018). Barriers analysis to effective implementation of BIM in the construction industry. *ISARC 2018 - 35th International Symposium on Automation and Robotics in Construction and International AEC/FM Hackathon: The Future of Building Things*, (Isarc). https://doi.org/10.22260/isarc2018/0009

Schapke, E., Beetz, J., König, M., Koch, C., & Borrmann, A. (2018). Collaborative Data Management. In A. Borrmann, M. König, C. Koch, J Beetz (Eds.) *Building Information Modeling: Technology Foundations and Industry Practice* (pp. 251-276). Switzerland: Springer. https://doi.org/10.1007/978-3-319-92862-3

Scheffer, M., Mattern, H., & König M. (2018). BIM-Based Collaboration. In A. Borrmann, M. König, C. Koch, J Beetz (Eds.) *Building Information*

Modeling: Technology Foundations and Industry Practice (pp. 235-249). Switzerland: Springer. https://doi.org/10.1007/978-3-319-92862-3

Semple, C., Hartman, F. T., & Jergeas, G. (1994). Construction Claims and Disputes: Causes and Cost/Time Overruns. *Journal of Construction Engineering and Management*, *120*(4), 785–795. doi: 10.1061/(asce)0733-9364(1994)120:4(785)

Shahhosseini, V., & Hajarolasvadi, H. (2018). A conceptual framework for developing a BIM-enabled claim management system. *International Journal of Construction Management*, *0*(0), 1–15. https://doi.org/10.1080/15623599.2018.1512182

Siemens AG. (2017). *BIM @ Siemens Real Estate*.

Singapore BIM Guide. (2013). Singapore BIM Guide Version 2. Building and Construction Authority. Singapore.

Solihin, W., & Eastman, C. (2015). Classification of rules for automated BIM rule checking development. *Automation in Construction*, *53*, 69–82. doi: 10.1016/j.autcon.2015.03.003

Söderlund, J. (2004). Building theories of project management: past research, questions for the future. *International Journal of Project Management*, *22*(3), 183–191. doi: 10.1016/s0263-7863(03)00070-x

Srinivasan, N. P., & Dhivya, S. (2020). An empirical study on stakeholder management in construction projects. *Materials Today: Proceedings*, *21*, 60–62. https://doi.org/10.1016/j.matpr.2019.05.361

Stamatiou, D. R. I., Kirytopoulos, K. A., Ponis, S. T., Gayialis, S., & Tatsiopoulos, I. (2019). A process reference model for claims management in construction supply chains: the contractors' perspective. *International Journal of Construction Management*, *19*(5), 382–400. https://doi.org/10.1080/15623599.2018.1452100

Succar, B. (2010). Building Information Modelling Maturity Matrix. *Handbook of Research on Building Information Modeling and Construction Informatics Advances in Civil and Industrial Engineering*, 65–103. doi: 10.4018/978-1-60566-928-1.ch004

Tulke, J., & Schumann, R. (2018). BIM Manager. In A. Borrmann, M. König, C. Koch, J Beetz (Eds.) *Building Information Modeling: Technology Foundations and Industry Practice* (pp. 293-302). Switzerland: Springer. https://doi.org/10.1007/978-3-319-92862-3

Udom, K. (2012). BIM: mapping out the legal issues. Retrieved June 7, 2020, from https://www.thenbs.com/knowledge/bim-mapping-out-the-legal-issues

Uhm, M., Lee, G., & 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), 67–98. https://doi.org/10.1016/j.autcon.2017.06.002

University of South Florida. (2018). BIM Guidelines and Standards: For Architects, Engineers and Contractors. United States: University of South Florida.

University Of Southern California. (2012). Building Information Modeling (BIM) Guidelines version 1.6. USC Capital Construction Development and Facilities Management Services. United States.

Ussing, L. F., Svidt, K., & Wandahl, S. (2016). Legal Aspects Connected to the Use of BIM in the Danish Building Sector. Construction Research Congress 2016. doi: 10.1061/9780784479827.054

Waldron, B. D. (2006). *Scope for improvement: a survey of pressure points in Australian construction and infrastructure projects*. Sydney: Blake Dawson Waldron.

Wallbank, B. (2019). *An Introduction to BIM and Contracts*. 1–7.

Working Party Strategy Paper (WPSP). (2011). *A report for the Government Construction Client Group: Building Information Modelling (BIM) Working Party Strategy Paper*. Retrieved from https://www.cdbb.cam.ac.uk/system/files/documents/BISBIMstrategyReport.pdf

Wright, J. A. (2012). The integration of building information modeling and integrated project delivery into the construction management curriculum. *ASEE Annual Conference and Exposition, Conference Proceedings*.

British Standards Institution (BSI). (2013). PAS 1192-2:2013. United Kingdom: BSI Standards Limited.

British Standards Institution (BSI). (2014). BS 1192-3:2014. United Kingdom: BSI Standards Limited.

British Standards Institution (BSI). (2014). BS 1192-4:2014. United Kingdom: BSI Standards Limited.

British Standards Institution (BSI). (2015). BS 1192-5:2015. United Kingdom: BSI Standards Limited.

British Standards Institution (BSI). (2015). BS 8536-1:2015. United Kingdom: BSI Standards Limited.

British Standards Institution (BSI). (2018). BS 1192-6:2018. United Kingdom: BSI Standards Limited.

British Standards Institution (BSI). (2018). BS EN ISO 19650-1:2018. United Kingdom: BSI Standards Limited.

British Standards Institution (BSI). (2018). BS EN ISO 19650-2:2018. United Kingdom: BSI Standards Limited.

APPENDICES

APPENDIX A: Online questionnaire survey questions

APPENDIX B: First stage interview questions

APPENDIX A

Thank you for kindly participating in this questionnaire. Your feedback is very important and will be used for my master dissertation. This research focuses on the legal aspects of BIM-based construction projects and the critical aspects of BIM-based contract management.

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Önizleme sırasında cevaplarınız kaydedilmeyecektir.

LEGAL ASPECTS OF BIM-BASED CONSTRUCTION CONTRACTS

1 What is your profession? *

2 What is your role in the project? *

If you are not working on a specific project, please indicate your area of expertise

3 How many years of professional experience do you have? *

- ○ Less than 5 years
- ○ 5 - 10 years
- ○ 11 - 15 years
- ○ More than 15 years

4 How many years of BIM experience do you have? *

- ○ Less than 2 years
- ○ 2 - 4 years
- ○ 5 - 7 years
- ○ 8 - 10 years
- ○ More than 10 years

5 Do you agree with the following statements? (Please indicate the degree of agreement)

	Strongly Agree	Agree	Neither Agree or Disagree	Disagree	Strongly Disagree
Did you have difficulty in BIM integration?	○	○	○	○	○
Have you used standard contracts in the BIM integration process?	○	○	○	○	○
Do you think the international standard contracts are suitable for BIM?	○	○	○	○	○

6 Did you have difficulty in the BIM integration process with respect to the phases/topics provided?

	Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree
Tender Stage	○	○	○	○	○
Contract Stage	○	○	○	○	○
Design Stage	○	○	○	○	○
Intellectual Property	○	○	○	○	○
Data Security	○	○	○	○	○
Dispute Resolution	○	○	○	○	○
Clash Detection	○	○	○	○	○
Change Order	○	○	○	○	○
Health and Safety	○	○	○	○	○
Operating the Facility	○	○	○	○	○
Maintenance of Facility	○	○	○	○	○

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Önizleme sırasında cevaplarınız kaydedilmeyecektir.

1 How does BIM-based construction management affect the performance of the following items?

	Improve	Does not affect	Reduce
Tender Stage	○	○	○
Contract Stage	○	○	○
Design Stage	○	○	○
Intellectual Property	○	○	○
Data Security	○	○	○
Dispute Resolution	○	○	○
Clash Detection	○	○	○
Change Order	○	○	○
Interoperability	○	○	○
Health and Safety	○	○	○
Operating the Facility	○	○	○
Maintenance of Facility	○	○	○
Integration Management	○	○	○
Scope Management	○	○	○
Schedule Management	○	○	○
Cost Management	○	○	○
Quality Management	○	○	○
Resource Management	○	○	○
Communications Management	○	○	○
Risk Management	○	○	○
Procurement Management	○	○	○
Stakeholder Management	○	○	○

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Önizleme sırasında cevaplarınız kaydedilmeyecektir.

Can you identify the main challenges you face in the following headings?

1 Tender Stage

2 Contract Stage

3 Design Stage

4 Intellectual Property

5 Data Security

6 Dispute Resolution

7 Change Order

8 Clash Detection

9	Interoperability
10	Health and Safety
11	Operating the Facility
12	Maintenance of Facility
13	Pre-Construction Phase
14	Construction Phase
15	Post Construction Phase
16	Other

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Önizleme sırasında cevaplarınız kaydedilmeyecektir.

What are your recommendations for BIM Based Project Management under the following headings?

1 Tender Stage

2 Contract Stage

3 Design Stage

4 Intellectual Property

5 Data Security

6 Dispute Resolution

7 Clash Detection

8 Change Order

9 Interoperability

10 Health and Safety

11 Operating the Facility

12 Maintenance of Facility

13 Pre-Construction Phase

14 Construction Phase

15 Post Construction Phase

16 Other

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Önizleme sırasında cevaplarınız kaydedilmeyecektir.

Based on your experience, what are the critical points to be considered in the preparation phase of the following BIM documents?

1 BIM Execution Plan (BEP)

2 Organisational Information Requirements (OIR)

3 Asset Information Requirements (AIR)

4 Asset Information Model (AIM)

5 Project Information Requirements (PIR)

6 Exchange Information Requirements (EIR)

7 Project Information Model (PIM)

8 Pre-Qualification Questionnaire (PQQ)

9	Supply Chain Assessment Form	
10	Task Information Delivery Plan (TIDP)	
11	Master Information Delivery Plan (MIDP)	

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Önizleme sırasında cevaplarınız kaydedilmeyecektir.

1 Based on your experience, can you evaluate the compliance of the following project types to BIM

	Strongly Suitable	Suitable	Neither Suitable nor Not Suitable	Not Suitable	Strongly Not Suitable
Complex Projects	○	○	○	○	○
Small Scale Projects	○	○	○	○	○
Large Scale Projects	○	○	○	○	○
Infrastructure Projects	○	○	○	○	○
Superstructure Projects	○	○	○	○	○
National Projects	○	○	○	○	○
International Projects	○	○	○	○	○
Public Projects	○	○	○	○	○
Private Projects	○	○	○	○	○

2 What are the main concerns to be considered while preparing a contract in BIM-based projects?

3 In which areas, can contracts for BIM-based projects reduce conflicts and disputes?

4 In which areas, contracts for BIM-based projects have risk to increase conflicts and disputes?

5 Which skills should the contracts manager have in the BIM-based projects?

6 What was the most serious problem you had experienced in the BIM-based construction project management? How did you overcome it?

APPENDIX B

First Stage Interview Questions

Profession:

Experience:

BIM Experience:

Role in the Project:

1. Why did you decide to do the Metro project with BIM? What level did you choose BIM? What were your expectations? How did it end?
2. How was the integration process of BIM?
3. What level of development did you use?
4. What are the problems you have been struggling with for the supply chain when integrating the project to BIM?
5. Are there any protocols you use to integrate BIM into contracts? What were the points you were struggling with? How could it be better?
6. Do you think Turkish and international standard contracts are compatible with BIM? What would you recommend based on your experience in this regard?
7. What kind of innovations did BIM bring in the following headings? Have you had any problems? If you have lived, how can you take contractual measures to prevent this problem?

Pre-Construction	Construction	Post-Construction
Tender Phase	Interoperability	Operation
Contract Phase	Clash Detection	Maintenance
Design Phase	Repetition of Construction	
Establishing the Team	Change Order	
Intellectual Properties	Health and Safety	
Data Security	Dispute Causes and Resolutions	
Dispute Resoulutions		

8. How does BIM-based construction management affect the performance of the following items?

	Improve	Does not affect	Reduce
1. Tender Stage	☐	☐	☐
2. Contract Stage	☐	☐	☐
3. Design Stage	☐	☐	☐
4. Intellectual Property	☐	☐	☐
5. Data Security	☐	☐	☐
6. Dispute Resolution	☐	☐	☐
7. Clash Detection	☐	☐	☐
8. Change Order	☐	☐	☐
9. Interoperability	☐	☐	☐
10. Health and Safety	☐	☐	☐
11. Operating the Facility	☐	☐	☐
12. Maintenance of Facility	☐	☐	☐
13. Integration Management	☐	☐	☐
14. Scope Management	☐	☐	☐
15. Schedule Management	☐	☐	☐
16. Cost Management	☐	☐	☐
17. Quality Management	☐	☐	☐
18. Resource Management	☐	☐	☐
19. Communications Management	☐	☐	☐
20. Risk Management	☐	☐	☐
21. Procurement Management	☐	☐	☐
22. Stakeholder Management	☐	☐	☐

9. Based on your experience, can you evaluate the compliance of the following project types to BIM?

	Strongly Suitable	Suitable	Neither Suitable nor Not Suitable	Not Suitable	Strongly Not Suitable
1. Complex Projects	☐	☐	☐	☐	☐
2. Small Scale Projects	☐	☐	☐	☐	☐
3. Large Scale Projects	☐	☐	☐	☐	☐
4. Infrastructure Projects	☐	☐	☐	☐	☐
5. Superstructure Projects	☐	☐	☐	☐	☐
6. National Projects	☐	☐	☐	☐	☐
7. International Projects	☐	☐	☐	☐	☐
8. Public Projects	☐	☐	☐	☐	☐
9. Private Projects	☐	☐	☐	☐	☐

10. What are the main concerns to be considered while preparing a contract in BIM-based projects?
11. Based on your experience, what are the critical points to be considered in the preparation phase of the following BIM documents?

    1. BIM Execution Plan (BEP)
    2. Organisational Information Requirements (OIR)
    3. Asset Information Requirements (AIR)
    4. Asset Information Model (AIM)
    5. Project Information Requirements (PIR)
    6. Exchange Information Requirements (EIR)
    7. Project Information Model (PIM)
    8. Pre-Qualification Questionnaire (PQQ)
    9. Supply Chain Assessment Form
    10. Task Information Delivery Plan (TIDP)
    11. Master Information Delivery Plan (MIDP)

12. In which areas, can contracts for BIM-based projects reduce conflicts and disputes?
13. In which areas, can contracts for BIM-based projects increase conflicts and disputes?
14. Which skills should the contracts manager have in the BIM-based projects?
15. Is there anything else you would like to mention?

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