A BUILDING INFORMATION MODELLING BASED ON CONTRACTUAL FRAMEWORK FOR CONSTRUCTION OF BUILDING PROJECTS

AHMAD HUZAIMI BIN ABD JAMIL

UNIVERSITI TEKNOLOGI MALAYSIA

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AHMAD HUZAIMI BIN ABD JAMIL

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DEDICATION

This thesis is dedicated to my loving family to whom I owe special gratitude for their endless support and encouragement for success in all my academic pursuits. In loving memory of my late mother (**Hjh Noriah binti Razali**) and my dad, **Abd Jamil bin Ismail**, who made me who I am today. It is also dedicated to my one and only dedicated supervisor, **Dr. Mohamad Syazli bin Fathi** who taught me that great determination can overcome most obstacles. "So verily, with every difficulty, there is relief" [The Quran 94:5 (Surah al-Inshirah)]

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ABSTRACT

Globally, the construction industry is focusing on the execution of building information modelling (BIM), especially within the architecture, engineering, and construction (AEC) sector. The technical challenges of BIM affect its contractual uncertainty; hence, resolving the latter will lead to addressing the former. Nevertheless, the standard form of contract is only utilised to guide contract administration and this practice produces an average performance when solving contractual matters concerning execution of BIM. Thus, the contract might not provide a complete digital description of BIM environments and might not incorporate the specific conditions and amendments related to unsatisfactory technological interoperability problems, that can impede the flow of information throughout a project's lifecycle. This research aimed to propose a BIM-based contractual framework for building construction projects in Malaysia by determining appropriate provisions within the BIM-based contracting systems to address current practice deficiencies. In line with the latest BIM agenda set through the Public Works Department Strategic Plan 2021-2025 to reach 50% use of BIM by 2021 and 80% by 2025 in determining rational and unbiased outcomes for every BIM stakeholder, it is important to comprehend the impacts of BIM-based contract linked to the project's technology-related challenges, process-related challenges and stakeholder-related challenges. Thus, four design and build (D-B) Malaysian construction projects were chosen as case studies. The multiple case studies were employed as an exploratory study to assess the feasibility of the proposed conceptual framework based on Malaysia's local experiences and circumstances, that have endured BIM-based contractual challenges. Four case studies on complex building construction projects in which two were on-going while another two had been completed were purposely selected. The research methodology consisted of an initial exploratory study followed by 20 in depth semi-structured interviews. A substantial amount of archival project document data was collected using multiple triangulation techniques by means of interviews with BIM-expert stakeholders. This research explored the convergence of three core elements of BIM-based contractual framework, i.e. adequacy through uses of model information, accuracy and tolerances through scope of model information, and currency through organisation of model information towards achieving optimum BIM use, which must be offered for administrative and contractual purposes. The findings of this research show that the effectiveness of BIM-based contracts between various project stakeholders has been made possible on the basis of nine vital components of the BIM contractual provisions, namely, compensation and consideration, conditions of contract, data security, information and communication technology (ICT) protocols, intellectual property (IP), interoperability, procedures to ascertain information quality, professional liability, and legislation and judicial precedence.

ABSTRAK

Di peringkat global, industri pembinaan menumpukan pada pelaksanaan pemodelan maklumat bangunan (BIM), terutama dalam sektor seni bina, kejuruteraan, dan pembinaan (AEC). Cabaran teknikal BIM mempengaruhi ketidaktentuan kontraknya. Oleh kerana itu, penyelesaian kontrak berupaya menangani cabaran teknikalnya. Walaupun begitu, bentuk kontrak yang standard hanya digunakan untuk membimbing pentadbiran kontrak dan amalan ini menghasilkan prestasi yang sederhana ketika menyelesaikan masalah kontrak yang berkaitan dengan pelaksanaan BIM. Oleh itu, kontrak tersebut mungkin tidak memberikan gambaran digital yang lengkap mengenai lingkungan BIM dan berkemungkinan tidak memasukkan syarat dan pindaan khusus yang berkaitan dengan masalah saling kendali teknologi yang tidak memuaskan, yang dapat menghalang aliran maklumat sepanjang kitaran hidup projek. Penyelidikan ini bertujuan untuk mencadangkan kerangka kontrak berasaskan BIM untuk membina projek pembinaan di Malaysia dengan menentukan peruntukan yang sesuai dalam sistem kontrak berasaskan BIM untuk mengatasi kekurangan amalan semasa. Sejajar dengan agenda BIM terkini yang disusun melalui Pelan Strategik Jabatan Kerja Raya 2021-2025 untuk mencapai 50% penggunaan BIM menjelang 2021 dan 80% menjelang 2025 dalam menentukan hasil yang rasional dan tidak berat sebelah bagi setiap pihak berkepentingan BIM, adalah penting untuk memahami kesan kontrak berdasarkan BIM yang berkaitan dengan cabaran berkaitan teknologi projek, cabaran proses dan cabaran berkaitan pihak berkepentingan. Oleh itu, empat reka bentuk dan bina (D-B) projek pembinaan Malaysia telah dipilih sebagai kajian kes. Pelbagai kajian kes digunakan sebagai kajian eksploratif untuk menilai kemungkinan kerangka konseptual yang dicadangkan berdasarkan pengalaman dan keadaan setempat di Malaysia, yang telah mengalami cabaran kontrak berdasarkan BIM. Empat kajian kes, di mana dua sedang dalam fasa pembinaan sementara dua lagi telah selesai projek pembinaan bangunan kompleks, dipilih secara selektif. Metodologi kajian terdiri daripada kajian eksplorasi awal diikuti oleh 20 temuduga separa berstruktur mendalam. Sejumlah besar data dokumen projek arkib dikumpulkan dengan menggunakan teknik triangulasi berganda dengan temuduga bersama pihak berkepentingan pakar BIM. Penyelidikan ini meneroka penumpuan tiga elemen teras kerangka kontrak berasaskan BIM, iaitu kecukupan melalui penggunaan maklumat model, ketepatan dan toleransi melalui skop maklumat model dan mata wang melalui organisasi maklumat model untuk mencapai penggunaan BIM yang optimum, yang mesti ditawarkan untuk tujuan pentadbiran dan kontrak. Hasil kajian ini menunjukkan bahawa keberkesanan kontrak berdasarkan BIM antara pelbagai pihak berkepentingan projek adalah disebabkan oleh sembilan komponen penting dari peruntukan kontrak BIM, iaitu, pampasan dan pertimbangan, syarat kontrak, keselamatan data, teknologi maklumat dan komunikasi protokol (ICT), harta intelek (IP), saling kendali, prosedur untuk memastikan kualiti maklumat, tanggungjawab profesional dan perundangan dan keutamaan kehakiman.

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LIST OF ABBREVIATIONS

AEC	-	Architecture, Engineering and Construction
AIA		American Institute of Architects
BEP		BIM Execution Plan
BCF		BIM Collaboration Format
BIM		Building Information Modelling
CAD		Computer-aided Design
CIDB		Construction Industry Development Board
D-B	-	Design and Build
DBB		Design-bid-build
EIR		Employer's Information Requirements
FIDIC		International Federation of Consulting Engineers
FMT		Facility Management Team
ICE		Institution of Civil Engineers
ICT	-	Industry Foundation Classes
IFC		Information communication technology
IP		Intellectual Property
IPD		Integrated Project Delivery
JCT		Joint Contracts Tribunal
LOD		Level of Development
MEA		Model Element Author
NIBS		National Institute of Building Sciences
NOP		Non-Owner Participant
XML		Extensible Markup Language
PWD		Public Works Department
QCA		Qualitative Content Analysis
RIBA		Royal Institute of British architect
RFP		Request for Proposal
TOC		Target Outturn Cost
UTM	-	Universiti Teknologi Malaysia

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CHAPTER 1

INTRODUCTION

1.1 Introduction

The gross domestic product (GDP) of many nations, especially developing countries, is spearheaded by various sectors such as the construction industry, which has been lacklustre due to some obstacles. For example, disagreements among project stakeholders are common in the construction industry as revealed in a few legal cases (McAdam, 2010; Olantuji, 2011). Nevertheless, building information modelling (BIM) can resolve certain issues within the architecture, engineering and construction (AEC) sector by combining data gathered from facilities' lifecycle, in addition to organising and overseeing every construction activity (Azhar et al., 2015; Bui et al., 2016). Even though BIM has numerous advantages, its application is inefficient. Moreover, to adopt BIM into the industry, a lot of effort is needed in introducing a digitised setting for building construction projects.

Another issue concerns the satisfaction of stakeholders. Kuiper and Holzer (2013) have asserted that the development of the information communication technology (ICT) sector, particularly in the context of the AEC sector, has improved the spread of information amongst project players to increase output. Nevertheless, applying ICT in the construction industry has several challenges (Holzer, 2015; Arayici et al., 2011) that could create hindrances instead of supporting BIM implementation. As a result, there is a significant impact on the manner project stakeholders collaborate and the possible contractual challenges arising due to any disagreements that occur. Thus, it is imperative to understand BIM's functionality, and how it helps a project, which can possibly enable the vital foundations forming the applicable contractual context. Nonetheless, limited investigations have been conducted and most did not examine industry-wide trends in creating a standard form of BIM contract by critically aligning BIM functionality with various contractual

challenges to improve work efficiencies among project stakeholders. There has been little attention paid to conducting a systematic analysis of current standard forms of contract and how these forms might be impacted by using BIM in the project setting. In this current research, the range of BIM contractual challenges available in the literature was consolidated, followed by a systematic analysis of a contract contracting system to determine the changes required for current contractual approaches in the light of BIM implementation.

Due to the progress in science and technology in the 20th century, cultural memory that a nation or civilisation takes benefits on daily practices solidified as civil institutions and gets started a standard way of agreements in between project stakeholders (Azhar et al., 2015; Bosch-Sijtsema et al., 2017). There are two initial implications and thus two different approaches of standard contracts have been published, namely in the USA by and in the UK by Institution of Civil Engineers (ICE). The AEC sector widely benefits from these standard versions of contracts. In addition, use of these contracts has been enhanced via some technological solutions introduced during the end of the 20th century through the involvement of digital design, drafting tools, and the Internet (Chen et al., 2015). Eadie et al. (2013) have pointed out that these solutions have been provided by the development and introduction of BIM to the AEC sector, which is totally in conflict with traditional contract bodies. On the other hand, although BIM provides various benefits and tries to integrate all disciplines and stakeholders in a project's lifecycle, there are still differences in the standard form of contracts and contract addendums in BIM protocols published in the USA and UK.

1.2 Background of the Study

In the context of building construction, BIM has given positive and fulfilling results. These results have been confirmed through various yardstick measurements like the international efficiency benchmark for the AEC sector besides other services related to the building construction industry (Ashcraft, 2008; Chen et al., 2015). Furthermore, knowledge sharing is encouraged in BIM when information concerning a building or amenity is collected. Hence, firm decision-making from the conceptual

design stage until the demolition stage is generated, which represents a complete lifecycle (Azhar et al., 2015; McAdam, 2010). Apart from that, BIM is an information technology source incorporated in a multidisciplinary way that provides information that could be useful or detrimental for the construction field. It has been claimed that BIM is recognised as a model that is adversarial, fragmented, and crucial for a revolution of culture (Chen et al., 2015; Kuiper & Holzer, 2013). On the other hand, BIM-related issues concerning contractual matters seem to be impediments that should be investigated. An example of such an issue is the creation of contracts intended to form valuable outcomes in BIM (Kuiper & Holzer, 2015). Moreover, a unified design is unavailable in the current regulations and contract model; therefore, information gathered from construction projects' stakeholders are not successfully combined (Azhar et al., 2015; McAdam, 2010). This occurs because the effects of stakeholders' collaborations, and contractual consequences are significant.

Technology is advancing exponentially. Certain advancements have been made to solve specific construction issues, while developments in other sectors might result in benefits that can be transferred to the construction industry. As stated by Becerik-Gerber (2012), the implementation of BIM in AEC needs much effort, especially in improving the ICT sector. However, Steward & Mohamed (2003) have emphasised that many industry players have not been successful in securing BIM's benefits because of hindrances in the form of technology and contract expenses (Ashcraft, 2008; Larson & Golden, 2007). Research on BIM has focused on two key areas. The first concerns issues pertaining to contractual matters (Ashcraft, 2008; Larson & Golden, 2007; RIBA 2013) and the possible obstacles met in the construction industry. Meanwhile, the second aspect is regarding procurement model development to deliver BIM to encourage efficient data sharing (Ashcraft, 2008; Kuiper & Holzer, 2013). Nevertheless, past research did not consider the technological aspects and the contract procurement problems endured by current project players (Kuiper & Holzer, 2013; McAdam, 2010; Steward & Mohamed, 2003).

Volk et al. (2014) have listed as among the extensively researched areas in the construction field. Likewise, aspects of insurance, like risk-sharing and distribution of duties, are also important. As such, IP coverage is vital amongst project players to

determine a situation that necessitates the regulation of IP ownership (arrangement of real or implied licensing) from the stance of BIM (Kuiper & Holzer, 2013).

Besides, an IP framework inserts elemental features, i.e. trade secrets, for instance, construction techniques and data embedded in a specific sequence, file formats within an integrated system, and confidential data (Larson & Golden, 2007; McAdam, 2010). As the demand for BIM rises, Azhar et al. (2015) have asserted that channels which are more sophisticated are required to gain success through the application of IP within a shared environment that adds to IP allocation intricacy. Furthermore, matters regarding IP must be described and addressed for the development of BIM frameworks within the Internet setting.

Thus, conflicts regarding terminology and priority of documents can happen between the contract and chosen protocol. For example, the Chartered Institute of Building's Complex Projects Contract 2013 (CPC 2013) states that the contract terms have precedence over a BIM protocol, whereas the Construction Industry Council BIM Protocol (2013) states that the protocol has precedence over other contract papers (CIC BIM Protocol: Clause 2.1). Hence, changes to the documents could be necessary because agreements in contracts are the locus when a standard BIM contract form is generated, which can encourage more cooperative projects. This concurs with the concept emphasised by the Construction Industry Transformation Programme 2016–2020 (CITP), which aims to integrate BIM with advanced construction procedures. As such, understanding the effect of challenges concerning contracts' risk profile, responsibilities, and liabilities is crucial to find out realistic and fair outcomes for all BIM stakeholders.

1.3 Statement of Problem

BIM technology is applicable across disciplines and requires a platform for project stakeholders to share contents, whereby both data and model can be extracted and used to prevent sharing unnecessary and incorrect information. Additionally, Kuiper and Holzer (2013) highlighted the possible challenges faced by BIM-based

project stakeholders linked to traditional contract papers employed in a construction project. Two aspects in BIM, namely, liability of contract and professional indemnity (PI) of key stakeholders, are deemed important by authorities of design working in the BIM environment (Chong et al., 2017; Lee et al., 2018), particularly after acknowledgement of non-contracting participations to design contributions, including those changed using software.

Furthermore, this platform which provides data supplied by BIM contributors (recognised stakeholders), that are also used or depended upon by other stakeholders, has risks (Azhar et al., 2015). Nevertheless, research has shown that issues concerning negligence of contractual aspects as a central component to the efficiency of carrying information between contract variables (role and responsibilities of client, contractor/consultant or third party) were uncertain and complex (Fan et al., 2014; Kuiper & Holzer, 2013; Larson & Golden, 2007) and consequently can impede efficiency for continuous improvement throughout a project's lifecycle.

Models can be created for several uses. However, an inadequate model information may cause difficulties if used for a different purpose than intended. Currency, adequacy, and tolerances are three separate issues that need to be addressed when information in one model is used for another (Ashcraft, 2008; Kuiper & Holzer, 2013). It seems obvious to state that a model needs to be up-to-date. Still, a structural analysis model may not need to be absolutely synchronised with the architectural model to determine whether a structure is sound. Therefore, it is important to understand the contractual aspects within contract documents of BIM in building construction projects to prevent confusion amongst project stakeholders. This study has weighed in the contributions of carrying and managing the most crucial information among all the contractual aspects to be treated as part of developing a BIM-based contractual framework.

It was reported that inefficiencies during the project life cycle phase caused a loss of two-thirds of the projected cost (Arayici et al., 2011; Azhar et al., 2012). Even though updated BIM content is fundamental for any, model and content management responsibility during design and construction phases have not been comprehensively

investigated in the literature and contractual frameworks (Arensman & Ozbek, 2012). Hamid Abdirad (2015) has claimed that not every BIM aspect can be known at the initial contractual stage as other issues could appear and decisions will be taken at the later stages. In addition, the role of appointed BIM administrators has also been questioned. According to Almarri et al. (2018), these administrators are important at the initial stage in selecting the supervising parties and determining contract liability for coaxing at the later stage. Moreover, contract documents should provide BIM functional area, demands, and procedures in a greater degree, in contrast to contractual documents (Lowe & Muncey, 2008a; 2008b).

McAdam (2010) stated that BIM technology continued to be a significant obstacle for construction projects due to a lack of provision for electronic data and data replication. Hence, it is imperative to list the function and processes of BIM for construction work to draft a feasible contract (Kuiper & Holzer, 2013; Stapleton et al., 2014). Nevertheless, no extensive research on industry trends in developing a standardised BIM contract has been done. In response to the problem, this research has identified the vital components and implications practical in implementing BIM, specifically in producing a contract document which portrays the BIM process.

Moreover, limited data regarding BIM ownership emphasises for protection in the form of copyrights, etc. (Azhar et al., 2015; Chen et al., 2014; Kuiper & Holzer, 2013). Therefore, after the adoption of BIM by project stakeholders, it is crucial to form specific contracts to fulfil the requirements and solve restrictions in BIM contracts. According to Alwash et al. (2017), the best way to solve copyright disagreements is by preparing contract documents with an extensive definition of uses of model information, scope of model information, organisation of model information, rights of ownership, roles, permitted users, and confidentiality and quality of data through contract procurement practice by developing a viable BIM-based contractual framework.

1.4 Research Objectives

The aim of this research was to propose a BIM-based contractual framework for the building construction industry by determining appropriate significant contract provisions with regard to the designation of contract documents. Thus, the objectives of this study were:

1. To identify the contractual challenges facing BIM-based building construction projects.
2. To analyse the vital components of contractual aspects that serve as contract provisions to mitigate BIM-based contractual challenges.
3. To develop a BIM-based contractual framework for building construction projects.

1.5 Research Questions

Research question 1: What are the main challenges, disagreements or disputes specifically related to the contractual aspects of BIM-based building construction projects?

Research question 2: (a) To what extent have BIM-related contractual aspects provided sufficient consideration to the challenges that are unique to BIM implementation and ensured that they have been mitigated?

(b) What are the vital components that serve as the contract provisions in BIM contracts?

Research question 3: (a) How will the Building Information Management process be integrated seamlessly into the D-B procurement system for building construction projects?

(b) How do the vital components of contractual framework provide practical implications for BIM-based project environment?

1.6 Research Scope

The BIM concept is not only focused on the technology, but also on the policy and the process involved in a project. It is, therefore, essential to understanding the implementation processes of BIM projects by construction stakeholders. This research did not aim to generate final or conclusive proof; instead, the goal was to propose several hypotheses for changing deliverable contract requirements (See section 2.12) to be examined. This research's scope was restricted to the construction stakeholders involved in D-B in building construction projects using BIM in the Malaysian construction industry. The scope of this research is as follows:

(a) Targeted respondents

Five (5) different construction stakeholders (client, architect, engineer, contractor, and BIM consultant) were identified from the list of respondents from the selected project cases have experience implementing BIM in D-B building construction projects. Respondents participating in projects utilising BIM were selected on the basis of purposeful sampling at the design and construction phases, the objectives of BIM, utilisation and execution process of the building information management framework in the BIM projects. Those respondents were chosen on the basis of their involvement in the implementation of BIM in selected project cases. Therefore, the information collected from the respondents offered in-depth information on the execution of the BIM contract and its future enhancement.

(b) Research Area

This research concentrated on the current practices of BIM in the Malaysian construction industry. Current practices concentrate on the BIM implementation processes among construction stakeholders, as well as on contractual challenges and barriers during implementation. In order to understand the process of BIM,

information is needed to illustrate the work process. This information includes BIM uses, project delivery methods, BIM work contracts, the roles and responsibilities of construction stakeholders and the technology involved. The BIM work process for this study is based entirely on the D-B delivery method as there is no BIM project that has successfully benefited from its BIM objectives and implementation starting from designing phase to construction phase. Work processes and contractual challenges during implementation of BIM that prevent construction stakeholders from achieving BIM benefits will be delineated in the following sections. This research, therefore, concentrated on building information management's activities that could enable construction stakeholders to overcome contractual challenges and improve the implementation of BIM.

(c) Type of project

D-B contracting can be used in any type of infrastructure project as well as vertical project. In the building sector they are used mostly in a number of healthcare (hospital) facilities, commercial and educational buildings. In the infrastructure projects they are being predominantly used in civil as well as transport infrastructure projects including road, railways, airport, pipeline, tunnel, and bridge projects.

Generally, D-B is the preferable procurement choice when building construction projects are complex, scope of work is unclear, risk is significantly uncertain, the timeframe is short and community and stakeholder interest are critical. In the building sector, where projects have very complicated and integrated functions and systems and the need for aesthetic space, D-B contracting is considered the best solution for the successful completion of high-performance buildings.

D-B contracts generally have taken place in projects ranging from RM2 million to over RM1 billion regarding the project dimensions. In Malaysia, D-B contracts have been predominantly implemented in large projects with costs varying from RM100 million to up to one billion. D-B contracting requires more effort and time to stipulate the agreement and build an integrated team. Therefore, clients usually use traditional forms of contracts for small projects because the effort and additional cost needed for a cooperative delivery method is not justifiable for such small projects.

1.7 Significance of the Study

Based on research of the impact of D-B procurement system on BIM, the prevailing procurement approach for projects resulting from improving the practical, technical, and industrial aspects does enhance project delivery towards successful BIM execution (Kuiper & Holzer, 2013; Smith, 2014; Steward & Mohamed, 2003). Nevertheless, Malaysia's current contract practices offer information on duties of contractors in designing and on civil, mechanical, and electrical engineering, by following the design work employers have agreed by employers (Zakaria et al., 2013) in giving BIM project players access to planning, designing, reviewing, programme, cost, and/or managing construction projects. Nonetheless, contractual matters concerning BIM execution in local and international construction industries have not yet been extensively investigated. Not only that, Manderson (2012) asserted that certain issues such as intellectual property, liability, and project-related challenges must be considered in current projects, necessary to accommodate administrative and contractual purposes, consistent with optimal BIM usage.

As such, this research has offered an opportunity to enhance knowledge of a feasible method to solve the perceived fragmented and isolated way of the current construction projects via the creation of standard BIM contractual forms. When used properly, the contract developed could be beneficial for the project team. Additionally, this research has presented some key insights on innovation in Malaysia's construction industry. Although numerous investigations have focused on both the advantages and disadvantages of BIM usage, none examined BIM delivery methods via the creation of standard BIM contractual forms. However, several scholars have analysed the consolidation of BIM into standard forms of contract, whereby most have utilised a quantitative approach rather than qualitative, which draws together the presently known contractual challenges to analyse the issues of BIM, based on the AEC sector and thus fill the research gap.

From the perspective of applied research, past studies have only made recommendations for contract amendments (Porwal & Hewage, 2013) and have not investigated the impact of BIM on standardised contracts or specifically the ones used

for public sector procurement. Thus, this research has provided a framework for analysing public sector contracts and a basis for future studies that should examine standardised construction contracts extensively applied in the AEC sector. Moreover, it is also believed that the underlying qualitative methodology applied in this study can be used for any contractual analysis.

Due to the perceived contractual challenges, exclusive BIM contractual delivery approaches are necessary for the effective implementation of BIM into the contract procurement system. It will also give an instant understanding of contractual issues that can affect BIM's effectiveness in its implementation, application, and teamwork within a project's team.

1.8 Research Operational Framework

Research operational framework, as presented in Figure 1.4, are particularly appropriate for research questions that need a thorough comprehension of BIM-based contractual settings, primarily due to the rich data gathered as part of a case study (Yin, 2014). According to Yin (2003), in case study investigations, a phenomenon is not separated from its original context but instead is precisely of interest since the goal is to comprehend how BIM management processes are affected within the context of organisations and the environment.

The unique strength of case studies is their ability to gather evidence beyond what is available in the conventional historical study (Creswell, 1998). This research was operationalised through interaction with BIM-based project stakeholders who represented small samples that were investigated in-depth and over time. Furthermore, interpretive philosophy presumes that reality is attained via social constructs like language, consciousness, shared meanings, and instruments (Lincoln & Guba, 1985).

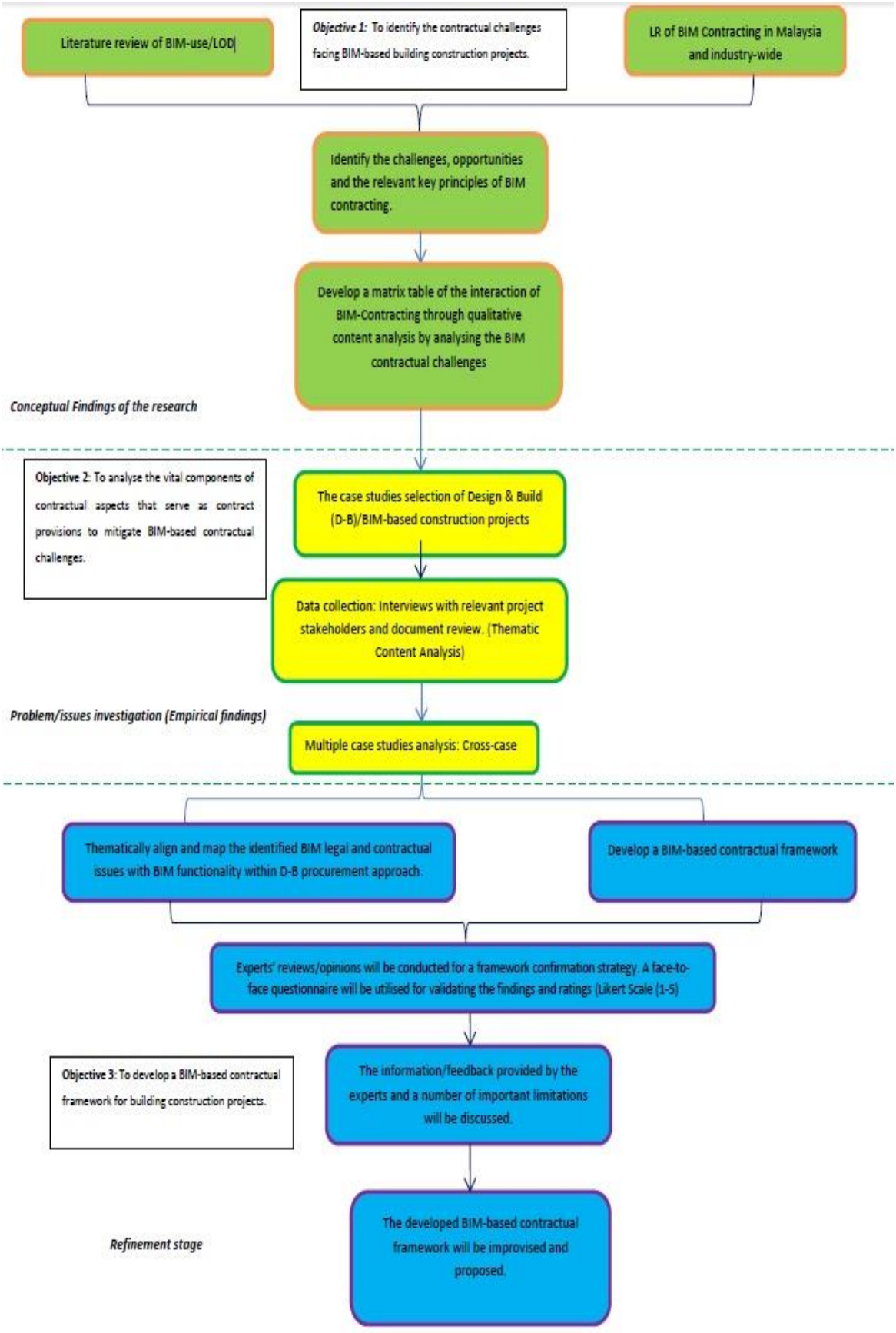

Figure 1.1 Research Operational Framework

1.9 Structure and Content

This study has been structured to enable the research objectives to be achieved. The overall structure of this study focused on the use of literature review to examine the changes needed for building construction contracts to allow the integration of BIM using qualitative content analysis (QCA).

Following this first introductory chapter, a review of the literature on contractual implications of BIM usage in the building construction industry is presented in Chapter 2. The second chapter draws together a wide range of knowledge to facilitate an understanding of the topic and to provide a contextual background to the research regarding the contractual repercussions of BIM, industry-wide procurement, and the development and use of standardised BIM contracts. A systematic literature review was performed to identify and synthesise core thematic areas and associated subthemes that were then used in subsequent analyses to examine the selected contract documents. The outcomes of Chapter 2 present the thematic areas that served as an initiated conceptual framework.

Next, Chapter 3 will describe the overall research design, methods, and methodology, with a focus on how the research questions and objectives will be answered within the Malaysian building construction industry context. This chapter will explain how the research collected and analysed the data using a multiple-case study design, by employing a QCA tool. It also discusses the limitations and validity of the selected method and justification of the number of cases selected. On the other hand, Chapter 4 presents and discusses the results of the case studies content analysis. The core thematic areas and subthemes were overlaid on the contract procurement structure to identify specific changes required to the contract to enable BIM integration in a shared environment.

In the following chapter, an interpretation of the results is provided, and the significance of the changes required in designing the BIM-based contract in relation to the core thematic areas are discussed. This chapter answers the research questions stated in Chapter 1. It also presents new insights into the problem under investigation.

Finally, Chapter 6 draws together the findings from previous research and of the current investigation to recommend changes to the Malaysian building construction industry to facilitate the successful incorporation of BIM into the construction procurement practice. In addition, it highlights this study's restrictions and provides recommendations for future investigations.

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Appendix A Interview protocol

Structure and example of interview questions	Justification for structure and questions
Introduction: Researcher introduces himself - Explain the purpose of the study - Provide informed consent - Describe the interview structure (audio recording, taking notes, etc.) **1. Demographic Profile** Example of questions: • How long have you been working here? • What has been your role in the BIM Unit/Team? (ice breaker) 2. **Familiarity and understanding regarding the topic** Example of questions: • What has happened since the event that you have been involved in? (content question) Use any of these probes: i. Tell me more. Please explain. ii. I need more details. iii. What is an example of that? iv. Could you explain your response more? v. What does 'not much' mean? 3. What has been the impact of BIM implementation on the organisation? (content question) a. Use any of these probes: i. Tell me more. Please explain. ii. I need more details. iii. What is an example of that? iv. Could you explain your response more? v. What does 'not much' mean?	The researcher believes that by asking demographic questions, he could build rapport and gain a better understanding of respondent's perceptions besides being able to justify respondent's qualifications as a sample. The researcher also believes it is important to know that the respondent understands and is familiar regarding the topic to justify their qualification and reliability as a respondent.
Main topic or research interest The case study questions are deductively formulated based on the identified themes and sub-themes from the systematic literature review: **1. Compensation and consideration** The need to extensively establish a contract; BIM-based costs of execution at a project and business level, whereby including additional costs on a tender price may make the contractor/consultant uncompetitive in the short-term (Arayici et al., 2011; Azhar et al., 2012). Hence, this study proposes that there is a need to extensively estimate cost as early as at the conceptual design phase with the involvement of the contractor and FMT. Example of questions: • Can you describe how the contract allows for implementing BIM at a business or project level? (financial incentives and reward for implementing BIM specified in the contract) • How do the payment conditions and schedules allow the contractor to claim prepayment amounts against the Contract Price? • To what extent do the project contract conditions explicitly cover the issue of recouping the costs of technology adoption within a business framework? **2. Conditions of contract** A contract will usually consist of a document that specifies the Conditions of Contract, which details the rights, responsibilities, and obligations of the various parties that are privy to the agreement. Hughes and Greenwood (1996) noted that the conditions provide mechanisms to administer and manage the	The researcher asks questions, from simple to more specific, pertaining to research topics structure to get respondent's response and understanding about the study in detail. The questions also aim to get respondent's personal opinions and perceptions about the topics. Some questions are addressed specifically to get direct and detailed answers from the respondent, meanwhile, in most others, simple words suitable to respondents' background and knowledge are used to ensure the respondent

contract and go some way to control the behaviours of the parties to the agreement. There could be limited opportunities for formal design collaboration, reference to the model status or the inclusion of any BIM deliverables in the contract. Example of questions: • How detailed the contract conditions provide procedures for managing behaviours and detailing obligations for varying the contract scope and price, ensuring payment to the contractor and detailing the extent of construction? • How extensively do the contract conditions reflect the characteristics of formal processes for implementing change, identifying errors and omissions, with certain roles, responsibilities and liabilities for the various project stakeholders? • How explicit are the requirements for archiving project information, and then comparing it to the as-built model information-submission conditions and format outlined in the contract? • To what extent does the contract refer to the status of the model, either for any design requirements or for justification of any claims or variations? • How is the involvement of subcontractors associated with the BIM subcontracting requirements such as information and communication protocols, deliverables, model status and the contract? **3. Data Security** Example of questions: • How does the construction contract include limitations (e.g., a blanket restriction on data protection) for data access and sharing, which can restrict any unauthorised manipulation of information? • Furthermore, does this blanket restriction inhibit the ability for project stakeholders to collaborate, formally and informally, how and why? (the issue associated with this is the reference to documents, what constitutes a document, and whether it can be extended to include electronic documents and models) • How related stakeholders tackle issues relating to data security and data integrity in the event the data information is leaked/accidentally shared with unauthorised parties? • The development of the BIM model is a joint effort by various parties. There is a possibility that a third-party may make an infringement claim. How do you see the issue being tackled to avoid any infringements or copyrights issues on the drawings and documents? • Does the contract provide a comprehensive statement for the protection of confidential information, and therefore implicitly, proprietary information? • If yes, how does the aforementioned comprehensive statement facilitate a further level of protection for any information that is classified as 'restricted', such as designs for prisons or other such documents? • In your opinion, do you think it is necessary for the project to consider insuring for any losses caused by data loss or corruption? **4. ICT Protocols, Processes and Responsibilities** Communication is a component of the KPI utilised to monitor the performance of the contract management team. This also concerns communication with subcontractors, suppliers, and consultants (Holzer, 2015; Kog, 2010; Larson & Golden, 2007). Existing contract documents could have a formal process for communication among stakeholders.	really understands and is capable to answer questions in a reliable way.

Example of questions:

- How do you see the focus on the process management would impact the changes in the model? (i.e., how the management process is being documented, who is notified, and the consequences of change, be it client or contractor initiated)
- Would you please describe in detail about the specific range of protocols and procedures including documentation and standardised letters to support the administration of the contract?
- In case changes to the model are needed, who are the responsible parties for the process management of the contract, irrespective of the liability for the changes?
- From your point of view, why reference to BIM is needed in the definitions section?
- How does it impact other project stakeholders, particularly with BIM-specific requirements, obligations and liabilities for each party?
- How does the project identify which LoD will be used for different project lifecycle phases?
- Following the aforementioned explanations, with the high level of detail possible by employing BIM authoring tools, how do you see the agreed information and specific methods to a design problem stop this method from being used in either for this project?

5. Intellectual property (IP)

Azhar et al. (2008) believe that there is no simple answer to the issue of IP and BIM data and design ownership. A unique response is needed for each project, according to the specific requirements of the project stakeholders.

Example of questions:

- In your opinion, why do you think that it is significant to determine the status and application of IP/copyright over the aforementioned development stage of the project lifecycle?
- Does the contract clearly refer to the term 'data', does the definition include a reference to digital records, and what is considered a digital record?
- How would it be beneficial to clarify between what is a document and what is a digital record?
- Does the contract require the contractor to indemnify the principal against any claims for infringement of copyright?
- How any particular costs associated with this risk are covered within the contract to obtain insurance?
- Do the current forms of insurance cover the Contractor for any such losses incurred from actions taken associated with the breach of IP rights?
- If yes, to what extent the insurance covers the contractor; why and how would it be beneficial to the contractor?

6. Interoperability

Interoperability is a key component to gain the full advantages of BIM. Basically, a technical issue, it remains significant to detail the information-transfer requirements and formalises these requirements within the contract documents (pre-contract, project delivery, and operational stages).

Example of questions:

- In your opinion, do you think that the development of the BIM model should work in advance in all project development stages, and why?
- At which stage of project lifecycle should a construction-ready BIM model be developed, and why and how

would it be beneficial to the stakeholders throughout the project lifecycle? • Presently, what are the approaches being used by the project to ensure interoperability at different stages? • In the current implementation at project level, what are among the strategies (detail of BIM Plan) or solutions, as it may be hard to reconcile if the project stakeholders employ different BIM-authoring-analysis- and auditing software technology with limited interoperability? • Why do you think it is appropriate to adopt such approaches to avoid interoperability issues? • How do the aforementioned approaches facilitate respondents in understanding the interoperability requirements? • How is the incompatibility issue which is commonly experienced between different software packages being tackled and solved? • Who will be responsible to pay the costs for the management process, file servers, and the rectification of errors?	
Conclusions **1. Seek suggestions and recommendations** Example of questions: • As a BIM practitioner, what do you really hope is perceived when implementing BIM? • To whom should I talk to find out more about the development of BIM contract documents? (follow-up question) a. Use any of these probes: • i. Tell me more. Please explain. • ii. I need more details. • iii. What is an example of that? • iv. Could you explain your response more?	The aim is to get respondents' insights on what they assume to be gained and needed in the industry through their opinions and perceptions based on their knowledge and experience.

Appendix B Validation of the BIM-based contractual framework

PhD's Thesis Survey: The significant/influential legal aspects that serve as the contract provisions for BIM-based construction Projects

My name is Ahmad Huzaimi bin Abd Jamil and I am currently studying for a Doctoral degree in Construction Management at Universiti Teknologi Malaysia (UTM). I am conducting a research into the identification of significant legal aspects that serve as contract provisions for BIM-based construction projects. This survey consists of 53 legal aspects in relation to gain insights from practitioners about the significant/influential legal aspects to be used as contract provisions when designing BIM contracts. (***Please kindly rate from 1 to 5. 1=Not Important 5=Very Important***). All responses will be kept anonymous and no one will be identifiable in the research. Please tick the brackets provided to show your consent to be part of the research ( ).

1. What is your role within the BIM construction project?
   Researcher / Academician
2. How long have you worked in the BIM-related construction industry?
   ( ) Less than a year (✓) 1-5 years ( ) 5-10 years ( ) more than 10 years
3. Which one of the following serves as purposes of using BIM in Design and Build project?
   ( ) Project Visualization ( ) Improve Project Design (✓) Detect Design Clashes

   Other (Please state): _____
4. Do you find the proposed contractual framework for BIM-based project provides insightful references for practitioners to articulate their performance requirements and help them to identify any potential conflicting issues throughout the life cycle of a project?
   1-( ) 2-( ) 3-( ) 4-( ) 5-(✓)
5. Do you have any suggestion(s) to improve the proposed contractual framework?
   – It is a good framework!

Thank you for taking part in this research.

Endorsed/verified by:

DR.
Pensyarah Kanan

Index (theme)	Explanation (Subthemes)	Response
Compensation and Consideration		
1	*Implementation costs* - BIM-based costs of implementation at a project and business level	1-( ) 2-( ) 3-( ) 4-( ) 5-(✓)
2	*Project costs* - the costs for data re-entry will need to be recovered to enable data sharing and data security.	1-( ) 2-(✓) 3-( ) 4-( ) 5-( )
3	*Payment schedules* – The ability to meet changing payment schedules.	1-( ) 2-( ) 3-( ) 4-(✓) 5-( )
4	*Effort/reward* - Cost for model development should be clarified including the penalty and rewards involved, if any	1-( ) 2-( ) 3-( ) 4-( ) 5-(✓)
Conditions of Contract		
5	*Collaboration* – collaboration could be hinders, thus turning into sources of renunciations, disclaimers, and limitations on data dependence	1-( ) 2-( ) 3-( ) 4-( ) 5-(✓)
6	*Model status* – Data limitations in relation to the CAD files seem to emphasis only at the designing phase.	1-( ) 2-( ) 3-( ) 4-(✓) 5-( )
7	*Deliverables* – The content of design having met the requirements, timing of the delivery, and the format/type of electronic platform.	1-( ) 2-( ) 3-( ) 4-( ) 5-(✓)
8	*Subcontracts* - The head contract BIM deliverables and requirements being both coordinated with any subsequent subcontract with subcontractors and/or suppliers	1-( ) 2-( ) 3-( ) 4-( ) 5-(✓)
9	*E- Collaboration* - In order for guarantees to be considered legal, communications via electronic medium is required to be in written forms based on a number of jurisdictions within the integrated system.	1-( ) 2-( ) 3-( ) 4-( ) 5-(✓)
10	*Punitive measures* – Range of measures linked to the performance of the contractor in delivering the BIM requirements.	1-( ) 2-( ) 3-( ) 4-( ) 5-(✓)
11	*BIM functions adoption and software* selections should be clearly stated	1-( ) 2-( ) 3-( ) 4-( ) 5-(✓)
12	*Obligation to have BIM staff on-site* / co-location of BIM staff	1-( ) 2-( ) 3-( ) 4-( ) 5-(✓)
13	*BIM Staff Competencies*- BIM related staff certifications, skills and knowledge of BIM staff/stakeholders.	1-( ) 2-( ) 3-( ) 4-( ) 5-(✓)
Data Security		
14	*Data loss and corruption* - To curb the loss of information and preserving the data embedded in the model.	1-( ) 2-( ) 3-( ) 4-( ) 5-(✓)
15	*Data protection* - QR-Code should be adopted to prevent any infringements or copyrights from becoming lost and manipulation	1-( ) 2-( ) 3-( ) 4-( ) 5-(✓)
16	*Access and sharing* - Protect the confidential data from unauthorized individuals and to protect the integrity of data sharing.	1-( ) 2-( ) 3-( ) 4-( ) 5-(✓)
17	*Insurances* - In the event of estimating the costs related to rework resulting from data ruined or loss, suitable insurance policies are suggested.	1-( ) 2-( ) 3-(✓) 4-( ) 5-( )
18	*BIM networking establishments* (e.g., intranets, extranets, common data environment and platforms, etc.)	1-( ) 2-( ) 3-( ) 4-( ) 5-(✓)

19	*Security Event Response Plan*- when a security event is detected, it is immediately shared/communicated with the liable teams are notified and assembled to immediately address the event.	1- ( ) 2-( ) 3-( ) 4-( ) 5-(✓)
ICT Protocols		
20	*Process/change management* - To prioritize the BIM processes involved in administration	1- ( ) 2-( ) 3-( ) 4-( ) 5-(✓)
21	*Responsibilities* - Necessary changes in process may occur within organizations when new roles are observed.	1- ( ) 2-( ) 3-( ) 4-( ) 5-(✓)
22	*Communication* - The contract language has to be strong, and the required data in the documents have to be spelled out meticulously.	1- ( ) 2-( ) 3-( ) 4-( ) 5-(✓)
23	*Model Level of development (LOD)* - To handle the substance of the model by means of the definition of agreed five LoDs	1- ( ) 2-( ) 3-( ) 4-( ) 5-(✓)
24	*BIM execution plan* - To help overcome various issues associated with both the technical and administrative	1- ( ) 2-( ) 3-( ) 4-( ) 5-(✓)
25	aspects of the projects based on BIM.	
	Archiving protocols- Appropriative details on how the project information will be archived in a format that can be easily accessed in the future need to be considered when requesting any 'as-built' to support (OM/FM).	1- ( ) 2-( ) 3-( ) 4-( ) 5-(✓)
Intellectual Property		
26	*Ownership of BIM model and data* – The ownership of copyright when the model is created ✗	1- ( ) 2-( ) 3-( ) 4-( ) 5-(✓)
27	*Confidential/proprietary information* - The trademark embedded into BIM, which may leak among contenders.	1- ( ) 2-( ) 3-( ) 4-( ) 5-(✓)
28	*Ongoing protection* – The requirements for ongoing intellectual property and access to information project rights.	1- ( ) 2-( ) 3-( ) 4-( ) 5-(✓)
29	*Licensing for use* - It requires the contractor to obtain IP licensing for almost all aspects of the project	1- ( ) 2-( ) 3-( ) 4-( ) 5-(✓)
30	*Indemnity insurance* - The contract requires the Contractor to take responsibility for any claims for breaches of IP data provided for the contract	1- ( ) 2-( ) 3-( ) 4-( ) 5-(✓)
Interoperability		
31	*Technology compatibility* – Compatibility between BIM authoring, analysis, and auditing software is considered necessary at the pragmatic level.	1- ( ) 2-( ) 3-( ) 4-( ) 5-(✓)
32	*Transfer procedures* - Attempts to include transfer protocols such as the file format, data exchange monitoring, and correction of blunders for data transfer is imminent.	1- ( ) 2-( ) 3-( ) 4-( ) 5-(✓)
33	*Responsibility* - The responsibility of the project participants in managing process and its related error rectification.	1- ( ) 2-( ) 3-( ) 4-( ) 5-(✓)
34	*Auditing* - The processes of recording and auditing require the attention of the members to help trail any changes and exchange of data among project members.	1- ( ) 2-( ) 3-( ) 4-( ) 5-(✓)
35	*Requirement for Project participants' responsibilities to work closely with end users*-contractual responsibilities to	1- ( ) 2-( ) 3-( ) 4-( ) 5-(✓)

	software can make in updating the design and that the design is undertaken in a collaborative environment by non-licensed professionals.	1-( )2-( )3-( )4-( )5-(✓)
48	*Professional Liability Insurances*- it relates to design input and responsibility when BIM is used in a project and non-professional stakeholders have input into the design.	1-( )2-( )3-(✓)4-( )5-( )
49	*Spearin Doctrine*- The Spearin doctrine should be applied and upheld. The contractor shall not be held liable for the loss caused by the insufficient information the contractor received or followed solely. DBB ✓ DCB ×	1-(✓)2-( )3-( )4-( )5-( )
Legislation and udicial Precedence		
50	*Privity third party reliance*- a designer may not be able to claim the lack of privity of contract for his or her defense, especially under a collaborative system	1-( )2-( )3-( )4-( )5-(✓)
51	*Legislative jurisdiction*- the relevant legislative jurisdiction needs to be identified in the contract documents.	1-( )2-( )3-( )4-( )5-(✓)
52	*E-contracting/E-transactions*- confirmation that the authority to contract exists, the status of electronic notices and the ability to amend a contract electronically	1-( )2-( )3-( )4-( )5-(✓)
53	*Archiving*- contracting agencies of a government agency, it must comply with the statutory obligation to retain public records in ensuring the records remain accessible and the integrity of the records is maintained, and conforms to the statutory requirements.	~~1-( )2-( )3-( )4-( )5-~~( ) 1-( )2-( )3-( )4-( )5-(✓)

PhD's Thesis Survey: The significant/influential legal aspects that serve as contract provisions for BIM-based construction Projects

My name is Ahmad Huzaimi bin Abd Jamil and I am currently studying for a Doctoral degree in Construction Management at Universiti Teknologi Malaysia (UTM). I am conducting a research into the identification of significant legal aspects that serve as contract provisions for BIM-based construction projects. This survey consists of . legal aspects in relation to gain insights from practitioners about the significant/influential legal aspects to be used as contract provisions when designing BIM contracts. (***Please kindly rate from 1 to 5. 1=Not Important 5=Very Important***). All responses will be kept anonymous and no one will be identifiable in the research. Please tick the brackets provided to show your consent to be part of the research ( ).

1. What is your role within the BIM construction project?
   to develop the BIM implementation & best practices in construction industries.
2. How long have you worked in the BIM-related construction industry?
   ( ) Less than a year ( ) 1-5 years ( ) 5-10 years (✓) more than 10 years

3. Which one of the following serves as purposes of using BIM in Design and Build project?
   (✓) Project Visualization (✓) Improve Project Design ( ) Detect Design Clashes

   Other (Please state): Improve supply chain of information between all stakeholders.

4. Do you find the proposed contractual framework for BIM-based project provides insightful references for practitioners to articulate their performance requirements and help them to identify any potential conflicting issues throughout the life cycle of a project?
   1-( ) 2-( ) 3-( ) 4-( ) 5-(✓)

5. Do you have any suggestion(s) to improve the proposed contractual framework?
   Have to implement the contract first.
   to see the effectiveness of the subject or proposed criteria. so that we will identify which area or criteria to improve.

Thank you for taking part in this research.

Endorsed/verified by:

Arkitek Penguasa Kanan
Unit Building Information Modelling

Index (theme)	Explanation (Subthemes)	Response
Compensation and Consideration		
1	*Implementation costs* - BIM-based costs of implementation at a project and business level	1-( ) 2-( ) 3-( ) 4-( ) 5-( )
2	*Project costs* - the costs for data re-entry will need to be recovered to enable data sharing and data security.	1-( ) 2-( ) 3-( ) 4-( ) 5-( )
3	*Payment schedules* – The ability to meet changing payment schedules.	1-( ) 2-( ) 3-( ) 4-( ) 5-( )
4	*Effort/reward* - Cost for model development should be clarified including the penalty and rewards involved, if any	1-( ) 2-( ) 3-( ) 4-( ) 5-( )
Conditions of Contract		
5	*Collaboration* – collaboration could be hinders, thus turning into sources of renunciations, disclaimers, and limitations on data dependence	1-( ) 2-( ) 3-( ) 4-( ) 5-( )
6	*Model status* – Data limitations in relation to the CAD files seem to emphasis only at the designing phase.	1-( ) 2-( ) 3-( ) 4-( ) 5-( )
7	*Deliverables* – The content of design having met the requirements, timing of the delivery, and the format/type of electronic platform.	1-( ) 2-( ) 3-( ) 4-( ) 5-( )
8	*Subcontracts* - The head contract BIM deliverables and requirements being both coordinated with any subsequent subcontract with subcontractors and/or suppliers	1-( ) 2-( ) 3-( ) 4-( ) 5-( )
9	*E- Collaboration* - In order for guarantees to be considered legal, communications via electronic medium is required to be in written forms based on a number of jurisdictions within the integrated system.	1-( ) 2-( ) 3-( ) 4-( ) 5-( )
10	*Punitive measures* – Range of measures linked to the performance of the contractor in delivering the BIM requirements.	1-( ) 2-( ) 3-( ) 4-( ) 5-( )
11	*BIM functions adoption and software* selections should be clearly stated	
12	*Obligation to have BIM staff on-site* / co-location of BIM staff	
13	*BIM Staff Competencies*- BIM related staff certifications, skills and knowledge of BIM staff/stakeholders.	
Data Security		
14	*Data loss and corruption* - To curb the loss of information and preserving the data embedded in the model.	1-( ) 2-( ) 3-( ) 4-( ) 5-( )
15	*Data protection* - QR-Code should be adopted to prevent any infringements or copyrights from becoming lost and manipulation	1-( ) 2-( ) 3-( ) 4-( ) 5-( ) 1-( ) 2-( ) 3-( ) 4-( ) 5-( )
16	*Access and sharing* - Protect the confidential data from unauthorized individuals and to protect the integrity of data sharing.	1-( ) 2-( ) 3-( ) 4-( ) 5-( )
17	*Insurances* - In the event of estimating the costs related to rework resulting from data ruined or loss, suitable insurance policies are suggested.	
18	*BIM networking establishments* (e.g., intranets, extranets, common data environment and platforms, etc.)	1-( ) 2-( ) 3-( ) 4-( ) 5-( )

ICT Protocols		
19	*Process/change management* - To prioritize the BIM processes involved in administration	1-( ) 2-( ) 3-( ) 4-( ) 5-(✓)
20	*Responsibilities* - Necessary changes in process may occur within organizations when new roles are observed.	1-( ) 2-( ) 3-( ) 4-( ) 5-(✓)
21	*Communication* - The contract language has to be strong, and the required data in the documents have to be spelled out meticulously.	1-( ) 2-( ) 3-( ) 4-( ) 5-(✓)
22	*Model Level of development (LOD)* - To handle the substance of the model by means of the definition of agreed five LoDs	1-( ) 2-( ) 3-( ) 4-( ) 5-(✓)
23	*BIM execution plan* - To help overcome various issues associated with both the technical and administrative aspects of the projects based on BIM.	1-( ) 2-( ) 3-( ) 4-( ) 5-(✓)
24	*Archiving protocols*- Appropriative details on how the project information will be archived in a format that can be easily accessed in the future need to be considered when requesting any 'as-built' to support (OM/FM).	1-( ) 2-( ) 3-( ) 4-( ) 5-(✓)
Intellectual Property		
25	*Ownership of BIM model and data* – The ownership of copyright when the model is created	1-( ) 2-( ) 3-( ) 4-( ) 5-(✓)
26	*Confidential/proprietary information* - The trademark embedded into BIM, which may leak among contenders.	1-( ) 2-( ) 3-( ) 4-( ) 5-(✓)
27	*Ongoing protection* – The requirements for ongoing intellectual property and access to information project rights.	1-( ) 2-( ) 3-( ) 4-( ) 5-(✓)
28	*Licensing for use* - It requires the contractor to obtain IP licensing for almost all aspects of the project	1-( ) 2-( ) 3-( ) 4-( ) 5-(✓)
29	*Indemnity insurance* - The contract requires the Contractor to take responsibility for any claims for breaches of IP data provided for the contract	1-( ) 2-( ) 3-( ) 4-( ) 5-(✓)
Interoperability		
30	*Technology compatibility* – Compatibility between BIM authoring, analysis, and auditing software is considered necessary at the pragmatic level.	1-( ) 2-( ) 3-( ) 4-( ) 5-(✓)
31	*Transfer procedures* - Attempts to include transfer protocols such as the file format, data exchange monitoring, and correction of blunders for data transfer is imminent.	1-( ) 2-( ) 3-( ) 4-( ) 5-(✓)
32	*Responsibility* - The responsibility of the project participants in managing process and its related error rectification.	1-( ) 2-( ) 3-( ) 4-( ) 5-(✓)
33	*Auditing* - The processes of recording and auditing require the attention of the members to help trail any changes and exchange of data among project members.	1-( ) 2-( ) 3-( ) 4-( ) 5-(✓)

Information quality standard procedures/protocols	integrity. / Moding Model. The model should always update. with current information.	
34	*Frequent value engineering*-using cost estimating software to address inconsistencies, which often results in compromises to the original design. –	1-( ) 2-( ) 3-( ) 4-( ) 5-(✓)
35	*Model Data Validation*- serves as a platform upon developing plans of transitions by protecting the model and the data from becoming lost, corrupted or manipulated; detail out for asset and inventory management. +d procedures/checklist -	1-( ) 2-( ) 3-( ) 4-( ) 5-(✓)
36	*BIM Test benchmarking procedures*- Status data collection on site/off site (Match degree between implemented standards and status and goals of the organization) Audit - BEP / comply.	1-( ) 2-( ) 3-( ) 4-( ) 5-(✓)
37	*Soft-landings* - a platform that requires the involvement of FMT in BIM meetings from the start of the project and up to its completion in order to facilitate a proper handover and close out. EIR - objective.	1-( ) 2-( ) 3-( ) 4-( ) 5-(✓)
38	*Clash Detection and inspection* - Insertion of accepted procedure and safeguarding provisions to minimize the risk of errors in exchanging information.	1-( ) 2-( ) 3-( ) 4-( ) 5-(✓)
Professional Liability		
39	*Design Control*- the need to determine who is in overall control of the design. In a typical project, there are multiple contributors to the design such as subcontractors, suppliers and even the client. – Donath.	1-( ) 2-( ) 3-( ) 4-( ) 5-(✓)
40	*Design Liability* -Determining who is professionally responsible for the design, particularly in a collaborative project environment, to produce models in accordance with agreed Levels of Detail (LoD)	1-( ) 2-( ) 3-( ) 4-( ) 5-(✓)
41	*Standard of care*-will have a direct relationship to the level of reliance detailed in the contract, for example the higher level of care a designer takes in detailing the model will allow for a greater amount of reliance on the model – BIM Manager.	1-( ) 2-( ) 3-( ) 4-( ) 5-(✓)
42	*Design delegation*- outsourced to other firms. How this delegation is treated, with due consideration to the risk posed to the project participants and legislative requirements is critical by assessing a reasonable exposure to risk	1-( ) 2-( ) 3-( ) 4-( ) 5-(✓)
43	*Software Generated Design Liability*- any errors in the design caused by these software bugs remain the responsibility of the designers. Which raises the question is there a responsibility for the design professional to track and check these changes? Strategy - Implement - develop component.	1-( ) 2-( ) 3-( ) 4-( ) 5-(✓)
44	*Design Professional Licensing*- This individual is assuming a significant amount of liability considering the changes software can make in updating the design and that the design is undertaken in a collaborative environment by non-licensed professionals. – capability.	1-( ) 2-( ) 3-( ) 4-( ) 5-(✓)
45	*Professional Liability Insurances*- it relates to design input and responsibility when BIM is used in a project and non-professional stakeholders have input into the design.	1-( ) 2-( ) 3-( ) 4-( ) 5-(✓)

46	*Spearin Doctrine*- The Spearin doctrine should be applied and upheld. The contractor shall not be liable for the loss caused by the insufficient information the contractor received or followed solely.	1-( ) 2- ( ) 3- ( ) 4-( ) 5-(✓)
Legislation and judicial Precedence		
47	*Privity third party reliance*- a designer may not be able to claim the lack of privity of contract for his or her defense, especially under a collaborative system	1-( ) 2- ( ) 3- ( ) 4-( ) 5-(✓)
48	*Legislative jurisdiction*- the relevant legislative jurisdiction needs to be identified in the contract documents.	1-( ) 2- ( ) 3- ( ) 4-( ) 5-(✓)
49	*E-contracting/E-transactions*- confirmation that the authority to contract exists, the status of electronic notices and the ability to amend a contract electronically e-tendering / signing / password.	1-( ) 2- ( ) 3- ( ) 4-( ) 5-(✓)
50	*Archiving*- contracting agencies of a government agency, it must comply with the statutory obligation to retain public records in ensuring the records remain accessible and the integrity of the records is maintained, and conforms to the statutory requirements. → up date / current. / life update.	1-( ) 2- ( ) 3- ( ) 4-( ) 5-(✓)

Appendix C Letter of Student Verification

UTM Razak School of Engineering and Advanced Technology
UTM Kuala Lumpur
UNIVERSITI TEKNOLOGI MALAYSIA

UTM Razak School of Engineering
and Advanced Technology
Level 7, Menara Razak
Universiti Teknologi Malaysia
Jalan Sultan Yahya Petra
54100 Kuala Lumpur, Malaysia

Tel: +(6)03-21805138 Fax: +(6)03-21805380 http://www.razakschool.utm.my

OUR REF.: UTM.K.40.02.03/13.11/1/4 Jld.8 (59) 20 September 2017

KEPADA SESIAPA YANG BERKENAAN

Tuan,

NAMA	:	**AHMAD HUZAIMI BIN ABD JAMIL**
NO. MATRIK	:	**PRS163013**
NO. K/P	:	**840814-10-5381**
PROGRAM	:	**DOKTOR FALSAFAH (SEPENUH MASA)**
SEMESTER SEMASA	:	**SEMESTER 1, SESI 2017/2018**
TAJUK PROJEK	:	**[illegible] CONTRACT FOR BUILDING INFORMATION MODELLING (BIM) CONSTRUCTION PROJECTS IN THE MALAYSIAN CONSTRUCTION INDUSTRY**
PENYELIA	:	**DR. MOHAMAD SYAZLI BIN FATHI**
E-MAIL	:	**syazli@utm.my**

Adalah disahkan bahawa penama di atas adalah mahasiswa **Doktor Falsafah** di UTM Razak School of Engineering and Advanced Technology, Universiti Teknologi Malaysia, Kuala Lumpur.

2. Sehubungan itu, Pihak UTM Razak School of Engineering and Advanced Technology berharap pihak tuan dapat memberi pertimbangan sewajarnya agar pelajar ini dapat untuk membuat penyelidikan / tugasan / rujukan di tempat tuan.

Kerjasama dari pihak tuan didahului dengan ucapan ribuan terima kasih.

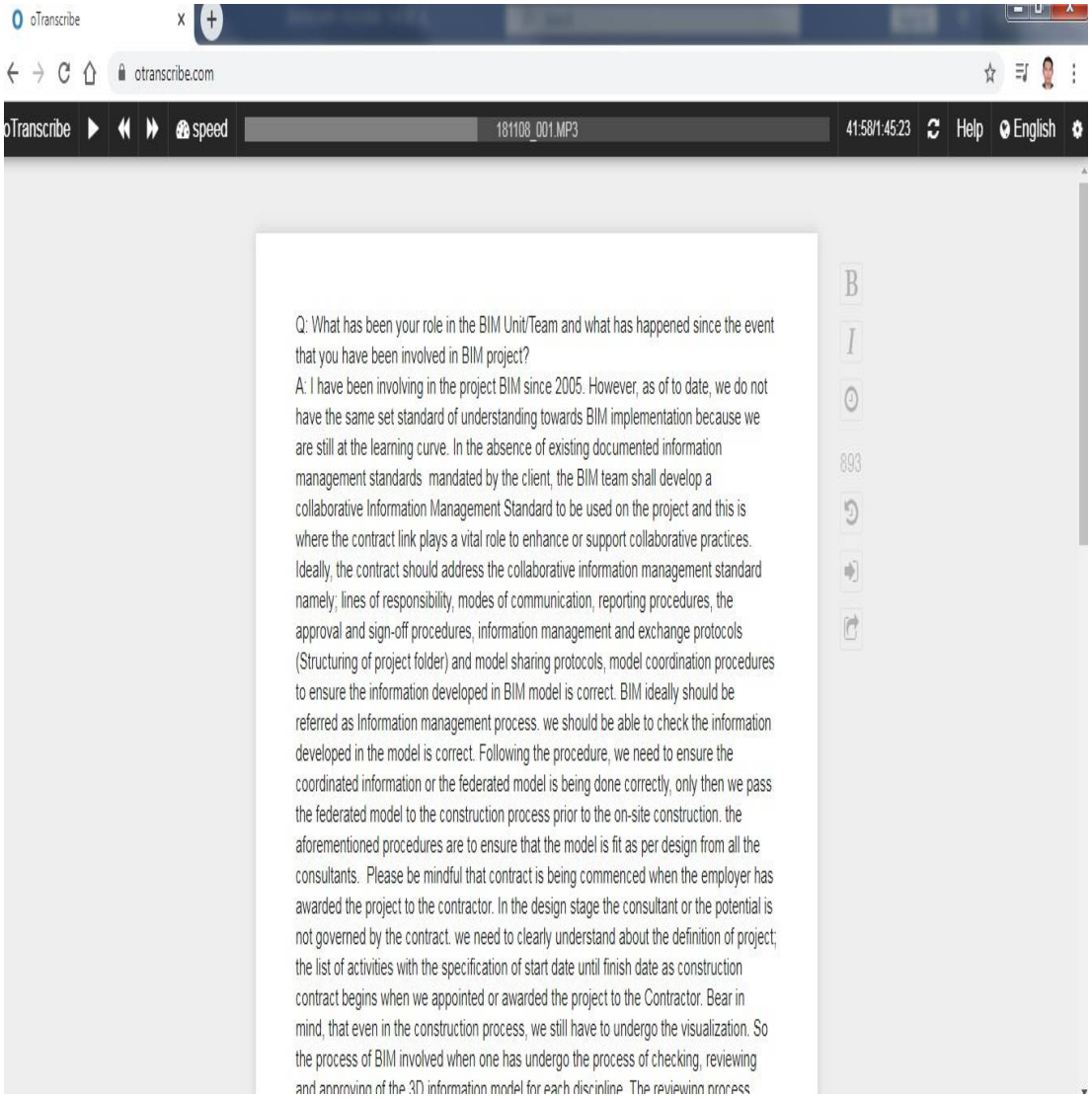
"Berkhidmat untuk Negara kerana Allah"

Yang benar,

NASIR BIN OSMAN
Timbalan Pendaftar
UTM Razak School of Engineering and Advanced Technology
UTM Kuala Lumpur
b/p Naib Canselor
☎ 03 - 21805360
🖷 03 - 26154380
✉ nasir.kl@utm.my

s.k - Penyelia

Appendix D Example of O-Transcribe Interview



Q: What has been your role in the BIM Unit/Team and what has happened since the event that you have been involved in BIM project?
A: I have been involving in the project BIM since 2005. However, as of to date, we do not have the same set standard of understanding towards BIM implementation because we are still at the learning curve. In the absence of existing documented information management standards mandated by the client, the BIM team shall develop a collaborative Information Management Standard to be used on the project and this is where the contract link plays a vital role to enhance or support collaborative practices. Ideally, the contract should address the collaborative information management standard namely; lines of responsibility, modes of communication, reporting procedures, the approval and sign-off procedures, information management and exchange protocols (Structuring of project folder) and model sharing protocols, model coordination procedures to ensure the information developed in BIM model is correct. BIM ideally should be referred as Information management process. we should be able to check the information developed in the model is correct. Following the procedure, we need to ensure the coordinated information or the federated model is being done correctly, only then we pass the federated model to the construction process prior to the on-site construction. the aforementioned procedures are to ensure that the model is fit as per design from all the consultants. Please be mindful that contract is being commenced when the employer has awarded the project to the contractor. In the design stage the consultant or the potential is not governed by the contract. we need to clearly understand about the definition of project; the list of activities with the specification of start date until finish date as construction contract begins when we appointed or awarded the project to the Contractor. Bear in mind, that even in the construction process, we still have to undergo the visualization. So the process of BIM involved when one has undergo the process of checking, reviewing and approving of the 3D information model for each discipline. The reviewing process

Appendix E Confidential Disclosure Letter and Email Invitation

Dear IR. Zai

The bearer of this letter, I am Ahmad Huzaimi bin Abd Jamil is a PhD student of UTM Razak School of Engineering and Advanced Technology, Kuala Lumpur. As part of my Doctoral research studies, I am required to conduct a case study at your firm. Hence, in this regard I am currently conducting a research study entitled "] [illegible] Contract for Building Information Modelling (BIM) Construction Projects in The Malaysian Construction Industry". The tasks in my research studies are to conduct a case study by analyzing the related BIM contract documents as well as to conduct interviews session with relevant project teams/stakeholders of your firm. The ultimate outcomes of this research study is to propose additional elements required for BIM contract documents based on standard LoD.

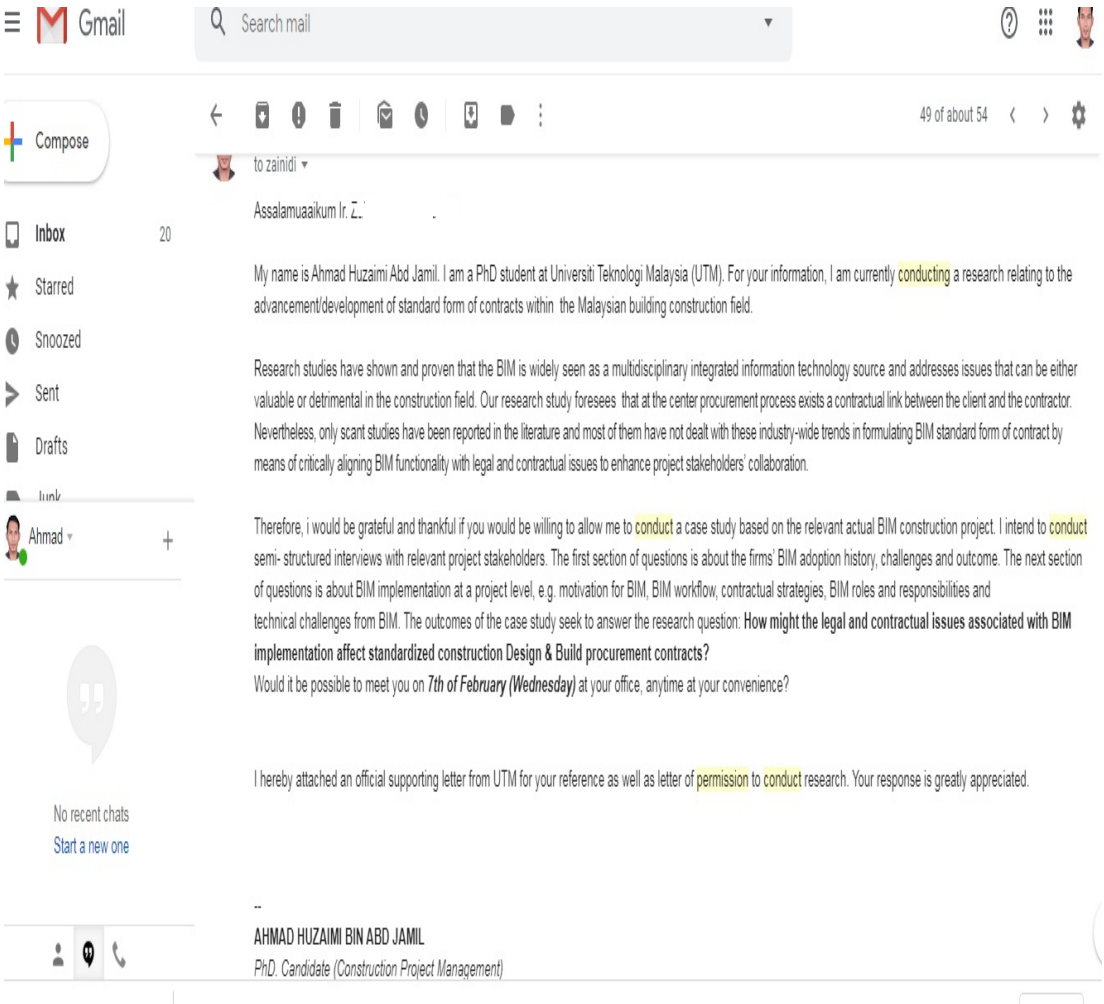
After the research study has been completed, you are welcome to preview the outcomes of this research anytime you want. I assure you that there will be no misuse of this information and the source of this information will be kept concealed and strictly confidential. As a researcher, I will be responsible for any misuse of this information.

I hope that in light of above mentioned events you will allow to conduct the research study at your firm. I shall be very thankful to you for this kind favor. Attached with this letter is an official supporting and confirmation letter from Universiti Teknologi Malaysia (UTM).

Thank you.

Yours sincerely,

Ahmad Huzaimi bin Abd Jamil
PhD candidate
UTM Razak School of Engineering and Advanced Technology
UTM Kuala Lumpur



Appendix F Example of Interview Transcript (Member Checking)

12. In your opinion, do you think it is necessary for the project to consider insuring for any losses caused by data loss or corruption? How the acquisitions of appropriate insurance would give benefits to cover the costs for rework resulting from data?

Currently, we do not have any related insurance covers under specific causes such as data corrupted and losses but I somehow agree that it is good for the contract to have such inclusion that would cover the cost of rework resulting from data corruption or perhaps manipulation to rectify the related information. (the quotation from need to carry out with control / unauthorised mechanism).

13. How do you see the focus on the process management would give impact to the changes of the model, i.e: how the management process is being documented, who is notified, and the consequences of change, be it client- or contractor initiated?

We do impose such implementation called NOC. It is normally initiated by the client. Notably, it should be documented the NOC where it also followed by Request for inspection (RFI). This is due to the handover data of close out phase, the RFI methodology and the information is not updated. What even worse, the construction has already completed but the information of the model is not well documented and archived. What can I say here, the management process outline in the employer information requirement and BEP remains theoretical. At some given moment, the contractor and the client know the responsibilities and obligations but they don't have control mechanism with regards the liability of the design changes to main contractor. Another important great aspect to be considered in the future would be to conduct value engineering or in other words information quality assessment procedures or protocols.

HCR (non-conformance record).

CNCR document clearly in the BEP.

Finalyst to close the HCR.

14. How the digital model is treated and is it a separate issue from the intellectual property of the design? For example, with the high level of detail possible using BIM authoring tools, how do you see the background information and specific approaches to a design problem prohibit this approach from being applied to either for this project?

It should be clearly detailed out in the contract the type of BIM authoring tools, for example; the licensing software agreement as it will somehow affected the interoperability of the data.

MANAGING DIRECTOR

SDN BHD

Appendix G Summary of Outcomes of Case Studies

Case study	Event description	Context and causes (qualitative analysis findings)	Contracting issues	Mitigation strategies	Concerned party
A and C	Inadequate detailed design	Context 1) At the post-contract phase, because of changes in the client's organisation, the Client asked to move the location of the emergency room/intensive care unit (ICU). 2) This resulted in a change in specification concerning the safety and health of end-users, leading to new design parameters for the medical equipment system. Reasons 3) Upon reviewing the new comprehensive design parameters, it was determined that the initial design's capacity was inadequate and needed to be raised. 4) This caused a design change in the speciality-equipment system that needed the approval of the Client. 5) The MEP design affected other relevant construction activities like interior finishing, testing, and commissioning.	The consequences derived from some contracting issues were: 1) The BEP and need statement were perceived as too general. There was no clear mention as to how the project team should have collaborated and the information exchange protocol was not provided. 2) In terms of BIM implementation costs, the contract did not specify the costs of data re-entry to allow data sharing. 3) A client representative claimed that the contractor could not perform some of the BIM requirements or deliverables. The client commented that penalty should be imposed when the required BIM functional area was not delivered.	1) A specific standard form of contract is essential for including the extent of all works and requirements of BIM. 2) For highly complex construction projects like hospitals, clients and end-users should have closely collaborated as early as at the planning phase. 3) Scope and requirements of BIM should have been adequately integrated with client/end-user and covered using an addendum. 4) Scope and requirements of BIM must not be mandated with legal repercussions.	Project client, architect and designer
B	Detailed design - Design discrepancy	Context After being awarded the contract, the main Contractor must finish the project based on the initial design intent.	1) The contract stated that the Contractor shall establish and use in-house BIM modelling quality control guidelines and exchange protocols. However, due to	The design process should have been coordinated with an agreed standard like BS1192. This should have also been mentioned in the Consultant's	

		After the detailed design was approved, the Consultant's role was reduced to site supervision with a loose contractual agreement (the site supervision team differed from the initial design team). This made conveying the design intent to the contractor terribly hard. Design drawings that were unfinished and inconsistent along with incomplete specifications led to the main Contractor interpreting the design drawings that resulted in numerous variations. Causes Absence of design coordination at the design phase led to inconsistent design drawings. Absence of an agreement to manage the creation of a detailed design via an automated system. Lack of clear standards, like the UK National Building Specification (NB), to generate detailed specifications, which resulted in a design with incomplete specifications.	some changes and time constraint, the contractor had to appoint a third-party to ensure BIM deliverables. The issues came into the hotly contested derives under from the context of determining professional liability. Furthermore, IP and data quality standard procedures were not clearly mentioned in the contract. 2) The model development and BIM deliverables were stated in general. There was no clear indication of what was the key functional areas of BIM that should be delivered in the contract. 3) The contractor had difficulties to cooperate with FM by incorporating as-built information into FM tools and software as the FM information requirements were not stated in the BEP.	contract. However, there was no mention in the contract under which specification the agreed standards of the contract should be governed by. Client leadership should have been applied during the design phase to make sure the coordinated system was executed. Specifications standard should have been approved by the Client and followed by the Consultants. The consultants or the Client should have suggested and used an automated system to coordinate the design process. Including the main Contractor before tendering would have revealed most of the design inconsistencies when the design is reviewed with the Consultant. Challenges Local practices give total design responsibility to consultants with limited Client participation and no clear authority to oversee and review design progress. Lack of local specifications standards. In the event of any inconsistencies, 2D drawings will have precedence over 3D drawings, or 3D drawings with extensive details of the BIM model will have precedence over 2D drawings.	

C and D	Unsuitable quality control for the structural reinforcement work	Context The structural design caused certain building elements to be extremely crammed with steel reinforcement. Thus, regular concrete mix became inappropriate, i.e. gravels could not pass through and/or compacted efficiently. This issue was noted on site as construction proceeded, and solutions were produced on site. Both the Contractor and the Client representative addressed this issue either by redesigning building elements with a different system like composite steel and concrete sections or ordering a special concrete mix like micro-concrete/self-compacted concrete. Causes Design codes were not firmly followed and constructability of the structural design solution was disregarded. The local contractor had absolutely no role at the detailed design stage.	The contractor did not provide a suitable and interoperable viewing platform, inspection procedures, and output file formats, i.e. no tools to check the validity and accuracy of files and observance of modelling standards.	1) BIM Manager's new role should be involved in the early design stage of the project by extensively reviewing: - A detailed modelling of the structural design in BIM should have revealed this issue. - At the design review, the 3D visualisation of the detailed structural elements should have clearly shown this issue. The duties and scopes of works of every party involved should be detailed in the contract; the participation of the contractors at the design phase and their involvement in structural design review should have highlighted this problem. The contract should specify BIM's objectives and quality audit for varying stages of BIM model development and a detailed simulation of the construction process should have emphasised this problem if it was not noted during design review. The contractual relationship amongst the client, designers, and contractors should be clearly mentioned and connected to the project. Local culture and practices hinder better collaboration among the project's partners. This always leads to bad and uncoordinated planning.	General contractor, designers and BIM consultants
A, B and C	Insufficient planning for the transfer procedure	Context An external consultant was hired to perform the necessary structure modifications.	The amount of information needed was not functionally integrated during model coordination as the MEP model was yet to establish	The contract should have specified a stronger client's role in handling and supervising the design modification process, including performing a complete assessment of	Client, contractor and designers

		Limited coordination amongst the Consultant, Contractors, and Client led to numerous additional reworks on site. The Contractor underestimated the work needed and no suitable construction action or work plan was produced.	what it could be utilised for. The object property data was not extensively regarded in the BEP, whereby the clash analysis performed on the models was not efficiently conducted due to some missing model elements from the MEP discipline.	impact on construction. The design team should not be accountable for carelessness on the part of the design team. Such loss/damage should be recovered by the injured party or third-party. The contract should specify the client led task force, consisting of every project partner, and should have been formed with clear deadlines to make sure a fully coordinated design is produced.	
A and D	Reinstatement due to construction rework	Context Because of changes in the usage of the facility as required by the client, the design construction reworks had to be reinstated. Consequently, further approval from the relevant local authority was needed, which then increased costs. Causes - Unfamiliar with the Local Authority's requirements - Limited constant consultation with the Local Authority	Most of BIM project occurs when construction has started. This is because there is no proper plan for implementing BIM at an early phase as well as a delay in identification of BIM uses. Apart from that, the use of BIM only happens when the project is facing problems such as regularity of rework due to design changes	With BIM, the Consultant would have modelled the external roadwork for the Local Authority, hence, enhancing the interaction between the Client and Local Authority. Via BIM, a quicker solution would have been made possible. - The contract document should include digital data and information gathered from the consultation with the end-user or related authority - Cost/payment of BIM should be based on the progress payment for the work completed or the models' completion and its functions needed in the project.	BIM consultants, designers and project client

LIST OF PUBLICATIONS

1) **Abd Jamil, A. H.**, & Fathi, M. S. (2020). Enhancing BIM-based Information Interoperability: Disputes Resolution from Legal and Contractual Perspectives. *Journal of Construction Engineering and Management,* ASCE, 146 (7), 1-12 (Q1, Scopus and Q1, ISI indexed, IF: 2.968)
2) **Abd Jamil, A.H.** & Fathi, M.S., (2019). The Transformation of Construction Processes through Building Information Modelling-based Contractual Approach for Design-Build Construction Projects. *Connect-Us-Conference, Universiti Teknologi Malaysia Kuala Lumpur.* (Best Paper Award)
3) **Abd Jamil, A.H.**, & Fathi, M. S. (2019). Contractual issues for Building Information Modelling (BIM)-based construction projects: An exploratory case study. *IOP Conference Series: Materials Science and Engineering, 513, 012035*. (Scopus Indexed)
4) **Abd Jamil, A.H**. and Fathi, M.S., 2018. Contractual Challenges for BIM-based construction projects: a systematic review. *Built Environment Project and Asset Management*, pp. 1-15. (Q2, Scopus/ ISI Indexed, IF: 1.68)
5) **Abd Jamil, A.H.** & Fathi, M.S., 2017. *Akademia Baru Journal of Advanced Research in Business* An overview of contract documents for building information modelling (BIM) construction projects *Akademia Baru*. , 2(2), pp.68–72. (Non-indexed)
6) **Abd Jamil, A.H.** & Fathi, M.S., 2016. The Integration of Lean Construction and Sustainable Construction: A Stakeholder Perspective in Analyzing Sustainable Lean Construction Strategies in Malaysia. *Procedia Computer Science*, 100, pp.634–643. (Scopus Indexed)