EXPLORE THE ISSUES AND CHALLENGES TO ADOPT BUILDING INFORMATION MODELLING (BIM) LEVEL 3

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A project report submitted in partial fulfilment of the requirements for the award of Bachelor of Science (Honours) Quantity Surveying

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DECLARATION

I hereby declare that this project report is based on my original work except for citations and quotations which have been duly acknowledged. I also declare that it has not been previously and concurrently submitted for any other degree or award at UTAR or other institutions.

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APPROVAL FOR SUBMISSION

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ABSTRACT

Over the past decade, Building Information Modelling (BIM) has become widely used in the construction sector especially in the United States (US), United Kingdom (UK), Singapore and China. Malaysia has also set up a strategic plan for BIM implementation in the Malaysian construction industry through the Construction Industry Transformation Programme (CITP) 2016-2020. BIM is an evolving technology; the earlier researchers had introduced maturity level of 0-3 to delineate the features and challenges of each of the maturity level. This research intends to explore the issues and challenges towards BIM Level 3 adoption in the Malaysian construction industry. The objectives of this study are: (i) to demystify the driving factors that need for initiating the BIM Level 3 adoption; (ii) to investigate the current practices of BIM in the Malaysian construction industry and (iii) to uncover the issues and challenges of BIM Level 3 adoption in the Malaysian construction industry. Six categories of BIM Level 3 drivers, namely, ISO19650, Industry Foundation Classes, cloud-based BIM, open BIM and single shared model were identified through literature review. Questionnaire survey was formulated to collect empirical data from the industrial practitioners via online survey tools. Data collected from 230 respondents are analysed by Cronbach's alpha reliability analysis, descriptive analysis to determine the frequency distribution, mean, and standard deviation; inferential statistics tests such as a K-independent samples test, the Kruskal-Wallis H test in order to derive a generalisable findings. The result revealed that practices of BIM Level 1 are commonly found in Malaysia, but many efforts to promote the adoption of BIM Level 3 is yet to be seen. Among the different actors in the industry, suppliers are the leading adopters of BIM and have a higher readiness toward BIM Level 3 adoption. Furthermore, the findings also revealed the three most crucial barrier to the adoption of BIM Level 3 are the need to upskill the knowledge of professionals in the advanced level of BIM knowledge, to adopt open BIM in improving the interoperability of building information and the need to use cloud-based BIM. The findings are useful to the construction industry, regulatory bodies and academia to pre-empt the issues and challenges which may be encountered in the implementation of BIM Level 3 in the construction industry.

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LIST OF SYMBOLS / ABBREVIATIONS

BIM	Building Information Modelling
US	United States
UK	United Kingdom
CITP	Construction Industry Transformation Programme
BCA	Building and Construction Authority
JKR	Public Works Department
CIDB	Construction Industry Development Board
iBIM	Integrated Building Information Modelling
ASI	Austria Standards International
RICS	Royal Institution of Chartered Surveyors
NIBS	National Institute of Building Sciences
CAD	Computer-aided Design
CDE	Common Data Environment
ISO	International Organisation for Standardisation
IFC	Industry Foundation Classes
NIST	National Institute of Standards and Technology
bSDD	buildingSMART Data Dictionary
BCF	BIM Collaboration Format
PIR	Project Information Requirement
EIR	Employers’ Information Requirement
DBB	Digital Built Britain

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CHAPTER 1

INTRODUCTION

1.1 Background

The construction industry has been lagging behind other industries due to communication, coordination, and standardisation difficulties. Building information modelling (BIM) is perceived as one of the most promising technology-led changes that improving the delivery of construction projects, which will evolve the conventional construction practices in the industry.

From an international perspective on BIM, many countries have expressed strong interest in adopting BIM throughout the construction industry. Since April 2016, all centrally procured construction projects in the UK are required to achieve BIM Level 2 (Paul, 2018). In Singapore, the Building and Construction Authority (BCA) has implemented BIM on all the public projects from year 2015 onwards (Paul, 2018). In an effort to keep up with the global digital construction trend, Malaysia has also set up a strategic plan for BIM implementation in the construction industry through the Construction Industry Transformation Programme (CITP) 2016-2020. In addition, the Public Works Department (JKR) of Malaysia has set the adoption of the mechanism to reach 50% in 2021 and 80% by 2025 in its Strategic Plan 2021-2025 (JKR, 2020).

Malaysia Building Information Modelling Report 2019 disclosed a positive trend was recorded in BIM adoption rate with 49% of the respondents have adopted BIM in their construction projects (CIDB, 2020). This shows a highly significant rise in BIM adopters from the previous study with 17% of adoption in 2016. However, most BIM projects are practising BIM Level 2, which has no integrated system in leveraging BIM data, thus, it leads to inconsistencies, confusion and miscommunications among project stakeholders (Marty, 2014). While moving to BIM Level 3, the data chain is fully connected from start to finish, eliminate process information silos and enable end-to-end lifecycle management (Richards, 2019). In fact, BIM Level 3 is a complex subject that requires substantial time and effort to grasp correctly. Therefore, this research intends to initiate a discourse on the issues and challenges of BIM Level 3 adoption in the Malaysian construction industry.

1.2 Problem Statement

The adoption of BIM is snowballing around the world as its benefits to the industry are becoming more widely recognised. AlMashjary, Zolkafli and Abdul Razak (2020) studied and established key factors towards achieving integrated BIM (iBIM) adoption in the Malaysian construction industry. Four primary key factors influencing the use of iBIM are identified, including standardisation, learning and education, policy and interoperability. In addition, the CIDB BIM Report 2016 revealed the hindrances of BIM implementation in the Malaysian construction industry are expensive BIM software, technology, training cost, lack of experts with BIM knowledge and unavailability of training on BIM (CIDB, 2017).

The government of UK and Digital Built Britain have published the strategic plan for BIM Level 3 and promises more investment will be made towards achieving BIM Level 3 implementation (Terol, 2020). Furthermore, Paul (2018) indicates that A 6241-2 is one of the standards developed and published by the Austrian Standards International (ASI) that introduces BIM Level 3 to the Austrian market. In Malaysia, the Construction 4.0 Strategic Plan (2021-2025) has determined 12 disruptive technologies which will potentially change the future of the construction landscape to become more technology competent (CIDB, 2020). BIM is a vital emerging technology to grasp Construction 4.0. It can be inferred that there is an agreement on the opportunities offered by BIM by the industry players of different countries. However, most of them are concerned transitioning from existing practises to BIM will be costly and challenging to execute.

BIM Level 3 is intended to usher in a new era of transformation in the construction industry. However, the industry is still on the dawn of BIM Level 3. Besides, previous studies such as Blay, Tuuli and Mensah (2019), Awwad, Shibani dan Ghostin (2020), Attrill dan Mickovski (2020) and Shafiq (2021) have focused on BIM Level 2, very few studies have focussed on BIM Level 3. Therefore, this study attempts to unveil the underlying issues and challenges towards BIM Level 3 adoption. The research questions to be addressed are: What are the driving factors that encourage BIM Level 3 compliance? What are the current practices of BIM in the Malaysian construction industry? What are the issues and challenges towards BIM Level 3 adoption?

1.3 Research Aim

The research aims to uncover the underlying issues and challenges towards BIM Level 3 adoption.

1.4 Research Objectives

To achieve the above-mentioned research aim, the following research objectives have been established:

(i) To demystify the driving factors that need for initiating the BIM Level 3 adoption.

(ii) To explore the current practices of BIM in the Malaysian construction industry.

(iii) To anticipate the issues and challenges of BIM Level 3 adoption in the Malaysian construction industry.

1.5 Research Method

An exploratory approach is adopted to uncover the underlying issues and challenges of adopting BIM Level 3 in the Malaysian construction industry. In this study, the questionnaire survey was distributed through internet-based approaches for data collection. All data collected from the questionnaire were analysed through descriptive and inferential analysis. The research approaches carried out to achieve the research objectives is shown in Figure 1.1.

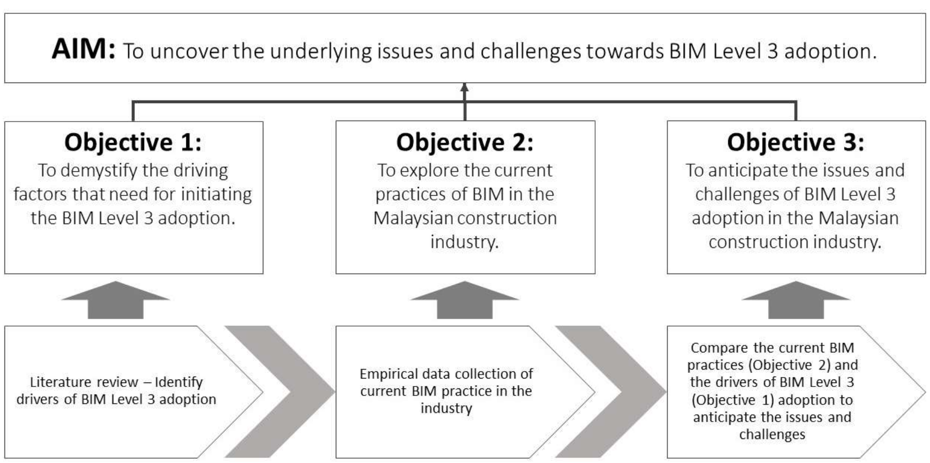

Figure 1.1: Research Methodology Framework

1.6 Research Scope

The research scope is to explore the practices of the construction industry related to BIM currently and to anticipate the potential issues and challenges of BIM Level 3 implementation. This empirical data was collected through a questionnaire design after demystifying of BIM Level 3 from the relevant literature reviews. The target respondents are the construction practitioners involved in different processes of construction supply chain. The attributes of respondents' diversity background from different professions and length of working experience in the construction industry were collected for in depth analysis and comparisons. As this research is an exploratory nature in study, therefore no specific limitations are set on the qualifications of the respondents other than the participants must be part of the construction community.

1.7 Report Structure

The layout of this research project report is divided into five chapters: Introduction, Literature Review, Methodology and Work, Result and Discussion, and Conclusion and Recommendations. The overview of each chapter is outlined in the following paragraphs.

Chapter 1 covers the background of study and problem statement of BIM Level 3 adoption based on previous studies. Besides, the aim, objective, research method, research scope and limitations of the study, and report structure are outlined in this chapter.

Chapter 2 provides a brief definition of BIM and illustrations of the maturity level of BIM. Subsequently, this chapter reviewed the published literature and documentations on BIM, particularly focused on BIM Level 3 adoption. This chapter further explores the challenges of BIM Level 3 adoption. Finally, a conceptual framework consists of six factors is proposed at the end of the chapter.

Chapter 3 explains the research methodology adopted for this research. This chapter also highlights the research approach, research strategies, sampling methods, and data analysis techniques. Data analysis method such as reliability test, descriptive statistics and inferential statistics are adopted to derive a generalisable findings. A details explanation and justification of the design of questionnaire is included in this chapter.

Chapter 4 reviews and discuss the result of data analysis. The frequency distribution in descriptive statistics was used to present the respondents' demographic information. Besides, the Cronbach's alpha reliability test was used to examine the reliability of the collected data. In addition, the perceptions between the different groupings of respondents are examined by using inferential statistics tests such as Kruskal-Wallis H test. The findings are reached by comparing and contrasting the results with the literature reviews.

Chapter 5 is the final chapter conclude this research. It summarises the achievement of the three research objectives and accomplishment of the research aim. Besides, this chapter outlines the research implications to the industrial practitioners, regulators and professional bodies, and academia and research institutions. It also reflects the limitations and shortcomings of this research. Finally, recommendations for the future research are made after considering the lesson learned in this project.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

BIM is a collaborative system based on generating and exchanging data and information throughout the entire project lifecycle. The collaborative working method is described as different levels of shared collaboration between project stakeholders, known as BIM maturity levels. This chapter briefly defined the definition of BIM and reviewed their maturity from BIM Level 0 to BIM Level 3. While progressing with BIM adoption, the complexity of the process is intensified, and there is prejudice to the requirements and challenges of BIM Level 3 adoption in the industry. Hence, this chapter also highlighted the factors and challenges of BIM Level 3 adoption. Lastly, this chapter proposes a conceptual framework of the challenges of BIM level 3 adoption.

2.2 Building Information Modelling (BIM)

The concept of BIM is originated from Charles M. Eastman in the 1940s (Latiffi, Brahim, Fathi, 2014). Different terms on the definition of BIM have been discussed and developed broadly with different perspectives. RICS (2020) states that BIM is supported by technology and a collaborative process for the creation and management of information over the project life cycle.

The National Building Information Model Standard Project Committee (NIBS) defines BIM as the representation of a facility's physical and functional attributes in digital form. It serves as a shared knowledge resource for information that forms a reliable basis for decisions during the project life cycle (NIBS, 2015). According to CIDB (2017), BIM is a modelling technology and set of processes for creating, communicating, analysing, and using digital information models throughout the project life cycle.

2.3 BIM Maturity Level

The conceptual underpinnings of BIM can date back to the early days of computing (Smith, 2014). Dr. Patrick J. Hanratty developed Pronto, a commercial numerical-control programming system in the year 1957. Charlott (2017) considers this as the first commercial computer-aided design (CAD) software system to practice 2D CAD drafting techniques; and it started BIM Level 0. After that, the first true 3D software in history, Sketchpad, was developed by Ivan Sutherland in 1963, which gave way to solid modelling programs; it is beginning of BIM Level 1 (Geddes, 2020) and together with the development of computing subsequently, 3D modelling emerged in the early 1970s (Eastman et al., 2011). In 1982, the ArchiCAD software, which is considered by many as the real beginning of BIM, was developed. The International Foundation Class (IFC) file format was developed in 1995 to allow data to flow across platforms, making a file compatible with different BIM programs in order to promote collaborative working; it is asserted as BIM Level 2 (Charlott, 2017). Recent years, the concept of Open BIM was introduced, where the data is shared, collected and stored using a single source of data which promises deeper collaboration among project stakeholders; it is labelled as BIM Level 3 (Choudhary, 2020). It is envisioned that BIM will continue its evolution and development, the possibilities for the future of BIM are infinite. Bew and Richards (2008) described the four levels of BIM maturity in the BIM maturity model, as illustrated in figure 2.1.

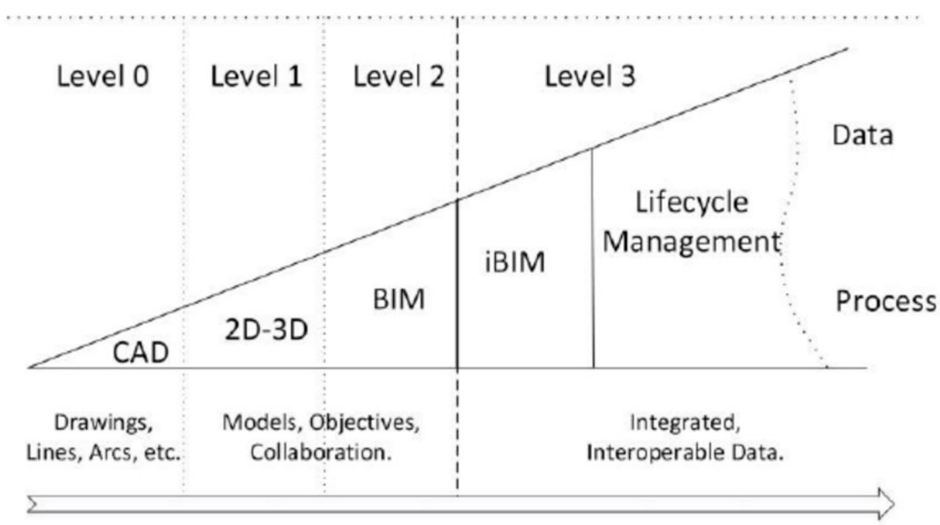

Figure 2.1: The UK Maturity Model [Source: Bew & Richards, 2008]

Level 0 BIM is defined as unmanaged CAD and promotes zero collaboration between project team (Kjartansdóttir, et al., 2017). At this stage, 2D act as the most likely data exchange mechanism (Kumar, 2015). The output and distribution of 2D CAD information, consisting of lines, circles, and text, is shared in paper or electronic prints (Mordue, Swaddle, Philp, 2016).

Level 1 BIM is defined as managed CAD that includes a combination of 2D and 3D CAD, including drafting statutory approval documentation and Production Information (2D) and concept work (3D) (McPartland, 2014). The difference between Level 0 and 1 are insignificant process changes and contractual relations (Kjartansdóttir, et al., 2017). Overall, level 1 BIM promotes low collaboration as models are not shared between different stakeholders.

Level 2 BIM is a controlled 3D environment with data attached that is generated in distinct discipline-based models. Besides, construction programme (4D) and cost information (5D) are introduced to the project (Kumar, 2015). Through a model-based collaboration approach, several stakeholders are actively collaborating with each other. Instead of working on a single shared model, each party works on their own 3D CAD model. The collaboration appears as a result of the parties exchanging information, which becomes the most fundamental feature of this level (Kjartansdóttir, et al., 2017). Design information must be exported and shared through a common file format such as IFC or COBie file (McPartland, 2014). Level 2 BIM promotes full collaboration among the stakeholders and creates a federated BIM model.

Level 3 BIM is defined as a fully integrated BIM (iBIM) where the team members share and collaborate on a common shared model stored in a cloud-based environment (Mordue, Swaddle, Philp, 2016). Furthermore, Ibrahim and Abdelatif (2020) stated that level 3 BIM is an online, single collaborative, project model that includes building information such as scheduling (4D), cost information (5D) and lifecycle properties (6D). Mordue, Swaddle, Philp (2016) additionally asserts that level 3 BIM relies on open-data standards and moves toward real-time data that creates an integrated and automated environment that allows all parties to work on a single model simultaneously and improve organizational performance. Basically, Level 3 BIM promotes full integration throughout the entire life cycle of a building.

2.4 Demystify BIM Level 3

BIM Level 3 is a great initiative to advance the necessary cultural shift in the construction industry to promote a fully collaborative environment and enhance productivity. The following sections elaborates the key factors driving BIM Level 3 adoption, which include ISO 19650, IFC Model, Cloud-based BIM, Open BIM, Skill up Professionals and Single Shared Model.

2.4.1 ISO 19650

The availability of an international set of standards is one of the key driving factors influencing BIM Level 3 adoption, where it is required to manage and guide BIM procedures and processes (Terol, 2020). According to CIDB (2020), BIM standards and guidelines are essential guidance documents in implementing BIM. In addition, these documents set out the requirements for standardized process in producing, managing, and distributing construction information using BIM. As a result, BIM guidelines and processes must be standardised to successfully adopt BIM Level 3 (Azhar, 2011).

The benefits of the PAS 1192 series were recognized internationally by owners and clients, resulting in the development of the new ISO 19650 series (Shillcock, 2019). ISO stands for International Organization for Standardization. The ISO 19650 Guidance Part 1: Concepts developed by the UK BIM Framework (2019) mentioned that the ISO 19650 series is an international standard that outlines information management concepts and criteria in the built environment disciplines and sectors as part of a larger context of digital transformation. The benefits of the PAS 1192 series were recognized internationally by owners and clients, resulting in the development of the new ISO 19650 series (Shillcock, 2019).

ISO 19650 series consists of six standards. ISO 19650-1 introduces the concepts and principles, ISO 19650-2 specifies requirements for the information management process, ISO 19650-3 focuses on the operational phase of assets, ISO 19650-4 recommends concepts and principles for information exchange, ISO 19650-5 concentrates on the security of information and ISO 19650-6 on health and safety information. Shillcock (2019) further asserts that the ISO 19650 series depicts the most current industry standards and best practices, as well as a unified strategy that facilitates project delivery teams to work around a globally recognized set of standards. Multinational teams are developing the capability and capacity to manage and create information in compliance with the ISO 19650 standard, allowing remote teams to collaborate effectively with project teams.

2.4.2 Industry Foundation Classes (IFC)

According to Abanda et al. (2018), interoperability is one of the critical success factors for adopting BIM Level 3. Interoperability defined as the capability of two or more systems to exchange information and utilize the exchanged information. In relation to software, the term interoperability explains the ability of different programs to exchange data through a common set of exchange formats (Golabchi and Kamat, 2013).

Santos and Eduardo (2009) advocate the view that Industry Foundation Classes (IFC) is a standard developed by buildingSMART International and is often cited as the prominent role in achieving BIM interoperability. According to buildingSMART International (2017), IFC represents an open specification for the project stakeholders to exchange and share BIM data information throughout the projects. ISO 16739-1:2018 is an international and open standard that is intended to be vendor-neutral and applicable to a wide range of software platforms, hardware devices, and interfaces. The IFC schema specification is the principal technical deliverable of buildingSMART International to accomplish its objective to promote open BIM. According to Majcher (2019), the IFC schema is continually developing. The current version implemented in the industry is IFC 4, officially released in March 2013.

However, the question of IFC is the approach and solution to achieve interoperability raised. BD Manager at Autodesk, Green (2016) mentioned that bring true interoperability to BIM would take time and effort. The preferred method to gain traction with IFC and facilitate interoperability is to make it open-source. Green (2016) further point out that the construction sector relies on self-developed or commercial toolkits to convert data from a specific software programme to the IFC format. Although this strategy has not yet shown to be a reliable operation, it has made progress.

2.4.3 Cloud-based BIM

A cloud-based BIM is one of the critical factors to be implemented to realise multi-user access and collaborative interaction for BIM Level 3 implementation (Terol, 2020). This finding is supported by Wong, et al. (2014) states that the emerging cloud-BIM technology is considered an enabling technology to overcome the standalone nature of traditional BIM. It encourages more coordination and collaboration among project stakeholders and provides a reliable real-time communication platform. According to the NIST (2011), cloud computing is the delivery of different computing services through the Internet, such as networks, servers, storage, applications, and services that offer faster innovation, flexible resources, and economies of scale. Given the economies of scale afforded by commercial hosting and administration of cloud services, cloud computing offers a cost-effective alternative to the existing state of information exchange and storage for BIM-based technologies (Mahamadu, Mahdjoubi and Booth, 2013).

Cloud computing has three service types and four deployment models (NIST, 2011). When migrating to the cloud, organisations can choose the best mix of these models to meet their objectives, as service models and deployment models offer various advantages and disadvantages. Wong, et al (2014) findings establish that Cloud-BIM technology provides real-time progress monitoring, construction scheduling, clash detection and information sharing among the project stakeholders, regardless of time and location during the design and construction stages. Wong, et al (2014) further points out that most of the current applications of Cloud-based BIM concentrate on the design and construction stages of the project life cycle. Meanwhile, applications in operation, maintenance, and facility management, as well as energy efficiency and destruction, are restricted.

2.4.4 Open BIM

The rise of BIM adoption has been accompanied by increased interest in open BIM, a notion in the existence of international standards and benchmarks and file formats that enable interoperability in any BIM software. Currently, BIM approaches are haphazard, varying by different organization requirements, which lacks mandated or widely used national BIM standards (Peters, 2021).

The open BIM movement was initiated by building SMART and major software suppliers utilising the open buildingSMART Data Model to promote and support the open BIM concept across the construction industry (building SMART, 2021; Data Design System, 2020).

According to Baldwin (2018), open BIM is a global approach to collaborative building design, construction, and operation based on open standards and processes. Choudhary (2020) states that project stakeholders can access the information model without affecting the original design owing to open BIM. It is an approach for collaborating on the design, realisation, and operation of buildings using open standards such as IFC, bSDD and BCF. Chodhary (2020) further explains the open BIM workflow concept. A model is created and shared in an open exchange format instead of the native file to protect the original model content while the model data is still viewable, measurable and usable. Peters (2021) additionally advocate that open BIM aims provide uniform standards to limit the time designers spend ensuring their BIM model meets open BIM guidelines.

There are several benefits of open BIM to the built asset industry. Open BIM encourages an open and transparent process by enabling project stakeholders to engage in spite of the software tools they utilise. By providing a standard language for widely referenced procedures, it enables the industry to procure projects with transparent commercial engagement, comparative service evaluation, and ensured data quality. In addition, it provides long-lasting project data for usage throughout the building lifecycle and eliminating repeated inputs of the same data and mistakes. Furthermore, the best-of-breed approach applied in open BIM enables software suppliers to compete on a system-independent basis. (BIM Forum, 2020; Choudhary, 2020).

2.4.5 Skill Up Professionals

The role players in the construction industry need to skill up their professionals, which will necessitate a shift in mindset that encourages and promotes open and collaborative working (Terol, 2020). According to Kennyingram (2016), organisations throughout the industry continue to overlook the fact that effective BIM adoption involves more than just software; it necessitates a shift in mindset and culture that involves new ways of working. For a successful BIM implementation, all disciplines must broaden their horizons about how it can benefit their firm and must be prepared to overhaul their traditional business processes completely.

Bataw, Kirkham and Lou (2016) propose that BIM level 3 will radically transform the way professionals approach their daily tasks, from working with fragmented paper to working inside an informational collaborative model that necessitates constant communication across diverse disciplines from early phases. As a result, both new and existing professionals must be trained and educated to comprehend their obligations and tasks appropriately. Moreover, to guarantee that services are delivered in line with the collaborative nature of BIM, these obligations and responsibilities must be reviewed and established within the contractual contracts. This is supported by Zakaria, et al. (2013) indicate that professionals inside the organisation should be prepared with BIM knowledge and training for a successful BIM implementation. One of the techniques for equipping people with skills and information is education.

Experiences of BIM adoption vary greatly among construction professionals from various backgrounds and cultures, which will result in an appropriate output. Therefore, construction organisations must search for trends that will ease the training and education curves for BIM practitioners. (Shang and Shen, 2014). Furthermore, BIM learning modules should be designed to meet a wide range of objectives, from fundamental and universal to specialized and advanced. Incorporating new technologies like BIM into the curriculum is one of the cornerstones to construction education. (Abbas, Din and Farooqui, 2016). Professionals with experience and leadership are required for a successful BIM implementation and define their roles and responsibilities, which need specific training programs in line with global demand (Yaakob et al., 2016).

2.4.6 Single Shared Model

According to United BIM (2019), the scope of BIM Level 3 has yet to be clarified entirely. However, it aims to be a single collaborative model stored in a central repository to allow project stakeholders around the globe to collaborate and communicate. BIM level 3 is often termed as open BIM. Terol (2020) believes that the idea behind BIM Level 3 comes to the concept of open BIM aims to have a single BIM model available to all project teams throughout the project life cycle. However, in practical terms, most BIM software vendors state that open BIM can be achieved by allowing project stakeholders to access the information model based upon open standards without working on a single model (Graphisoft, 2020; Tekla, 2020; Allplan, 2020; Nemetschek, 2020; BIMcollab, 2020; Vectorworks, 2020). This is supported by a case study from the Netherlands, project Amersfoort Buyten, where several construction partners worked together with various specialised software based on open standards such as IFC to achieve open BIM (Graphisoft, 2020). This is more likely working on a single federated model. As a result, there seems to be a contradiction between working on a single model and a federated model in achieving BIM Level 3.

2.5 The Challenges of BIM Level 3 Adoption

BIM Level 3 has the potential to deliver far more significant benefits by reducing inefficiencies, boosting productivity, and promoting collaboration among project teams. However, despite the advantages of BIM Level 3, it has limited adoption due to a variety of challenges. The challenges studied are reviewed in Table 2.1.

Table 2.1: Challenges of BIM Level 3 Adoption in Construction Industry

Key Factor	Challenges in BIM Level 3 adoption	Previous Research
ISO 19650	Language barrier	Nicoleta (2015), Cicco, (2019), Peters and Mathews (2019)
	Lack of clear guidance	Fitz (2019), Nicoleta (2015), Peters and Mathews (2019)
IFC	Loss of data during exporting and importing process	BIM&CO (2018), Lai and Deng (2018), Singh (2016)
	Slow processing performance due to large IFC file size	Singh (2016)
	Loss of parametric intelligence	Singh (2016)

Table 2.1 (Continued)

Cloud-based BIM	Lack of legal and contractual implication of BIM	Mahamadu, et al. (2013), Redmond, et al. (2012), Afsari, Shelden and Eastman (2016),
	Lack of cloud specific standards	Afsari, Shelden and Eastman (2016)
Open BIM	Lack of education related to open BIM management	BIM Journal (2017)
	Lack of security and protection of data	Mills (2017)
Skill up Professionals	Lack of experts with relevant skills and knowledge	Ahmed (2018), Wu, et al. (2021)
	Lack of proper training and learning resources	Ahmed (2018), Wu, et al. (2021)
	Lack of awareness about and involvement in the change	AlMashjary, Zolkafli and Abdul Razak (2020), Wu, et al. (2021), Zakaria, et al. (2013)
Single shared model	Lack of standardised definition on the scope of BIM Level 3	McPartland (2017), Solihin, Eastman and Lee (2016), RICS (2020)

2.5.1 ISO 19650

There are mainly two challenges for the implementation of ISO 19650, which are lack of guidance provided by the ISO and language barrier in the ISO documents. According to Peters and Mathews (2019), ISO 19650 is a high-level document with limited guidelines, which lead to one of the challenges in its adoption. Fitz (2019) added that the ISO 19650 provides limited guidance or a recommended code of practice in defining the Level of Detail, Level of Development, Level of Definition or Level of Information Need. It is a standard full of concepts and principles but not finite detail. The study done by Nicoleta (2015) shows that leading professionals have expressed dissatisfaction with the ISO 19650 due to the absence of details in the ISO documents. Consequently, experts analyse and interpret the standard according to their own interpretations, which can be exhausting, leading to misunderstandings and prolonged debates.

Peters and Mathews (2019) further assert that the alterations to the established BIM term are a flaw in the ISO 19650 suite. For instance, the term of project information requirements (PIR) replaces the employers' information requirements (EIR) from PAS 1192. These are simple changes that were most likely made to internationalise the standard and introduce new users. Nonetheless, it is confusing when the new term introduced with the same acronym as the term replaced. This is supported by Cicco (2019) believes that the language barrier between ISO 19650 and its predecessor PAS 1192 has posed some challenges in implementing the ISO throughout the world, specifically for organisations that have invested effort adopting PAS 1192 only to transition. As a result, a high degree of industry understanding is required to guarantee a seamless global implementation of ISO 19650 in the future. Nicoleta (2015) additionally emphasise that the terminology is another negative aspect of ISO 19650. When reading the document, the terminology might be complicated and confusing. Besides, the graphics in ISO are simple and challenging to understand, and they do not support the visual communication that such a high standard should deliver.

2.5.2 Industry Foundation Classes (IFC)

Despite advancements in the IFC schema, the industry is experiencing a multitude of challenges while implementing IFC in its work processes. The analysis of the Singh (2016) paper shows that the primary cause for the industry's limited or non-use of IFC is data loss during the import and export of IFC files. BIM&CO (2018) added that the issue of data loss is frequently associated with the creation of objects, and it has the potential to degrade their intelligence. In practice, the ISO IFC standards must be followed for the objects to be exported successfully. The export of content is directly affected by an inadequate specification of the object in the model. The study done by Lai and Deng (2018) shows that data loss and misrepresentation, such as geometric misrepresentation, missing objects, and inaccurate object types, are frequent during data sharing and transfer utilising IFC formats.

Singh (2016) further points out that the huge file size of IFC is another reason behind the limited usage of IFC. IFC files are typically larger than the file types used by their parent BIM authoring tool. Exporting the models to IFC increases the file size even further, which slowing down the entire process. Furthermore, the loss of parametric intelligence in the IFC file format is also a barrier for IFC adoption (Singh, 2016).

2.5.3 Cloud-based BIM

According to Afsari, Shelden and Eastman (2016), security issues such as responsibility and BIM model ownership arise due to the collaborative nature of Cloud-BIM data integration. In addition, as user authentication and authorization are critical for Cloud-BIM implementation, cloud identity management and role-based user access are becoming increasingly important, demanding advances in trust and privacy-protection approaches. This is supported by Mahamadu, et al. (2013) states that the security challenges imposed by the collaborative exchange model of cloud computing are the concern of liability, responsibility and model ownership related to the system. Furthermore, Redmond, et al., (2012) believes that the incompetence of contractual relationships and uncertainties about data ownership are now viewed as the most significant challenges to adopting BIM-Cloud Integration.

Afsari, Shelden and Eastman (2016) additionally point out that There is a lack of cloud-specific standards for BIM interoperability. Besides, standardization among Cloud-BIM service providers is becoming increasingly important as the number of Cloud-BIM services developed by various providers expands. Open standards such as the IFC data schema must be developed to accommodate the requirements of Cloud-based applications.

2.5.4 Open BIM

Open BIM is a novel concept for most of the countries in the world. Hence, there are many challenges that prohibit open BIM adoption in the industry. According to Mills (2017), the security and protection of data with open BIM and intellectual Property issues are the primary concern in open BIM adoption due to the handing over control of the design data. In addition, the concept of a collaborative workflow must be adequately controlled, ensuring that when one discipline enters and works within a model, other disciplines cannot enter and change it. If an amendment is made incorrectly, this could result in significant expenses later in the project. Furthermore, the analysis of the BIM Journal (2017) report shows that a lack of education holds the key to the challenges stem from collaborative workflows in an open BIM environment. Education relates to the proper management of open BIM between organisations that are less versed in the day-to-day world of BIM.

2.5.5 Skill Up Professionals

According to AlMashjary, Zolkafli and Abdul Razak (2020), a traditional practice in construction projects has dominated most organisations in the construction industry. However, there is a limited collaboration and awareness among the construction players because of cultural differences and resistance to change. Due to cultural resistance, organisations resist the adoption of BIM (Wu, et al., 2021). This is supported by Zakaria, et al., (2013) shows that convincing individuals to enter an unknown environment is challenging. It is difficult for the employees to change from practising the 2D work process to the 3D work process due to fear of the unknown and the reluctance to change, although top management is fully supportive.

The survey done by Wu, et al., (2021) revealed that one of the primary challenges in BIM adoption is the lack of talents with relevant skills and knowledge. Without trained professionals who can embrace and promote BIM, technological advancement will be difficult. Furthermore, because of a lack of knowledge, some people have poor self-confidence when it comes to integrating new technologies (Ahmed, 2018). Moreover, Wu, et al., (2021) believes that the slow uptake of BIM-related technologies has caused challenges to BIM adoption. The learning curve and adoption process for newcomers to BIM may be time-consuming, creating extra burdens and costing resources to employees. Ahmed's (2018) findings propose that the industry is not interested in adopting BIM technology due to the high cost of training and the steep learning curve required for the successful adoption of BIM technology in the construction sector. Wu, et al., (2021) further added that due to the unavailability of proper training on BIM, the current BIM education and training has mostly focussed on the specialised software operation, keeping project-based applications neglected.

2.5.6 Single Shared Model

The contradiction between working on a single model and a federated model as mentioned in previous section has raised concerns about the collaborative method of working in BIM Level 3. According to McPartland (2017), A federated model is a combined BIM that is developed by merging many different separate models into one. In contrast, all project members are allowed to access a single shared model, which allows multiple users to work on the model simultaneously (RICS, 2020). The survey done by Solihin, Eastman and Lee (2016) states that a single shared model is challenging to achieve, and it is becoming increasingly challenging as models become more complicated and greater in size, causing it impracticable to merge them into a single model. The growth in popularity of federated models by tools is a reaction to the constraint imposed by the idea of a single integrated model.

BIM level 3 was replaced by the term 'Digital Built Britain' (DBB) in the Digital Built Britain Level 3 strategic plan published in 2015. According to a report published by RICS (2020), DBB outlined the next step in the BIM journey, which builds on level 2 as a stepwise development to allow for wide-ranging industrial transformations. The strategic plan divided the implementation phases into four phases, namely 3A, 3B, 3C and 3D as illustrated in Table 2.2.

Table 2.2: DBB BIM Level 3 Phases

Phases	Activities
Level 3A	Enabling improvements in the level 2 model
Level 3B	Enabling new technologies and systems
Level 3C	Enabling the development of new business models
Level 3D	Capitalising on world leadership

[Source: UK Department for Business, Innovation and Skills, 2015]

In the DBB BIM level 3 phases, Level 3A and 3B mainly encompassed the definition of BIM Level 3 introduced in the Bew-Richards BIM maturity model, shifting from individual federated models to a single shared model to assist collaboration, requiring updated protocols, standards and building on the new procurement routes. Furthermore, the greatest variety is observed at level 3C, which attempts to achieve cross-sector innovations by utilising data analytics. This puts a strain on present procedures and roles, as well as the existing manner of doing things.

2.6 Proposed Conceptual Framework

Six factors were identified as key contributors to BIM Level 3 adoption through the literature reviews. Figure 2.2 depicted the conceptual framework of BIM Level 3 adoption and performance. It is assumed that the awareness of BIM Level 3 adoption will be enhanced from the BIM practices experienced by early adopters. The awareness of construction practitioners of the adoption of BIM Level 3 has a contingent effect on the performance of BIM Level 3 adoption.

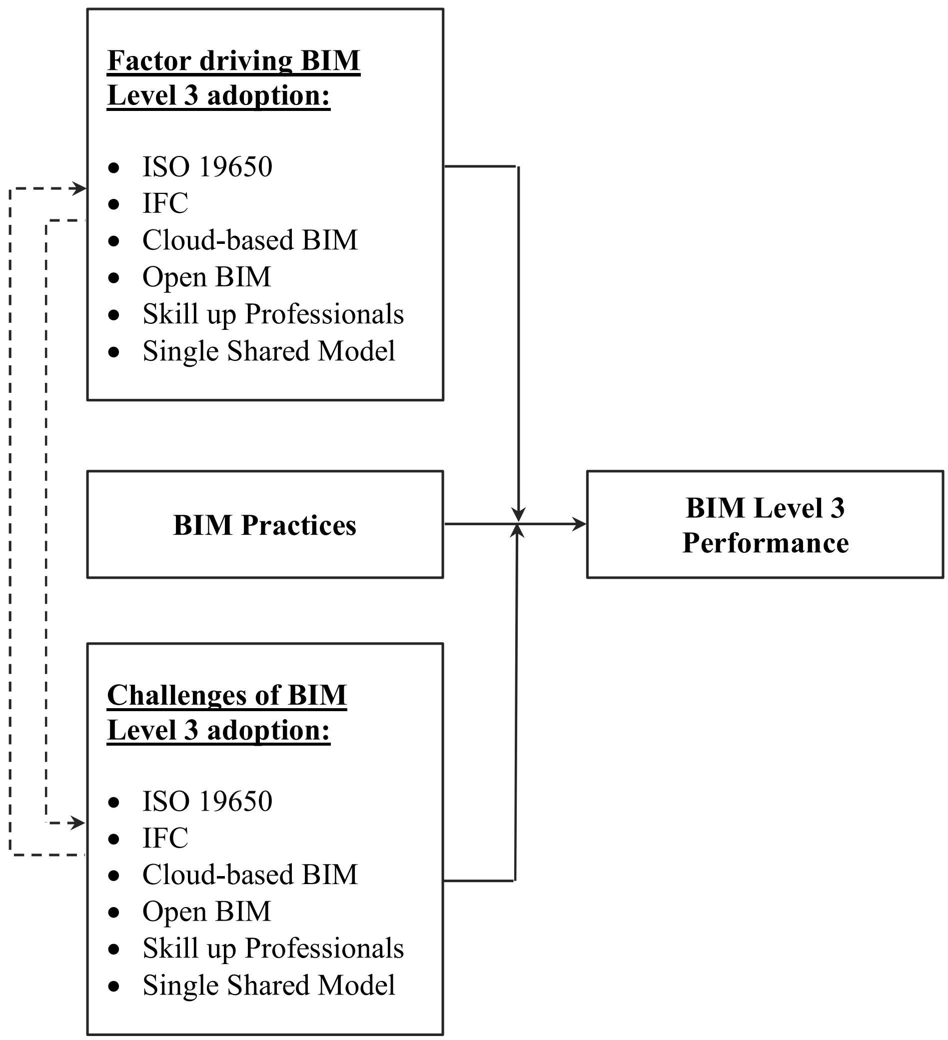

Figure 2.2: Conceptual Framework Proposal

CHAPTER 3

METHODOLOGY AND WORK PLAN

3.1 Introduction

This chapter begins with a review of research approach followed by a description of the overall research strategies which involves the design, purpose and rationale of questionnaire. Next, the sampling method was explained in the sampling design section. Moreover, this section also defined the sample size and target respondents aimed for this study. In addition, the data analysis section outlines the proposed methods such as Cronbach's alpha reliability test, frequency distribution, mean rank, and Kruskal-Wallis H test, which are used in tabulating, organising and analysing various types of data. The last section of this chapter highlighted the research ethics.

3.2 Research Approach

The exploratory approach was selected in this research. According to Saunders, Lewis and Thornhill (2016), exploratory research endeavours to seek new insights into phenomena, asks questions and evaluates the phenomena in a different light. The exploratory approach aims to explore the practices of the construction industry related to BIM currently and to anticipate the potential issues and challenges of BIM Level 3 implementation in the Malaysian construction industry.

3.3 Research Strategies

In this research, quantitative analyse was adopted to uncover the underlying issues and challenges in BIM Level 3 adoption. The questionnaire was used to collect empirical data from the industrial practitioners via online survey tools such as Google Forms. The design and structure of questionnaire are further discussed in the following sub-sections.

3.3.1 Questionnaire Design

The questionnaire design comprised of four primary sections: Section A is aim to explore the current practices of BIM in the Malaysian construction industry, Section B is aim to demystify the driving factors that need for initiating the BIM Level 3 adoption, Section C is aim to uncover the underlying issues and challenges of BIM Level 3 adoption in the Malaysian construction industry, the last section covered demographic information. The questionnaire design was developed based on the conceptual framework proposed in Chapter 2 as shown in Figure 3.1

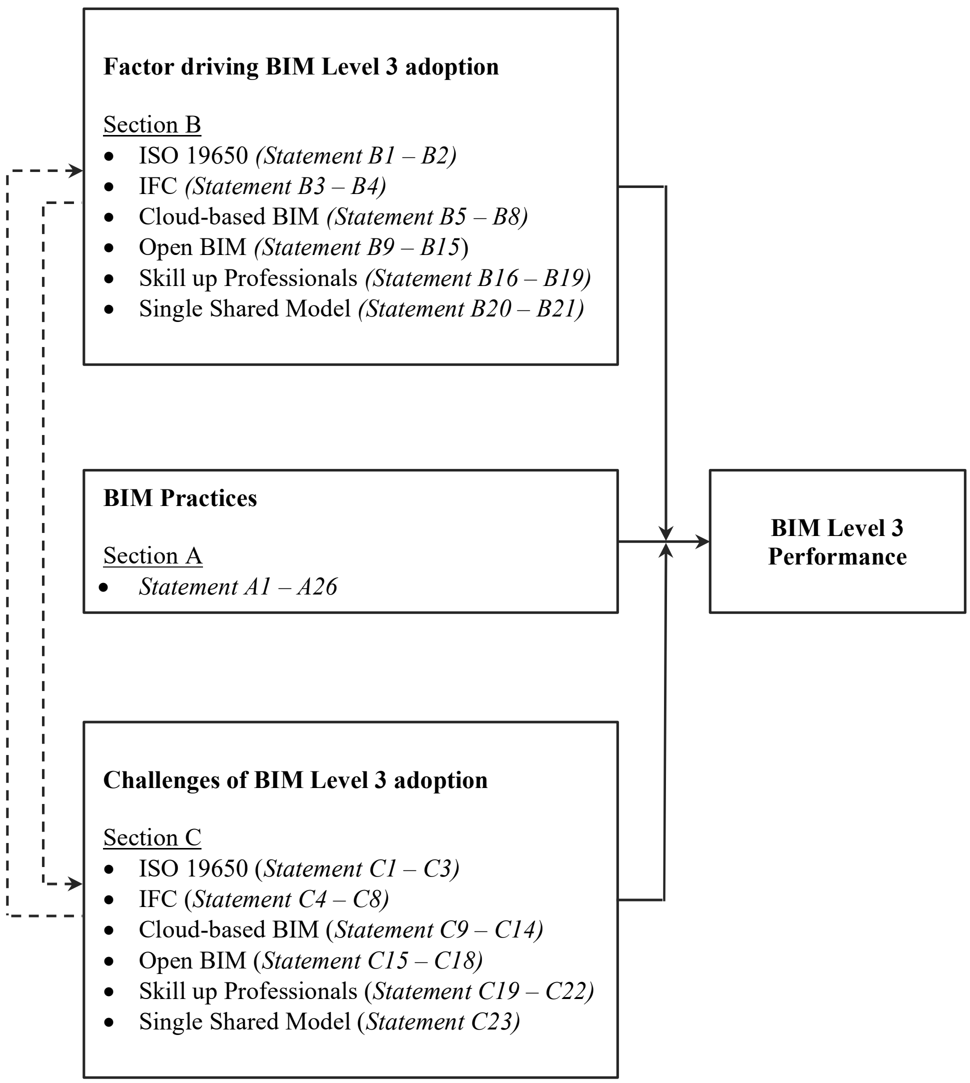

Figure 3.1: Conceptual Framework for Questionnaire Design

3.3.1.1 Section A: Practice of BIM adoption

The questions included in Section A consisted of a set of statements related to the nine categories of BIM practices synthesised from the critical review of published literature. Each of the categories of practices are accompanied by few statements as shown in Table 3.1. The depths of involvement of different statements within a category of BIM practices are varied. Respondents are required to indicate their degree of agreement or disagreement for each of the 26 statements.

Table 3.1: Formulation of Question on Section A

Ref. Code	Statement	Categories	Reference
A1	Project teams are using traditional drafting tools and techniques to create paper-based drawings	Drafting	Gunes (2019); Leidy (2020); Marty (2014)
A2	Project teams are using CAD tools to create 2D drawings		
A3	Project teams are using CAD tools to create 3D drawings		
A4	Project teams are using BIM tools to model building information in 3D		
A5	Project teams are using Building Lifecycle Management (BLM) system		
A6	Project files are being shared via paper	Data Sharing	Interscale (2020); LetsBuild (2019); United BIM (2019); Biblus (2019)
A7	Project files are being shared via digital file		
A8	Project files are being shared via an online shared platform		
A9	Project files are being shared via an open data file format		
A10	Project teams operate on a single shared model via a cloud-based environment		
A11	Project teams keep their own generated models	Data Accessibility	Interscale (2020); LetsBuild (2019); United BIM (2019); Biblus (2019)
A12	The generated models are accessible to project team members only		
A13	The generated models are accessible to all stakeholders		
A14	The generated models are modifiable to all stakeholders		

Table 3.1 (Continued)

A15	Project teams are using BIM tools to visualise a building's structure in 3D	Visualization	United BIM (2019); Hamil (2021)
A16	Project teams are using site logistics model to support logistics planning and control	Scheduling	Dassault Systèmes (2014); United BIM (2019); Flannigan (2021); Azhar (2011); Hamil (2021)
A17	Project teams are using equipment routing animation to visually track site readiness requirements		
A18	Project teams are using project timeline stimulation to schedule construction sequences		
A19	Project teams taking off quantities from paper printouts	Quantity Take-offs	United BIM (2019); Azhar (2011);
A20	Project teams taking off quantities from CAD tools		
A21	Project teams taking off quantities from BIM tools		
A22	Project teams are using cost estimation to estimate construction cost	Cost Estimation	Kumar (2019); Hamil (2021); Ocean (2020)
A23	Project teams are using real-time cost visualization to control construction cost		
A24	Project teams are using energy estimation to analyse the energy consumption of a building	Energy Analysis	Tesla OS (2018)
A25	Project teams using BIM to facilitate decision making related to component installation	Facility Management	United BIM (2019); Hamil (2021); Ocean (2020); Mills (2015)
A26	Project teams are using facility management to operate and maintain building		

3.3.1.2 Section B: Factors that need for initiating BIM Level 3 adoption

Section B was designed to evaluate their agreement with the six categories of factors required by the BIM Level 3 adoption which had been demystified through literature reviews. This section comprised of 21 statements regarding the factors that need for initiating BIM Level 3 adoption as shown in Table 3.2. Respondents are required to rate their level of importance ascribed to each statement on a scale from not important to very important.

Table 3.2: Formulation of Question on Section B

Ref. Code	Statement	Categories	Reference
B1	A standardised processes and procedures	ISO19650	Terol (2020); CIDB (2020); Azhar (2011)
B2	An international set of standards		
B3	Data can be exchanged between different software applications	IFC	Abanda et al. (2018); Golabchi & Kamat (2013) buildingSMART International (2017)
B4	Data can be exchanged without compatibility problems		
B5	Data can be accessed through the internet	Cloud-base BIM	Terol (2020); Wong, et al. (2014)
B6	Data can be accessed regardless of time		
B7	Data can be accessed regardless of location		
B8	Data can be stored regardless of size		
B9	An optimized work breakdown for construction	Open BIM	Rozmanith (2014); BIM Forum (2020); Choudhary (2020)
B10	Project status can be monitored in real time		
B11	A virtual building for streamlining maintenance and operations		
B12	An open standard and workflow		
B13	Project stakeholders are using same design software		
B14	Project stakeholders are able freely to choose their preferred design software		
B15	A predictive building lifecycle management system for construction works		
B16	A mindset shift to new ways of working	Skill up Professionals	Terol (2020); Kennyingram (2016); Zakaria, et al. (2013); Abbas, Din & Farooqui (2016)
B17	Shaping skills and lifelong learning		
B18	Leadership of senior management		
B19	Support and enforcement by the government		

Table 3.2 (Continued)

B20	A single central model	Single Shared Model	United BIM (2019); Terol (2020); Graphisoft (2020); Tekla (2020); Allplan (2020); Nemetschek (2020); BIMcollab (2020); Vectorworks (2020)
B21	A federated model		

3.3.1.3 Section C: Issues and challenges of BIM Level 3 adoption

Section C was designed to assess their agreement with a set of statements related to the issues and challenges of BIM Level 3 adoption based on the six categories of BIM Level 3 drivers. This section contains of 23 statements regarding the issues and challenges of BIM Level 3 adoption as shown in Table 3.3. Respondents are required to specify their level of agreement to each statement from strongly disagree to strongly agree.

Table 3.3: Formulation of Question on Section C

Ref. Code	Statement	Categories	Reference
C1	Lack of government enforcement for implementing BIM industry standards as a contractual requirement	ISO 19650	Toe & Kong (2018); Patel, et al. (2021); Cicco (2019); Panagiotidou (2015); Peters & Mathews (2019); Fitz (2019)
C2	Lack of common language in the BIM industry standards documents		
C3	Lack of clear guidance for the use of BIM industry standards documents		
C4	Loss of data during translation of the open data format	IFC	BIM&CO (2018); Lai & Deng (2018); Singh (2016); Eadie & McClean (2015)
C5	Loss of parametric intelligence during translation of the open file format		
C6	Loss of geometric properties during translation of the open file format		

Table 3.3 (Continued)

C7	Slow processing performance due to large size of open file format		
C8	Lack of effort by software vendor to improve open file format		
C9	Lack of incentive to use cloud computing	Cloud-based BIM	Redmond, et al. (2012); Afsari, Shelden & Eastman (2016); Mahamadu et al. (2013);
C10	Lack of legal and contractual implication of using cloud computing		
C11	Lack of security and protection of data in cloud computing		
C12	Lack of cloud specific standards		
C13	Low bandwidth internet connection		
C14	Lack of management of interactions within a model among multidisciplinary team		
C15	Lack of support from project owners on open BIM implementation	Open BIM	Mills (2017); BIM Journal (2017); Fischer, Kam & Lo (2020)
C16	Lack of investment in a common data environment		
C17	Lack of performance measurement systems for open BIM implementation		
C18	Low level of cooperation between multidisciplinary team		
C19	Lack of experts with relevant skills and knowledge	Skill Up Professionals	Ahmed (2018); Wu, et al. (2021) AlMashjary, Zolkafli & Abdul Razak (2020); Zakaria, et al. (2013); Hamid, et al. (2018)
C20	Lack of proper training and learning resources		
C21	Lack of awareness and involvement in the change		
C22	Lack of financial resources to improve BIM-related technologies		
C23	Lack of standardised definition on the scope of BIM Level 3	Single Shared Model	McPartland (2017); RICS (2020); Solihin, Eastman & Lee (2016)

3.3.1.4 Section D: Demographic Information

Section D consisted of 4 questions to collect demographic profiles of respondents. The study respondents are asked to fill in their demographic profiles such their company's business activities, respondents' profession, respondents' knowledge in BIM and working experience.

3.4 Sampling Design

Cooper and Schindler (2014) states that the underlying concept behind sampling is a conclusion about the entire population can be made by selecting some of the elements in a population. The sampling method, sampling size required, and target respondents are explained in the following sub-sections.

3.4.1 Sampling Method

Convenience sampling was selected for data collection for this study. This is a non-probability haphazard sampling technique in which cases are chosen only based on their ease of convenience (Saunders, Lewis and Thornhill, 2016).

3.4.2 Sample Size

In this research, the Cochran formula and Central Limit Theorem (CLT) are selected to determine the sample size. Cochran formula is used to identify the optimum sample size given a desired degree of precision, a desired level of confidence, and the estimated fraction of the attribute existing in the population. This research assumes a 95% of confidence level ($Z = 1.96$) with 5% of precision level ($e = 0.05$). A five-point Likert scale was applied in the questionnaire design. Therefore, the p value will be 0.5 for each option. A sample size of 384 is determined and required for this study.

In addition, the CLT states that the sampling distribution of the sample means approaches a normal distribution as the sample size gets larger (Cooper and Schindler, 2014). This fact holds true for a sample size of 30 or more. Moreover, a sufficiently large sample can predict the parameters of a population such as the mean and standard deviation (McLeod, 2018). In this research, the sample size required for independent variables such as company's business activities, respondents' profession, respondents' knowledge in BIM and working experience should be 30 or more for each group.

3.4.3 Targeted Respondent

The target population is defined as the total group of responders who satisfy the specified criteria (Burns and Grove, 1997). The target respondents for this study involved the construction practitioners in the Malaysian construction industry from different business organisations, professions, working experience, and education levels. The target respondents are only those who reside in Malaysia.

3.5 Data Analysis

Data analysis is the logical and systematic application of statistical procedures to assess, interpret, and model data. In this research, the collected data were subjected to quantitative analysis using Statistical Package for Social Sciences (SPSS) to clarify the meaningful relationships between the variables derived from several statistical methods such as the Cronbach's alpha reliability test, descriptive statistics and inferential statistics, which will be further discussed in the following sub-section.

3.5.1 Reliability Test

The Cronbach's alpha reliability test was chosen to examine the reliability, or internal consistency for Section A, B and C of the questionnaire. Normally, the alpha coefficient ranges in value from 0 to 1. The alpha coefficient value of 0.7 or above implies that the items have shared covariance and are most likely measuring the same underlying idea.

3.5.2 Descriptive Statistics

Descriptive statistics are applied to describe and compare variables numerically which help to repurpose hard-to-understand quantitative insights across a large data set into bite-sized descriptions. In this research, there are two types of descriptive statistics which include frequency distribution and mean rank. Frequency distribution was used to organise the collected demographic data such as main business activities, professions, knowledge and skills in BIM and working experience in data form. In addition, the mean rank revealed the agreement of the respondents towards the statements in the questionnaire. Friedman's mean rank was utilised to determine the overall ranking of statements for each section in the questionnaire according to their mean rank.

3.5.3 Inferential Statistics

Inferential statistics includes the estimation of population values and the testing of statistical hypotheses (Cooper and Schindler, 2014). In this research, the inferential statistics tests such as a K-independent samples test, the Kruskal-Wallis H test was utilised to derive a generalisable findings.

3.5.3.1 Kruskal-Wallis H test

The Kruskal-Wallis H test is a non-parametric statistic applied to examine if two or more groups of an independent variable on a continuous or ordinal dependent variable have statistically significant differences. In this research, the Kruskal-Wallis H test followed by the post hoc test was used to examine whether there are statistically significant differences in perceptions between the different groupings of respondents. The groups intended to put into the tests are categories according to the main business activities, professions, and working experience. When the p-value of the statement is less than 0.05, it indicates the alpha value is the level probability at which the null hypothesis can be rejected with confidence while the research hypothesis can be accepted with confidence. After that, the results are compared with literature reviews in order to identify similarities and novel findings to reinforce the existing theories or report the new knowledge.

3.6 Research Ethics

According to World Health Organisation, research ethics govern the standards of conduct for scientific researchers. In addition, it forms the foundation for the protection of recruited research participants (Nchasi, 2021). Moreover, upon sending the questionnaire to the respondents, the questionnaire was submitted for ethical clearance to the UTAR Scientific and Ethical Review Committee (SERC) in order to ensure the research adheres to ethical principles that protect the dignity, rights and welfare of the research participants. The questionnaire was distributed once ethical clearance had been granted.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

This chapter presents and discusses findings from this study. It begins with a brief description of the respondent demographics, followed by the reliability test result for the three sections of the questionnaire. Next, the collected data were subject to quantitative analysis using Statistical Package for Social Sciences (SPSS) to clarify the meaningful relationships between the variables derived from several statistical methods. Lastly, the discussion section interprets the results, compares the significance of the findings with the literature review and research questions, and makes an argument in support of the overall conclusion.

4.2 Respondents' Background

Over a period of one month, a total of 230 valid questionnaires were collected via the LinkedIn, e-mail and personal contacts. Table 4.1 summarised the detailed profiling information of the 230 respondents, with 31.3% currently attached to the construction firms, while 22.6%, 17.4%, 15.2% and 13.5% are from consultants, developers, sub-contractor and supplier respectively. Table 4.1 reveals that majority (37.8%) of the respondents are currently work as a quantity surveyor. Additionally, more than one third of the respondents (36%) self-rated themselves have the good knowledge and skills in BIM. Almost 40% of the respondents have over 10 years of working experience in the construction industry.

Table 4.1: Demographic Information of Respondents (N = 230)

Demographic Characteristics	**Frequency (*n*)**	**Percentage (%)**
Company's Business Activities		
Developer	40	17.4%
Consultant	52	22.6%
Contractor	72	31.3%
Sub-contractor	35	15.2%
Supplier	31	13.5%

Table 4.1 (Continued)

Profession		
Architect	57	24.8%
Civil & Structural Engineer	36	15.7%
Mechanical & Electrical Engineer	33	14.3%
Quantity Surveyor	87	37.8%
Purchaser	8	3.5%
Sales Coordinator	6	2.6%
Production Operator	3	1.3%
Knowledge & Skills in BIM		
Do Not Know	2	0.9%
Very Poor	13	5.7%
Poor	49	21.3%
Fair	83	36.1%
Good	62	27.0%
Very Good	21	9.1%
Working Experience		
Less than 2 years	48	20.9%
At least 2 years, but less than 5 years	56	24.3%
At least 5 years, but less than 10 years	38	16.5%
At least 10 years, but less than 20 years	46	20.0%
20 years or more	42	18.3%

4.3 Reliability Analysis

The internal consistency of questionnaire items was tested using Cronbach's alpha reliability test to ensure metric reliability. The alpha value obtained for the overall section of questionnaire was 0.934, which indicated that all the 70 items included in the questionnaire had high internal consistency. Table 4.2 shows that the internal consistencies of the individual section of the questionnaire; all the three sections were regarded as reliable with Cronbach's Alpha value greater than 0.70.

Table 4.2: Cronbach's Alpha Reliability Test

Section of Questionnaire	Number of Items	Cronbach's Alpha
Section A:		
Practice of BIM adoption	26	0.848
Section B:		
Factors that need for initiating BIM adoption	21	0.723
Section C:		
Issues and challenges of BIM adoption	23	0.858

4.4 Practice of BIM Adoption in the Malaysian Construction Industry

Table 4.3 tabulated the mean ranks of the practices of BIM adoption in the Malaysian construction industry in descending order. The result of Friedman test indicated that there was a statistically significant difference between the mean ranks of the practices of BIM adoption, χ^2 (25) = 3424.7, p = 0.000.

A close examination of Table 4.3 reveals the five most common practices of BIM adoption are "Project teams are using BIM tools to visualise a building's structure in 3D" (mean rank = 19.00), "Project files are being shared via an online shared platform" (mean rank = 18.64), "Project teams taking off quantities from CAD tools" (mean rank = 18.85), "Project teams taking off quantities from paper printouts" (mean rank = 18.59) and "The generated models are accessible to project team members only" (mean rank = 18.44),. In contrast, the three least practices are "Project teams are using facility management to operate and maintain building" (mean rank = 4.18), "Project teams using BIM to facilitate decision making related to component installation" (mean rank = 4.13) and "Project teams are using energy estimation to analyse the energy consumption of a building" (mean rank = 3.82).

Table 4.3: Mean Ranking of Practice of BIM Adoption (N = 230, df = 25)

Ref Code	Statements	Mean Rank	Chi-square	Asymp. sig
A15	Project teams are using BIM tools to visualise a building's structure in 3D	19.00	3424.7	0.000
A7	Project files are being shared via digital file	18.64		
A20	Project teams taking off quantities from CAD tools	18.85		
A19	Project teams taking off quantities from paper printouts	18.59		
A12	The generated models are accessible to project team members only	18.44		
A8	Project files are being shared via an online shared platform	18.37		
A3	Project teams are using CAD tools to create 3D drawings	18.31		
A21	Project teams taking off quantities from BIM tools	18.15		

Note: N = number of respondents; df = degree of freedom

Table 4.3 (Continued)

A2	Project teams are using CAD tools to create 2D drawings	18.10
A5	Project teams are using Building Lifecycle Management (BLM) system	17.59
A6	Project files are being shared via paper	17.59
A11	Project teams keep their own generated models	17.45
A1	Project teams are using traditional drafting tools and techniques to create paper-based drawings	16.69
A14	The generated models are modifiable to all stakeholders	16.46
A10	Project teams operate on a single shared model via a cloud-based environment	16.27
A13	The generated models are accessible to all stakeholders	12.21
A4	Project teams are using BIM tools to model building information in 3D	12.16
A22	Project teams are using cost estimation to estimate construction cost	11.87
A18	Project teams are using project timeline stimulation to schedule construction sequences	7.45
A9	Project files are being shared via an open data file format	7.10
A16	Project teams are using site logistics model to support logistics planning and control	6.88
A23	Project teams are using real-time cost visualization to control construction cost	6.50
A17	Project teams are using equipment routing animation to visually track site readiness requirements	6.22
A26	Project teams are using facility management to operate and maintain building	4.18
A25	Project teams using BIM to facilitate decision making related to component installation	4.13
A24	Project teams are using energy estimation to analyse the energy consumption of a building	3.82

Note: N = number of respondents; df = degree of freedom

Post hoc test was conducted to test the pairwise comparisons between differences of respondents' perception on practices of BIM adoption according to their demographic characteristics.

(a) Differences of Respondents' Agreement on Practices of BIM Adoption based on Respondents' Company Business Activities

The null hypothesis rejected by post hoc pairwise comparisons are tabulated according to the respondents' company business activities in Table 4.4 (between Consultation Services and Supplying Business), Table 4.5 (between Contracting Business and Supplying Business), Table 4.6 (between Subcontracting Business and Supplying Business), and Table 4.7 (between Development Business and Supplying Business). Those involved in supplying business agreed that "Project teams operate on a single shared model via a cloud-based environment" more than those provide consultation services, contracting and subcontracting business and development business. Besides, the result shows that "The generated models are modifiable to all stakeholders" are regarded as high significant by those involved in supplying business compared to those provide consultation services, contracting and subcontracting business and development business. Moreover, the result also shows that "Project teams are using CAD tools to create 2D drawings" are more agreed by those involved in supplying business than those provide consultation services, contracting and subcontracting business.

Table 4.4: Rejected Null Hypotheses for the Practices of BIM Adoption between Consultation Services and Supplying Business

No	Null Hypothesis	Mean Rank		Sig.
		Consultant	Supplier	
1	The agreement of "Project teams are using traditional drafting tools and techniques to create paper-based drawings" is same	92.02	143.40	0.000
2	The agreement of "Project teams are using CAD tools to create 2D drawings" is same	107.26	138.06	0.024
3	The agreement of "Project files are being shared via digital file" is same	107.50	138.29	0.024

Table 4.4 (Continued)

4	The agreement of "Project teams operate on a single shared model via a cloud-based environment" is same	98.88	146.24	0.001
5	The agreement of "Project teams keep their own generated models" is same	94.30	141.05	0.001
6	The agreement of "The generated models are modifiable to all stakeholders" is same	95.31	154.02	0.000
7	The agreement of "Project teams are using equipment routing animation to visually track site readiness requirements" is same	94.87	137.76	0.002

Table4.5: Rejected Null Hypotheses for the Practices of BIM Adoption between Contracting Business and Supplying Business

No	Null Hypothesis	Mean Rank		Sig.
		Contractor	Supplier	
1	The agreement of "Project teams are using traditional drafting tools and techniques to create paper-based drawings" is same	115.17	143.40	0.034
2	The agreement of "Project teams are using CAD tools to create 2D drawings" is same	112.44	138.06	0.047
3	The agreement of "Project files are being shared via digital file" is same	104.86	138.29	0.010
4	The agreement of "Project teams operate on a single shared model via a cloud-based environment" is same	116.19	146.24	0.025
5	The agreement of "The generated models are modifiable to all stakeholders" is same	112.63	154.02	0.002

Table 4.6: Rejected Null Hypotheses for the Practices of BIM Adoption between Subcontracting Business and Supplying Business

No	Null Hypothesis	Mean Rank		Sig.
		Sub-con	Supplier	
1	The agreement of "Project teams are using CAD tools to create 2D drawings" is same	99.36	138.06	0.009
2	The agreement of "Project teams operate on a single shared model via a cloud-based environment" is same	110.99	146.24	0.022

Table 4.6 (Continued)

3	The agreement of "Project teams keep their own generated models" is same	110.13	141.05	0.040
4	The agreement of "The generated models are modifiable to all stakeholders" is same	108.91	154.02	0.003

Table 4.7: Rejected Null Hypotheses for the Practices of BIM Adoption between Development Business and Supplying Business

No	**Null Hypothesis**	**Mean Rank**		**Sig.**
		Developer	**Supplier**	
1	The agreement of "Project teams operate on a single shared model via a cloud-based environment" is same	115.98	146.24	0.043
2	The agreement of "The generated models are modifiable to all stakeholders" is same	122.84	154.02	0.037

4.5 Factors that Need for Initiating BIM Level 3 Adoption

Table 4.8 tabulated the overall mean ranks of the Six BIM Level 3 Driver that need for initiating BIM Level 3 adoption in the Malaysian construction industry in descending order. The result of Friedman test indicated that there was a statistically significant difference between the mean ranks of the factors that need for initiating BIM adoption, χ^2 (5) = 478.4, p = 0.000. The result shows that majority of the respondents felt that it was important for them to understand ISO19650 in adopting BIM Level 3. In contrast, the importance of IFC is perceived as the least important in BIM Level 3 adoption.

Table 4.8: Mean Ranking of Importance of Six BIM Level 3 Drivers (N = 230, df = 5)

Ref Code	**BIM Level 3 Driver**	**Mean Rank**	**Chi-square**	**Asymp. sig**
B1-B2	ISO19650	5.02	478.4	0.000
B5-B8	Cloud-based BIM	4.41		
B20-B21	Single Shared Model	3.47		
B16-B19	Skill Up Professionals	3.38		
B9-B15	Open BIM	3.09		
B3-B4	IFC	1.63		

In addition, Table 4.9 presents further analysis on the factors of the subcategories of the six BIM Level 3 drivers. The result of Friedman test indicated that there was a statistically significant difference between the mean ranks of the factors that need for initiating BIM adoption, χ^2 (20) = 1775.0, p = 0.000. Table 4.9 shows the five most important subcategories of factors that need for initiating BIM adoption are "A mindset shift to new ways of working" (mean rank = 14.82), "Data can be accessed regardless of time" (mean rank = 14.50), "A virtual building for streamlining maintenance and operations" (mean rank = 14.49), "An open standard and workflow" (mean rank = 14.42) and "Data can be accessed through the internet" (mean rank = 14.38). On the other hand, there are two statements with mean rank below 7.00 are "A predictive building lifecycle management system for construction works" (mean rank = 6.82) and "Data can be exchanged without compatibility problems" (mean rank = 6.32).

Table 4.9: Mean Ranking of Importance of Statements Related to the Six BIM Level 3 Driver (N = 230, df = 20)

Ref Code	Statements	Mean Rank	Chi-square	Asymp. sig
	ISO19650			
B1	A standardised processes and procedures	14.14	1775.0	0.000
B2	An international set of standards	14.02		
	IFC			
B3	Data can be exchanged between different software applications	6.94		
B4	Data can be exchanged without compatibility problems	6.32		
	Cloud-based BIM			
B6	Data can be accessed regardless of time	14.50		
B5	Data can be accessed through the internet	14.38		
B7	Data can be accessed regardless of location	14.25		
B8	Data can be stored regardless of size	7.33		
	Open BIM			
B11	A virtual building for streamlining maintenance and operations	14.49		
B12	An open standard and workflow	14.42		

Note: N = number of respondents; df = degree of freedom

Table 4.9 (Continued)

B10	Project status can be monitored in real time	14.18
B14	Project stakeholders are able freely to choose their preferred design software	8.40
B13	Project stakeholders are using same design software	7.50
B9	An optimized work breakdown for construction	7.38
B15	A predictive building lifecycle management system for construction works	6.82
	Skill Up Professionals	
B16	A mindset shift to new ways of working	14.82
B18	Leadership of senior management	13.98
B19	Support and enforcement by the government	7.97
B17	Shaping skills and lifelong learning	7.18
	Single Shared Model	
B21	A federated model	13.55
B20	A single central model	8.40

Note: N = number of respondents; df = degree of freedom

Post hoc test was conducted to test the pairwise comparisons between differences of respondents' agreement on factors that need for initiating BIM adoption according to their demographic characteristics.

(a) Differences of Respondents' Agreement on Factors that need for initiating BIM Adoption based on Respondents' Company Business Activities

The null hypothesis rejected by post hoc pairwise comparisons are tabulated according to the respondents' company business activities in Table 4.10 (between Consultation Services and Development Business), Table 4.11 (between Consultation Services and Supplying Business), and Table 4.12 (between Subcontracting Business and Consultation Services). Table 4.10 shows that "Leadership of senior management" and "Data can be accessed through the internet" are regarded as less significant by those involved in supplying business compared to those provide development business.

Table 4.10: Rejected Null Hypotheses for the Factors that Need for Initiating BIM Adoption Between Consultation Services and Development Business

No	Null Hypothesis	Mean Rank		Sig.
		Consultant	Developer	
1	The agreement of "Leadership of senior management" is same	92.40	120.81	0.025
2	The agreement of "Data can be accessed through the internet" is same	93.67	126.34	0.010

Table 4.11 tabulates that "Leadership of senior management" and "Data can be accessed through the internet" are less agreed by those involved in consultation services than those involved in supplying business. On the other hand, the supplier's agreement of "Project stakeholders are using same design software" is perceived as less significant than consultants, inferring those consultants as professional services are more concerned about using the same design software.

Table 4.11: Rejected Null Hypotheses for the Factors that Need for Initiating BIM Adoption Between Consultation Services and Supplying Business

No	Null Hypothesis	Mean Rank		Sig.
		Consultant	Supplier	
1	The agreement of "Leadership of senior management" is same	92.40	132.58	0.003
2	The agreement of "Data can be accessed through the internet" is same	93.67	141.74	0.000
3	The agreement of "Project stakeholders are using same design software" is same	132.56	92.21	0.003

Table 4.12 presents that those involved in subcontracting business agreed that "Leadership of senior management" are more important than those involved in consultation services. In contrast, "Project stakeholders are using same design software" is viewed as less important by those involved in subcontracting business compared to those involved in consultation services.

Table 4.12: Rejected Null Hypotheses for the Factors that Need for Initiating BIM Adoption Between Subcontracting Business and Consultation Services

No	Null Hypothesis	Mean Rank		Sig.
		Sub-con	Consultant	
1	The agreement of "Leadership of senior management" is same	135.01	92.40	0.001
2	The agreement of "Project stakeholders are using same design software" is same	99.19	132.56	0.011

(b) Differences of Respondents' Agreement on Factors that need for initiating BIM Adoption based on Respondents' Profession

The null hypothesis rejected by post hoc pairwise comparisons are tabulated according to the respondents' profession in Table 4.13 (between Architect and Civil and Structural Engineer), Table 4.14 (between Quantity Surveyor and Civil and Structural Engineer) and Table 4.15 (between Mechanical and Electrical Engineer and Civil and Structural Engineer). Table 4.13 and Table 4.14 shows that "A standardised processes and procedures" is regarded as less significant by civil and structural engineer compared to architect and quantity surveyor. In addition, civil and structural engineers agreed that "A mindset shift to new ways of working" more than architects, quantity surveyors and mechanical and electrical engineers, implying that civil and structural engineers are more likely to embrace new ways of working.

Table 4.13: Rejected Null Hypotheses for the Factors that Need for Initiating BIM Adoption Between Architect and Civil and Structural Engineer

No	Null Hypothesis	Mean Rank		Sig.
		Architect	C&S Engineer	
1	The agreement of "A standardised processes and procedures" is same	120.15	86.54	0.009
2	The agreement of "A mindset shift to new ways of working" is same	105.70	139.63	0.007

Table 4.14: Rejected Null Hypotheses for the Factors that Need for Initiating BIM Adoption Between Quantity Surveyor and Civil and Structural Engineer

No	Null Hypothesis	Mean Rank		Sig.
		Quantity Surveyor	C&S Engineer	
1	The agreement of "A standardised processes and procedures" is same	122.81	86.54	0.002
2	The agreement of "A mindset shift to new ways of working" is same	108.29	139.63	0.007

Table 4.15: Rejected Null Hypotheses for the Factors that Need for Initiating BIM Adoption Between Mechanical and Electrical Engineer and Civil and Structural Engineer

No	Null Hypothesis	Mean Rank		Sig.
		M&E Engineer	C&S Engineer	
1	The agreement of "A mindset shift to new ways of working" is same	107.86	139.63	0.025

4.6 Issues and Challenges of BIM Level 3 Adoption

Table 4.16 tabulated the mean ranks of agreement of issues and challenges in Six BIM Level 3 drivers in descending order. The result of Friedman test indicated that there was a statistically significant difference between the mean ranks of the issues and challenges of BIM adoption, χ^2 (5) = 631.2, p = 0.000. Table 4.16 shows that skill up professionals was ranked the highest in terms of issues and challenges in BIM Level 3 driver, followed by open BIM and cloud-based BIM. Meanwhile, the lowest areas of issues and challenges went to single shared model.

Table 4.16: Mean Ranking of Agreement of Issues and Challenges in Six BIM Level 3 Drivers (N = 230, df = 5)

Ref Code	BIM Level 3 Driver	Mean Rank	Chi-square	Asymp. sig
C19-C22	Skill Up Professionals	4.87	631.2	0.000
C15-C18	Open BIM	4.49		
C9-C14	Cloud-based BIM	4.48		
C4-C8	IFC	3.20		
C1-C3	ISO19650	2.62		
C23	Single Shared Model	1.34		

Furthermore, Table 4.17 presents further analysis on the issues and challenges of the subcategories of the six BIM Level 3 drivers. The result of Friedman test indicated that there was a statistically significant difference between the mean ranks of the issues and challenges of BIM adoption, χ^2 (22) = 2068.9, p = 0.000. A close examination of Table 4.17 unveiled the mean rank of all the subcategories for skill up professionals are mostly above 15.00, indicating that the industry has to pay more attention to the issues of "lack of experts with relevant skills and knowledge", "lack of proper training and learning resources", "lack of financial resources to improve BIM-related technologies" and "lack of awareness and involvement in the change". Meanwhile, the mean rank for categories of cloud-based BIM ranged from 8.63 to 15.71. Most mean ranks of open BIM are above 14.00 and the highest mean rank was 16.12, which was related to the issue of "lack of support from project owners on open BIM implementation". Furthermore, the mean rank for IFC ranges from 8.23 to 14.74.

Table 4.17: Mean Ranking of Agreement of Statements Related to the Issues and Challenges in Six BIM Level 3 Drivers (N = 230, df = 22)

Ref Code	Statements	Mean Rank	Chi-square	Asymp. sig
	ISO19650			
C3	Lack of clear guidance for the use of BIM industry standards documents	16.39	2068.9	0.000
C1	Lack of government enforcement for implementing BIM industry standards as a contractual requirement	8.38		
C2	Lack of common language in the BIM industry standards documents	4.44		
	IFC			
C8	Lack of effort by software vendor to improve open file format	14.74		
C7	Slow processing performance due to large size of open file format	14.00		
C4	Loss of data during translation of the open data format	9.60		
C5	Loss of parametric intelligence during translation of the open file format	8.68		
C6	Loss of geometric properties during translation of the open file format	8.23		

Note: N = number of respondents; df = degree of freedom

Table 4.17 (Continued)

	Cloud-based BIM	
C11	Lack of security and protection of data in cloud computing	15.71
C13	Low bandwidth internet connection	15.66
C9	Lack of incentive to use cloud computing	15.35
C12	Lack of cloud specific standards	14.68
C10	Lack of legal and contractual implication of using cloud computing	8.83
C14	Lack of management of interactions within a model among multidisciplinary team	8.63
	Open BIM	
C15	Lack of support from project owners on open BIM implementation	16.12
C17	Lack of performance measurement systems for open BIM implementation	14.61
C18	Low level of cooperation between multidisciplinary team	14.17
C16	Lack of investment in a common data environment	8.25
	Skill Up Professionals	
C19	Lack of experts with relevant skills and knowledge	16.33
C20	Lack of proper training and learning resources	15.42
C22	Lack of financial resources to improve BIM-related technologies	15.40
C21	Lack of awareness and involvement in the change	8.49
	Single Shared Model	
C23	Lack of standardised definition on the scope of BIM Level 3	3.88

Note: N = number of respondents; df = degree of freedom

Post hoc test was conducted to test the pairwise comparisons between differences of respondents' agreement on the issues and challenges of BIM adoption according to their demographic characteristics.

(a) Differences of Respondents' Agreement on Issues and Challenges of BIM Adoption based on Respondents' Company Business Activities

The null hypothesis rejected by post hoc pairwise comparisons are tabulated according to the respondents' company business activities in Table 4.18 (between Development Business and Consultation Services), Table 4.19 (between Contracting Business and Consultation Services), Table 4.20 (between Consultation Services and Supplying Business), Table 4.21 (between Contracting Business and Supplying Business) and Table 4.22 (between Subcontracting Business and Supplying Business). Table 4.18 and Table 4.19 reveals that "Slow processing performance due to large size of open file format" and "Low level of cooperation between multidisciplinary team" are regarded as less significant by those involved in consultations services compared to those involved in development business and contracting business. Meanwhile, those involved in consultation services agreed that "Loss of data during translation of the open data format" more than those provide development business and contracting business.

Table 4.18: Rejected Null Hypotheses for the Issues and Challenges of BIM Adoption Between Development Business and Consultation Services

No	Null Hypothesis	Mean Rank		Sig.
		Developer	Consultant	
1	The agreement of "Loss of data during translation of the open data format" is same	91.66	133.28	0.001
2	The agreement of "Slow processing performance due to large size of open file format" is same	133.98	95.01	0.003
3	The agreement of "Low level of cooperation between multidisciplinary team" is same	131.86	90.48	0.002

Table 4.19: Rejected Null Hypotheses for the Issues and Challenges of BIM Adoption Between Contracting Business and Consultation Services

No	Null Hypothesis	Mean Rank		Sig.
		Contractor	Consultant	
1	The agreement of "Loss of data during translation of the open data format" is same	110.99	133.28	0.037

Table 4.19 (Continued)

2	The agreement of "Slow processing performance due to large size of open file format" is same	117.92	95.01	0.043
3	The agreement of "Low level of cooperation between multidisciplinary team" is same	122.99	90.48	0.004

Table 4.20 shows that "Low level of cooperation between multidisciplinary team", "Lack of effort by software vendor to improve open file format" and "Lack of financial resources to improve BIM-related technologies" are regarded as less significant by those involved in consultation services compared to those provide supplying business.

Table 4.20: Rejected Null Hypotheses for the Issues and Challenges of BIM Adoption Between Consultation Services and Supplying Business

No	**Null Hypothesis**	**Mean Rank**		**Sig.**
		Consultant	**Supplier**	
1	The agreement of "Lack of effort by software vendor to improve open file format" is same	98.54	147.08	0.000
2	The agreement of "Low level of cooperation between multidisciplinary team" is same	90.48	121.94	0.026
3	The agreement of "Lack of financial resources to improve BIM-related technologies" is same	105.15	143.56	0.005

Table 4.21 and Table 4.22 tabulates that those involved in supplying business agreed that "Lack of effort by software vendor to improve open file format" and "Lack of financial resources to improve BIM-related technologies" more than those provide contracting and subcontracting business.

Table 4.21: Rejected Null Hypotheses for the Issues and Challenges of BIM Adoption Between Contracting Business and Supplying Business

No	**Null Hypothesis**	**Mean Rank**		**Sig.**
		Contractor	**Supplier**	
1	The agreement of "Lack of effort by software vendor to improve open file format" is same	109.53	147.08	0.004

Table 4.21 (Continued)

2	The agreement of "Lack of financial resources to improve BIM-related technologies" is same	105.46	143.56	0.003

Table 4.22: Rejected Null Hypotheses for the Issues and Challenges of BIM Adoption Between Subcontracting Business and Supplying Business

No	Null Hypothesis	Mean Rank		Sig.
		Sub-con	**Supplier**	
1	The agreement of "Lack of effort by software vendor to improve open file format" is same	116.46	147.08	0.043
2	The agreement of "Lack of financial resources to improve BIM-related technologies" is same	112.93	143.56	0.040

(b) Differences of Respondents' Agreement on Issues and Challenges of BIM Adoption based on Respondents' Working Experience

The null hypothesis rejected by post hoc pairwise comparisons are tabulated according to the respondents' working experience in Table 4.23 (between At Least 2 Years, but Less than 5 Years Working Experience and 20 Years or More Working Experience), Table 4.24 (between At Least 5 Years, but Less than 10 Years Working Experience and 20 Years or More Working Experience), and Table 4.25 (between Less than 2 Years Working Experience and 20 Years or More Working Experience). Generally, those with 20 years or more working experience agreed that "Lack of government enforcement for implementing BIM industry standards as a contractual requirement" more than those with at least 2 years, but less than 5 years working experience. Moreover, the result also reveals that "Lack of experts with relevant skills and knowledge" are more agreed by those with 20 years or more working experience than those with less than 2 years working experience, at least 2 years, but less than 5 years working experience and at least 5 years, but less than 10 years working experience.

Table 4.23: Rejected Null Hypotheses for the Issues and Challenges of BIM Adoption Between At Least 2 Years, but Less than 5 Years Working Experience and 20 Years or More Working Experience

No	Null Hypothesis	Mean Rank		Sig.
		At least 2 years, but less than 5 years	20 years or more	
1	The agreement of "Lack of government enforcement for implementing BIM industry standards as a contractual requirement" is same	97.41	122.25	0.044
2	The agreement of "Lack of experts with relevant skills and knowledge" is same	112.63	142.86	0.012

Table 4.24: Rejected Null Hypotheses for the Issues and Challenges of BIM Adoption Between At Least 5 Years, but Less than 10 Years Working Experience and 20 Years or More Working Experience

No	Null Hypothesis	Mean Rank		Sig.
		At least 5 years, but less than 10 years	20 years or more	
1	The agreement of "Lack of experts with relevant skills and knowledge" is same	90.33	142.86	0.000

Table 4.25: Rejected Null Hypotheses for the Issues and Challenges of BIM Adoption Between Less than 2 Years Working Experience and 20 Years or More Working Experience

No	Null Hypothesis	Mean Rank		Sig.
		Less than 2 years	20 years or more	
1	The agreement of "Lack of experts with relevant skills and knowledge" is same	99.98	142.86	0.001

4.7 Discussion

The following sections discuss the above results analysis in three aspects, which include the practice of BIM adoption in the Malaysian construction industry, the second subsection which focus on the factors that need for initiating BIM Level 3 adoption and the issues and challenges of BIM Level 3 adoption.

4.7.1 Practice of BIM Adoption in the Malaysian Construction Industry

(a) Current BIM Practices among Respondents

The responses to certain statements are interpreted as different maturity levels of BIM practices are embedded in section A of the questionnaire. Section 4.4 reveals that out of the 26 statements related to current BIM practices, the top five rank-ordered practices for BIM adoption fall under the category of BIM Level 0 and Level 1 practice. In contrast, respondents' responses to statements under BIM level 3 practices such as "Project teams are using facility management to operate and maintain building", "Project teams using BIM to facilitate decision making related to component installation" and "Project teams are using energy estimation to analyse the energy consumption of a building" where full life cycle integration considering maintenance and operation were found to be the least practices used by the current practitioners.

The findings discovered that the level of BIM implementation is still shallow, and the construction industry needs more effort to enhance the practitioners' orientation to BIM-based technology. Moreover, it can be found that only a minority of the industry remains at BIM Level 0 convenience stage. In addition, the implementation of BIM is not fully addressed, and a majority of the industry is practising modelling, which places it in the BIM Level 1 modelling stage. However, the industry started to move toward BIM Level 2, but still a long way to achieve BIM Level 3.

(b) Differences of Respondents' BIM experience according to Company Business Activities

The overall results from the Kruskal-Wallis H Test in Section 4.4(a) suggest that there was a significant difference, where respondents engaged in the supplying business perceived higher than respondents from other business activities such as development business, contracting business, consultation services and subcontracting business. This result highlights that BIM has an impact on suppliers of construction products in the industry.

Naturally, the characteristics of a building are strongly dependent on the characteristics of the installed products, so in order to build better buildings through BIM, everyone in the construction supply chain requires the need for more detailed models and product information from suppliers and manufacturers as they are the most credible data source in developing virtual product catalogues (cobuilder, 2016). In addition, if design teams know about the data regarding the suppliers' products and have the geometry of their products, then they are more likely to select those products and use them within buildings. Consequently, this encourages the supplier to align its incentives to advance the adoption of BIM compared to other business activities. There are plenty of suppliers and manufacturers in the current market that can provide the virtual product to be used in a BIM model (Allermuir, 2022; dormakaba, 2022; Dortek, 2022; Hilti, 2022; Jotun, 2022). More specifically, the supplier expresses a significantly higher readiness toward BIM Level 3 adoption compared to others group.

4.7.2 Factors that Need for Initiating BIM Level 3 Adoption

(a) Driving factors for BIM Level 3 adoption among Respondents

The driving factor that needs for initiating BIM Level 3 adoption was “A mindset shift to new ways of working”, found to be critical for the successful implementation of BIM Level 3. This finding echoes the study by Terol (2020), implying that construction practitioners must embrace a new mindset where open and collaborative working is encouraged and rewarded. Kennyingram (2016) further stated that there must be a change of mindset and culture to proactively embrace new ways of workings for successful BIM adoption.

On the other hand, “Data can be accessed regardless of time” was ranked as the second driving factor that needs for initiating BIM Level 3 adoption. The finding is supported by Wong et al. (2014), they indicate that cloud computing technology provides immense capabilities that could be an effective tool for the project team in managing projects regardless of time and location.

Meanwhile, the third driving factor that needs for initiating BIM Level 3 adoption is “A virtual building for streamlining maintenance and operations”. Ramanathan and Clemmons (2018) highlighted that a virtual building, in conjunction with BIM, is essential for streamlining construction projects which allows teams to reduce the complexity of the building process, while creating a stronger, safer, better-maintained building at the same time.

Furthermore, the fourth driving factor that needs for initiating BIM Level 3 adoption is “An open standard and workflow”. Choudhary (2020) stresses that open standard and workflow are significant for open BIM, where project teams can participate regardless of their software tools. Moreover, it is a philosophy that empowers all construction practitioners to participate with meaningful, bi-directional workflows, resulting in better buildings (Choudhary, 2020).

In addition, “Data can be accessed through the internet” was ranked as the fifth driving factor that needs for initiating BIM Level 3 adoption. This resonates with the study made by Mahamadu, Mahdjoubi and Booth (2013), the accessibility of data through the internet is viewed as a cost-effective alternative to the current state of data exchange and storage for BIM-based technologies in view of the economies of scale offered by commercial hosting and management of cloud services. Moreover, NIST (2011) explains that different computing services can be delivered through the internet, which offers faster innovation, flexible resources, and economies of scale.

(b) Differences of Respondents’ Perception on Driving Factors for BIM Level 3 adoption according to Their Background Information

Significant differences in respondents’ perception on driving factors for BIM Level 3 adoption were found between developer, consultant, contractor, sub-contractor and supplier. Based on the results obtained by Kruskal Wallis, respondents involved in consultation services have shown the lowest mean rank towards the importance of leadership of senior management. The consultant is a professional who is expert, capable and self-driven in the jobs that they are doing, then there is little need to lead them in the tasks that they are doing. In addition, the whole ethos and culture of the consulting company are around creating structures and controls, then leadership from senior management is probably inappropriate and would be rejected in favour of structured management approaches.

Regarding the professional perspective, the results show significant differences between civil and structural engineers, architects, quantity surveyors, and mechanical and electrical engineers, where the civil and structural engineers have reported a higher mean rank for the importance of a mindset shift to new ways of working. These findings are consistent with the findings of Danielson (2021), which emphasises the importance of engineers in acquiring a new mindset to comprehend technology adoption throughout the whole construction lifecycle, including capital planning, bidding and estimation, construction management, and asset maintenance—rather than just design.

Moreover, significant differences for standardised processes and procedures are found between civil and structural engineers, architects and quantity surveyors. Civil and structural engineers have shown the lowest mean rank towards the importance of standardised processes and procedures. Meanwhile, the result is different from the findings of AlMashjary, Zolkafli, and Asrul (2020), which stated that there is a need to define the standardised processes and procedures for BIM implementation in the view of engineers.

4.7.3 Issues and Challenges of BIM Level 3 Adoption

(a) Issues and Challenges of BIM Level 3 Adoption among Respondents

"Lack of clear guidance for the use of BIM industry standards documents" was ranked as the biggest challenge that hindered the adoption of BIM Level 3 in the Malaysian construction industry. The result is in line with Peters and Mathews (2019), they explain that the use of the ISO19650 series is very light on guidance that would create additional administrative burdens for the users. Fitz (2019) further stated that limited guidance is available on using the ISO19650 series, which leads to negative comments from leading experts.

"Lack of experts with relevant skills and knowledge" was ranked as the second challenge hindering the adoption of BIM Level 3. The result is consistent with Wu, et al. (2021) study; they revealed that the lack of skilled personnel is one of the critical challenges affecting the implementation of BIM. Ahmed (2018) further emphasises that there is a need to overcome the issue of a lack of BIM experts for the adoption of BIM.

"Lack of support from senior management on open BIM implementation" was ranked as the third challenge encountered by the industry during the implementation of BIM Level 3. The finding is consistent with the findings of the studies of Wu, et al., (2021). They indicate that the senior leaders act as an essential role to provide proper support and foundation for the BIM implementation. The development and application of BIM in the project will be significantly affected if support from senior management is lacking (Wu, et al., 2021).

The "Lack of security and protection of data in cloud computing" challenge was ranked at fourth place among the respondents. As highlighted by Afsari, Shelden and Eastman (2016), lack of data access and security is one of the challenges faced by the Cloud-based BIM, and meanwhile this issue is still an open research area. Moreover, Redmond, et al. (2012) supported that the main barrier against using a cloud platform was security issues. Most of the security issues revolved around data security by not knowing where the data is and who can access it.

"Low bandwidth internet connection" was ranked as the fifth challenge hindering the adoption of BIM Level 3. This result is supported by Redmond, et al. (2012), they stated that the most significant barrier to using a cloud platform was a low-bandwidth internet connection, which was caused by connectivity issues at some construction sites due to their distant location.

(b) Differences of Respondents' Perception on Issues and Challenges of BIM Level 3 adoption according to Their Background Information

Regarding the perspective of company business activities, the results obtained through the Kruskal Wallis test show significant differences in the respondents' agreement on issues and challenges of BIM Level 3 adoption between developers, consultants, contractors, sub-contractors and suppliers. On the basis of this, it showed that significant differences exist between consultants, developers, contractors and suppliers, where consultants have reported the lowest mean rank for the agreement of low level of cooperation between multidisciplinary team. This can be explained that some professionals are more driven by competition than cooperation, while others don't feel like there is enough trust or psychological safety to collaborate effectively. Project teams need to trust each other to work effectively. For instance, a project team member who misses deadlines or doesn't complete their assigned work can negatively impact the entire team's work. Eventually, this can lead to frustration and lack of trust among project teams, reducing the effectiveness of their work and creating tension in the workplace.

In addition, there are significant statistical differences found between suppliers, consultants, contractors and sub-contractors, where suppliers have shown the highest mean rank toward the agreement of lack of financial resources to improve BIM-related technologies. These findings are consistent with the results discussed in the previous section which suppliers are the leading adopters of BIM compared to other industry professionals. By allowing BIM to develop further, suppliers required more financial resources to enhance BIM-related technologies. The investment cost of BIM software is indispensable for a project. The high cost of software purchase and subsequent maintenance costs contribute to the high cost of BIM software, which hinders BIM implementation.

Besides, significant statistical differences are found between respondents with 20 years or more working experience and respondents with less than 20 years working experience. Respondents with 20 years or more working experience have shown the highest mean rank toward the agreement of lack of experts with relevant skills and knowledge. This can be explained that professionals with high working experience understand that as BIM develops on to Level 3 and beyond, the complexity of data required within each individual model is expected to increase. Consequently, this will continue to turn BIM into a specialist area that requires workers trained explicitly in BIM to produce the models and data needed.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction

This chapter summarises and concludes findings and discussions from the previous chapter. It begins with examines the accomplishment of research aim and objectives. Besides, the implication of this study to the construction industry, regulatory bodies and academia will be discussed. Next, the reflection of the whole research is highlighted in the limitations and lessons learned for future research is recommended in the final section.

5.2 Accomplishments

The accomplishments of the research objectives are summarised in the following sections. These will act as thrusts for the conclusion made in the subsequent paragraph.

5.2.1 Objective 1 – To demystify the driving factors that need for initiating the BIM Level 3 adoption

The first objective is accomplished by identifying the driving factors required by the BIM Level 3 adoption through literature reviews, standard documents and organisational reports and documents. The literature reviews revealed six key factors driving BIM Level 3 adoption, which include ISO19650, IFC, cloud-based BIM, open BIM, skill up professionals and single shared model. To be fully compliant with BIM Level 3, the six key factors are important for the construction industry to be able to compete. In addition, the survey revealed that ISO19650 is the most important factor that need for initiating BIM Level 3 adoption, followed by cloud-based BIM and single shared model. Meanwhile, IFC is perceived as the least important BIM Level 3 drivers among respondents.

5.2.2 Objective 2 – To explore the current practices of BIM in the Malaysian construction industry

The second objective is accomplished by assessing the depths of involvement of different statements related to the nine categories of BIM practices synthesised from the critical review of published literature. The result obtained from the Friedman test disclosed that the common practice of BIM is to visualise a building's structure in 3D by using BIM tools. Besides, the construction practitioners are more likely to share project files in digital format. In addition, the construction practitioners are using paper printouts and CAD tools in taking off quantities. Furthermore, the construction practitioners are tends to share the generated models with internal project stakeholders. These common practice of BIM implementation in the Malaysian construction industry lies between BIM level 0 and BIM level 1. On the other hand, the Kruskal Wallis test revealed that suppliers are the leading adopters of BIM in the Malaysian construction industry. Moreover, this may imply that suppliers are more likely to have a higher readiness toward BIM Level 3 adoption.

Moreover, the result revealed that the industry needs to skill up its professionals by shifting the mindset to new ways of working and becoming ready to open and collaborative working. Besides, cloud-based BIM is required for BIM Level 3, where data can be accessed through the internet regardless of time. Moreover, open BIM, which provides a virtual building for streamlining maintenance and operations while promoting an open standard and workflow, are necessary for BIM Level 3 adoption. Furthermore, the Kruskal Wallis test revealed that consultants perceived the leadership of senior management as low importance for BIM Level 3 adoption. In addition, civil and structural engineers perceived a mindset shift to new ways of working as significant for BIM Level 3 adoption, but in contrast, they perceived standardised processes and procedures as low importance for BIM Level 3 implementation.

5.2.3 Objective 3 – To anticipate the issues and challenges of BIM Level 3 adoption in the Malaysian construction industry

The third objective is accomplished by evaluating the respondents' agreement or disagreement on statements related to the issues and challenges of BIM Level 3 adoption based on the six categories of BIM Level 3 drivers. The result obtained from the Friedman test uncovered that the challenge of using ISO19650 for BIM Level 3 adoption is a lack of clear guidance. In addition, the lack of experts with relevant skills and knowledge in BIM is a challenge to skill up professionals in the industry, hindering the implementation of BIM Level 3. Besides, the lack of support from senior management on open BIM implementation is also one of the challenges in BIM Level 3 adoption. Moreover, cloud-based BIM is also the main challenge for the implementation of BIM Level 3, which is caused by a lack of security and protection of data in cloud computing and low bandwidth internet connection. Nonetheless, the Kruskal Wallis test revealed that consultants perceived that a low level of cooperation between the multidisciplinary team had a low effect on the challenges of BIM Level 3 adoption. Besides, suppliers perceived that the lack of financial resources to improve BIM-related technologies is the challenge of BIM Level 3 implementation. Furthermore, the construction practitioners with 20 years or more working experience perceived that the lack of experts with relevant skills and knowledge is also the challenge that hinders BIM Level 3 adoption.

5.3 Conclusion

The accomplishment of the research objectives justified the achievement of the research aim: the underlying issues and challenges towards BIM Level 3 adoption are: lack of clear guidance from regulators on the use of BIM standard, lack of experts with BIM-related skills and knowledge, lack of senior management support for open BIM implementation, lack of data security and protection in cloud computing and low bandwidth internet connection.

5.4 Research Implications

The findings are expected to provide a barometer of the practice of BIM in the Malaysian construction industry which will enable a better anticipation of the issues and challenges of BIM Level 3 adoption in the Malaysian construction industry. Moreover, the research implications are discussed from the perspective of the construction industry, regulatory bodies and academia.

In terms of practical contribution, this paper enables industry practitioners to pre-empt the problems in BIM Level 3 adoption. Specifically, this study provides construction companies that either possess low BIM maturity or are yet to adopt BIM the ability to identify and prioritise challenges in BIM Level 3 adoption. Thus, companies can make use of the results by tackling the issues and challenges at the earliest and avoiding severe complications in the future. In addition, the results from this study also can help the top management of the construction companies to develop a strategic plan in advancing the adoption of BIM in their organisation.

From the regulatory bodies' perspective, the insights of the proposed paper will be helpful in formulating policies to facilitate the adoption of the new technology by the industry to speed up the nation building. Besides, the outcome of the study helps the regulatory bodies to identify the issues and challenges of BIM Level 3 and also to know the level of BIM adoption in the Malaysian construction industry. This will help to take appropriate measures in improving the BIM strategy plan to enhance the overall BIM adoption level in the industry.

Academically, it helps the academics to better understand the demand of the practitioners to improve the design and revise BIM-related curriculum. Therefore, a more relevant course curriculum can be developed to supply the future human resources needed by the construction industry. This helps the academia to make progress in research, innovation and curriculum development.

5.5 Research Limitations

BIM Level 3 is a novel topic and thus the nature of this research is purely exploration. It needs to be extrapolated from the present information to make a prediction of the future state. It requires tapping into related expert groups. This may cause response bias and misunderstanding whereby the respondents give inaccurate or false answers to a question because the respondents may not have possessed a thorough knowledge of BIM Level 3. In addition, the total number of respondents are less than the sample size of 384 determined by the Cochran formula. Nevertheless, all the results adopted to report had met the requirement of Central Limit Theorem. Lastly, the results obtained in this study only reflect findings in the construction industry in Malaysia. Therefore, caution must be observed in generalising findings and conclusions to other countries or regions.

5.6 Research Recommendations

The lesson learned from the reflection of the limitation illustrated above lay the possibility of the following research in future: future researcher should recruit more participants to gain a large amount of data. In that way, newly information may be discovered through the research. Besides, future research also needs to be conducted to ascertain the severity of the identified challenges from the perspective of job positions such as project manager, construction manager, site supervisor, and others. This analysis is essential as each identified challenge can be perceived differently by each stakeholder, regarding the severity. Therefore, a severity analysis of the identified challenges from different job position perspectives is recommended in the future. Furthermore, future research can extend the targeted participants outside of Malaysia so that the result can be applied to other countries or regions.

REFERENCES

Abanda, F.H., Mzyece, D., Oti, A.H. and Manjia, M.B., 2018. A Study of the Potential of Cloud/Mobile BIM for the Management of Construction Projects. *Applied System Innovation*, [e-journal] 1(2), pp.9 https://doi.org/10.3390/asi1020009.

Abbas, A., Din, Z.U. and Farooqui, R., 2016. Integration of BIM in Construction Management Education: An Overview of Pakistani Engineering Universities. *Procedia Engineering*, [e-journal] 145(2016), pp.151 - 157. https://doi.org/10.1016/j.proeng.2016.04.034.

Afsari, K., Eastman, C. and Shelden, D., 2016. *Cloud-Based BIM Data Transmission: Current Status and Challenges*. In: 33rd International Symposium on Automation and Robotics in Construction. Auburn, USA, 18-21 July 2016. IAARC.

Ahmed, S., 2018. Barriers to Implement Building Information Modeling (BIM) to Construction Industry: A Review. *Journal of Civil Engineering and Construction*, [e-journal] 7(2), pp.107 - 113. https://doi.org/10.32732/jcec.2018.7.2.107.

Allermuir, 2022. *Allermuir – NBS National BIM Library*. [online] Available at: <https://www.nationalbimlibrary.com/en/allermuir/> [Accessed 4 April 2022].

Allplan, 2020. *OPEN BIM PROGRAM*. [online] Available at: <https://www.allplan.com/bim/openbim/> [Accessed 10 July 2021].

AlMashjary, B.M., Zolkafli, U.K. and Asrul S., 2020. Establishing key factors towards implementing integrated Building Information Modeling (BIM) in AEC industry: Malaysia study. *Journal of Building Performance*, [online] Available at: <http://journalarticle.ukm.my/15768/> [Accessed 22 June 2021].

AlMashjary, B.M., Zolkafli, U.K. and Asrul S., 2020. Measurement Model of Ibim Implementation in AECO Industry: Pls-Pm Approach. *Malaysian Construction Research Journal*, [e-journal] 9(1), pp.63 - 80. https://doi.org/10.1016/j.autcon.2013.11.010.

Attrill, R. dan Mickovski, S. B., 2020. *Issues to be addressed with current BIM adoption prior to the implementation of BIM level 3*. In: L Scott & CJ Neilson (eds), Proceedings of the 36th Annual ARCOM Conference. Glasgow, United Kingdom, 7-8 December 2020. Salford: ARCOM.

Awwad, K.A., Shibani, A., and Ghostin, M., 2020. Exploring the critical success factors influencing BIM level 2 implementation in the UK construction industry: the case of SMEs. *International Journal of Construction Management*, [e-journal] PP.1 – 8. https://doi.org/10.1080/15623599.2020.1744213.

Azhar, 2011. Leadership and Management in Engineering Leadership and Management in Engineering. *Leadership and Management in Engineering*, [e-journal] 11(3), pp.241 - 252. https://doi.org/10.1061/(ASCE)LM.1943-5630.0000127.

Baldwin, M., 2018. *What is openBIM?* [online] Available at: <https://bimconnect.org/en/wiki/what-is-openbim/> [Accessed 12 July 2021].

Bataw, A., Kirkham, R. and Lou, E., 2016. *The Issues and Considerations Associated with BIM Integration*. In: MATEC Web Conferences, The 4th International Building Control Conference 2016. Kuala Lumpur, Malaysia, 7-8 March 2016. EDP Sciences.

Bernama, 2003. CIDB to establish IR 4.0 roadmap for construction industry. *New Straits Times*, [online] 27 December. Available at: <https://www.nst.com.my/business/2018/12/444298/cidb-establish-ir-40-roadmap-construction-industry> [Accessed 17 July 2021].

Bew, M. and Richards, M., 2008. *BIM maturity model*. Construct IT Autumn 2008 Members' Meeting. Brighton, UK.

BIM Forum, 2020. *BuildingSMART*. [online] Available at: <https://bimforum.org/BuildingSMART> [Accessed 10 July 2021].

BIM Journal, 2017. *BIM Journal Issue One Closed BIM Versus openBIM* [online] Huddersfield. Available through: Issuu, Inc. <https://issuu.com/bimjournal/docs/bim_journal_issue_1> [Accessed 22 June 2021].

BIM&CO, 2018. *The future lies in OpenBIM, not ClosedBIM*. [online] Available at: <https://www.bimandco.com/bim/en/blog/6-the-future-lies-in-openbim-not-closedbim/> [Accessed 10 August 2021].

BIMcollab, 2020. *What is openBIM?* [online] Available at: <https://www.bimcollab.com/en/resources/openbim> [Accessed 10 July 2021].

Blay, K. B., Tuuli, M. M. and France-Mensah, J., 2019. Managing change in BIM-Level 2 Projects: Benefits, Challenges, and Opportunities. *Built Environment Project and Asset Management*, [e-journal] 9(5), pp.581 - 596. https://doi.org/10.1108/BEPAM-09-2018-0114

Bouchrika, I., 2021. *How to Write Research Methodology: Overview, Tips, and Techniques.* [online] Available at: <https://www.guide2research.com/research/how-to-write-research-methodology> [Accessed 10 July 2021].

BuildingSMART, 2017. *Industry Foundation Classes 4.0.2.1 Version 4.0 - Addendum 2 - Technical Corrigendum 1.* [online] United Kingdom. Available through: BuildingSMART International IFC Specification Database

<https://standards.buildingsmart.org/IFC/RELEASE/IFC4/ADD2_TC1/HTML/> [Accessed 24 June 2021].

Burns, N. and Grove, S.K., 2005. *The Practice of Nursing Research: Conduct, Critique and Utilization*. 5th Edition. Missouri: Elsevier Saunders.

Charlott, 2017. *A history of BIM* [online] Available at: <https://www.letsbuild.com/blog/a-history-of-bim> [Accessed 28 March 2022].

Choudhary, M., 2020. *What is openBIM and why is it important?* [online] Available at: <https://www.geospatialworld.net/blogs/what-is-openbim-and-why-is-it-important/> [Accessed 17 June 2021].

Cicco, R.D., 2019. *What we did to prepare for the release of ISO 19650?* [online] Available at: <https://www.linkedin.com/pulse/what-we-did-prepare-release-iso-19650-rebecca-de-cicco-fciob> [Accessed 18 June 2021].

CIDB, 2017. *Malaysia Building Information Modelling Report 2016*. [online] Kuala Lumpur. Available through: myBIM Malaysia <https://mybim.cidb.gov.my/download/malaysia-bim-report-2016/> [Accessed 21 June 2021].

CIDB, 2020. *Malaysia Building Information Modelling Report 2019*. [online] Kuala Lumpur. Available through: myBIM Malaysia <https://mybim.cidb.gov.my/download/bim-report-2019/> [Accessed 2 April 2022].

CIDB, 2020. *Construction 4.0 Strategic Plan (2021-2025)*. [online] Kuala Lumpur. Available through: Construction Research Institute of Malaysia <https://www.cream.my/my/publication/construction-4-0-strategic-plan-2021-2025/construction-4-0-strategic-plan-2021-2025> [Accessed 31 March 2022].

cobuilder, 2016. *Why is BIM important for manufacturers and will it increase their sales?* [online] Available at: <https://cobuilder.com/en/bim-for-manufacturers/> [Accessed 19 June 2021].

Cooper, D.R. and Schindler, P.S., 2005. *Business Research Methods*. 12th Edition. New York: McGraw-Hill.

Danielson, T., 2021. *Change Leader: We Can't Build Tomorrow's Infrastructure Using Yesterday's Technology* [online] Available at: <https://informedinfrastructure.com/68155/change-leader-we-cant-build-tomorrows-infrastructure-using-yesterdays-technology/> [Accessed 24 July 2021].

Data Design System, 2020. *About Data Design System*. [online] Available at: <https://www.dds-cad.net/company/> [Accessed 19 June 2021].

Dormakaba, 2022. *Dormakaba – NBS National BIM Library*. [online] Available at: <https://www.nationalbimlibrary.com/en/dormakaba-uk-ireland/> [Accessed 4 April 2022].

Dortek, 2022. *Dortek – NBS National BIM Library*. [online] Available at: <https://www.nationalbimlibrary.com/en/dortek-ltd/> [Accessed 4 April 2022].

Eastman, C., Teicholz, P., Sacks, R. and Liston, K., 2011. *BIM Handbook: A Guide to Building Information Modeling for Owners, Managers, Designers, Engineers and Contractors*. 2nd ed. Pittsburgh: John Wiley and Sons.

Fitz, D., 2019. *ISO 19650, The Good, The Bad and The Ugly*. [online] Available at: <https://www.symetri.co.uk/insights/blog/iso-19650-the-good-the-bad-and-the-ugly?r=2> [Accessed 15 June 2021].

Geddes, D., 2020. *The history of computer-aided design and computer-aided manufacturing (CAD/CAM)* [online] Available at: <https://www.technicalfoamservices.co.uk/blog/blog-history-of-cad-cam/#:~:text=The%20first%20true%20CAD%20software,(Massachusetts%20Institute%20of%20Technology)> [Accessed 27 March 2022].

Golabchi, A. and Kamat, V. R. 2013. *Evaluation of Industry Foundation Classes for Practical Building Information Modeling Interoperability*. In: IAARC (The International Association for Automation and Robotics in Construction), 2013 Proceedings of the 30th ISARC. Montréal, Canada, 17-26 August 2013. IAARC.

Graphisoft, 2020. *OPENBIM*. [online] Available at: <https://graphisoft.com/solutions/workflows/open-bim> [Accessed 21 July 2021].

Green, E., 2016. *The Role of Interoperability in BIM*. [online] Available at: <https://www.engineering.com/story/the-role-of-interoperability-in-bim> [Accessed 7 August 2021].

Hilti, 2022. *Hilti – NBS National BIM Library*. [online] Available at: <https://www.nationalbimlibrary.com/en/hilti-gt-britain-ltd/> [Accessed 4 April 2022].

Ibrahim, A. and Abdelatif, A.O., 2020. *Challenges Facing Building Information Modelling in Construction Industry in Sudan*, In: Qatar University Press, International Conference on Civil Infrastructure and Construction (CIC 2020). Doha, Qatar, 2-5 February 2020. Qatar: Qatar University Press.

International Organization for Standardization, 2015. *ISO 16757-1:2015 Data structures for electronic product catalogues for building services — Part 1: Concepts, architecture and model*. [online] International Organization for Standardization Online. Available at: <https://www.iso.org/standard/57613.html> [Accessed 30 June 2021].

Jotun, 2022. *Jotun – NBS National BIM Library*. [online] Available at: <https://www.nationalbimlibrary.com/en/jotun/> [Accessed 4 April 2022].

Kennyingram, 2016. *Overhaul your mindset if you want to win at BIM*. [online] Available at: <https://www.constructionnews.co.uk/special-reports/overhaul-your-mindset-if-you-want-to-win-at-bim-01-04-2016/> [Accessed 2 July 2021].

Kjartansdóttir, I.B., Mordue, S., Nowak, P., Philp, D. and Snaebjornsson, J. T., 2017. *Building information modelling - BIM*. [e-book] Civil Engineering Faculty of Warsaw University of Technology. Available at: <https://www.ciob.org/sites/default/files/M21%20%20BUILDING%20INFORMATION%20MODELLING%20-%20BIM.pdf > [Accessed 29 June 2021].

Kumar, B., 2015. *A Practical Guide to Adopting BIM in Construction Projects*. [Kindle DX version] Transworld Media. Available at: Amazon.co.uk <https://www.amazon.com/Practical-Guide-Adopting-Construction-Projects-ebook/dp/B07B1PLQBP> [Accessed 9 July 2021].

Lai, H.H. and Deng, X.Y., 2018. Interoperability Analysis Of IFC-Based Data Exchange Between Heterogeneous BIM Software. *Journal of Civil Engineering and Management*, [e-journal] 24(7), pp. 537 - 555. https://doi.org/10.3846/jcem.2018.6132.

Latiffi, A.A., Brahim, J. and Fathi, M.S., 2014. The Development of Building Information Modeling (BIM) Definition. *Applied Mechanics and Materials*, [e-journal] 567, pp.625 - 630. https://doi.org/10.4028/www.scientific.net/amm.567.625.

Mahamadu, A., Mahdjoubi, L. and Booth, C., 2013. *Challenges to BIM-Cloud Integration: Implication of Security Issues on Secure Collaboration*. In: IEEE (Institute of Electrical and Electronics Engineers), 2013 IEEE 5th International Conference on Cloud Computing Technology and Science. Bristol, United Kingdom, 2-5 December 2013. IEEE.

Mahamadu, A.M., 2013. *Challenges to BIM-Cloud Integration: Implication of Security Issues on Secure Collaboration*. In: 2013 IEEE 5th International Conference on Cloud Computing Technology and Science. Bristol, United Kingdom, 2-5 December 2013. IEEE.

Majcher, J., 2019. *Everything worth knowing about the IFC format*. [online] Available at: <https://bimcorner.com/everything-worth-knowing-about-the-ifc-format/> [Accessed 17 June 2021].

Marty, R., 2014. *What Is BIM Level 3?* [online] Available at: <https://blogs.3ds.com/perspectives/what-is-bim-level-3/> [Accessed 20 July 2021].

McLeod, S., 2018. *Questionnaire: Definition, Examples, Design and Types.* [online] Available at: <https://www.simplypsychology.org/questionnaires.html> [Accessed 19 July 2021].

McPartland, R., 2014. *BIM Levels explained.* [online] Available at: <https://www.thenbs.com/knowledge/bim-levels-explained> [Accessed 21 June 2021].

McPartland, R., 2017. *What is a federated Building Information Model?* [online] Available at: <https://www.thenbs.com/knowledge/what-is-a-federated-building-information-model> [Accessed 18 June 2021].

Mordue, S., Swaddle, P. and Philp, D., 2016. *A Building Information Modeling for Dummies*. [e-book] Chichester: John Wiley & Sons, Ltd. Available at: Wiley <https://www.wiley.com/en-gb/Building+Information+Modeling+For+Dummies-p-9781119060086> [Accessed 19 June 2021].

NBS, 2016. *What is Building Information Modelling (BIM)?* [online] Available at: <https://www.thenbs.com/knowledge/what-is-building-information-modelling-bim> [Accessed 22 July 2021].

Nchasi, G., 2021. *Research Ethical Clearance: Quick Guide for Young Researchers*. [online] Available at: <https://www.teamscopeapp.com/blog/research-ethical-clearance-quick-guide-for-young-researchers> [Accessed 21 July 2021].

Nemetschek, 2020. *The Nemetschek Group is driver of OPEN BIM*. [online] Available at: <https://www.nemetschek.com/en/company/about-us> [Accessed 21 July 2021].

NIBS, 2015. *WHAT IS A BIM?* [online] Available at: <https://www.nationalbimstandard.org/faqs> [Accessed 5 August 2021].

Nicoleta, P., 2015. *What I learned from studying the ISO 19650 BIM standards, (pros & cons).* [online] Available at: <https://www.breakwithanarchitect.com/post/what-i-learned-from-studying-the-iso-19650-bim-standards> [Accessed 18 June 2021].

NIST, 2011. *The NIST Definition of Cloud Computing*. [online] United State. Available through: Computer Security Resource Center <https://csrc.nist.gov/publications/detail/sp/800-145/final> [Accessed 22 June 2021].

Paul, S., 2018. *BIM adoption around the world: how good are we?* [online] Available at: <https://www.geospatialworld.net/article/bim-adoption-around-the-world-how-good-are-we/> [Accessed 23 July 2021].

Peters, J. and Mathews, M., 2019. *What is a BIM Design Model?* In: CITA BIM Gathering 2019. Galway, Ireland, 26 September 2019. TU Dublin.

Peters, T., 2021. *Renewed Efforts for a Universal BIM Standard*. [online] Available at: <https://www.architectmagazine.com/practice/renewed-efforts-for-a-universal-bim-standard_o> [Accessed 19 July 2021].

Public Works Department, 2020. *Public Works Department (JKR) Strategic Plan 2021-2025*. Kuala Lumpur: Public Works Department.

Ramanathan, R. and Clemmons, J., 2018. *How Virtual Design and Construction Streamlines Construction Projects* [online] Available at: <https://www.facilitiesnet.com/designconstruction/contributed/How-Virtual-Design-and-Construction-Streamlines-Construction-Projects--40530> [Accessed 12 April 2022].

Redmond, A., Hore, A., Alshawi, M. and West, R., 2012. Exploring how information exchanges can be enhanced through Cloud BIM. *Automation in Construction*, [e-journal] 24, pp.175 - 183. https://doi.org/10.1016/j.autcon.2012.02.003.

Richards, M., 2019. *Why Level 3 Building Information Modeling is about to change everything*. OpenText blog, [blog] 29 January. Available at: <https://blogs.opentext.com/why-level-3-building-information-modeling-is-about-to-change-everything/> [Accessed 23 June 2021].

RICS, 2020. *The future of BIM: Digital transformation in the UK construction and infrastructure sector*. [online] London. Available through: RICS Insights <https://www.rics.org/globalassets/rics-website/media/upholding-professional-standards/sector-standards/construction/future-of-bim_1st-edition.pdf> [Accessed 22 June 2021].

Santos and Eduardo, T., 2009. *Building Information Modeling and Interoperability*. In: SIGraDi (Sociedad Iberoamericana de Gráfica Digital), Proceedings of the 13th Congress of the Iberoamerican Society of Digital Graphics. Sao Paulo, Brazil, 16-18 November 2009. SIGraDi.

Saunders, M., Lewis, P. and Thornhill, A., 2016. *Research Methods for Business Students*. Seventh edition. England: Pearson Education Limited.

Shafiq, M. T., 2021. Client-Driven Level 2 BIM Implementation: A Case Study from the UAE. *The Open Construction and Building Technology Journal*, [e-journal] 15(1), pp.129 – 140. https://doi.org/10.2174/1874836802115010129.

Shang, Z. and Shen, S., 2014. *Critical Success Factors (CSFs) of BIM Implementation for Collaboration based on System Analysis*. In: ASCE (American Society of Civil Engineers), 2014 International Conference on Computing in Civil and Building Engineering. Orlando, Florida, United States, 23-25 June 2014. American Society of Civil Engineers.

Shillcock, P., 2019. ISO 19650: *When you should adopt it and why.* [online] Available at: <https://www.bimplus.co.uk/iso-19650-timetable-implementation/> [Accessed 16 July 2021].

Singh, S.K., 2016. *Investigating The Current State of Industry Foundation Classes in The Construction Industry*. Master. Texas A&M University. Available at: <https://core.ac.uk/download/pdf/147248061.pdf> [Accessed 27 July 2021].

Smith, P., 2014. BIM Implementation – Global Strategies. *Procedia Engineering*, [e-journal] 85, pp.482 - 492. https://doi.org/10.1016/j.proeng.2014.10.575.

Solihin, W., Eastman, C. and Lee, Y.C., 2016. A framework for fully integrated building information models in a federated environment. *Advanced Engineering Informatics*, [e-journal] 30(2), pp.168 - 189. https://doi.org/10.1016/j.aei.2016.02.007.

Systèmes, D., 2014. *End-to-end collaboration enabled by BIM level 3*. [online] Available through: Dassault Systemes Online <https://www.3ds.com/fileadmin/Industries/Architecture-Engineering-Construction/Pdf/Whitepapers/end-to-end-collaboration-enabled-by-bim-level-3-white-paper-aec.pdf > [Accessed 22 July 2021].

Tekla, 2020. *Tekla Promotes Open Approach to BIM*. [online] Available at: <https://www.tekla.com/about/collaboration> [Accessed 12 July 2021].

Terol, C., 2020. *BIM Level 3: is the industry ready?* [online] Available at: <https://www.globalcad.co.uk/bim-level-3-is-the-industry-ready/> [Accessed 8 August 2021].

UK BIM Alliance, 2019. *Information management according to BS EN ISO 19650 Guidance Part 1: Concepts*. [online] United Kingdom. Available through: UK BIM Alliance <https://www.ukbimalliance.org/wp-content/uploads/2019/04/Information-Management-according-to-BS-EN-ISO-19650_-Guidance-Part-1_Concepts_2ndEdition.pdf> [Accessed 7 August 2021].

UK Department for Business, Innovation and Skills, 2015. *Digital Built Britain Level 3 Building Information Modelling - Strategic Plan*. London: Department for Business, Innovation and Skills.

United BIM, 2019. *BIM Maturity Levels Explained- Level 0, Level 1, Level 2, Level 3*. [online] Available at: <https://www.united-bim.com/bim-maturity-levels-explained-level-0-1-2-3/> [Accessed 21 June 2021].

Vectorworks, 2020. *A Future-Proof Approach to AEC Collaboration* [online] Available at: <https://www.vectorworks.net/en-US/architect/open-bim> [Accessed 11 July 2021].

Wong, J., Wang, X.Y., Li, H., Chan, G. and Li, H.J., 2014. A review of cloud-based BIM technology in the construction sector. *Journal of Information Technology in Construction*, [online] Available at: <https://www.itcon.org/paper/2014/16> [Accessed 22 June 2021].

Wu, P., Jin, R., Xu, Y., Lin, F., Dong, Y. and Pan, Z., 2021. The Analysis of Barriers to BIM Implementation for Industrialized Building Construction: A China Study. *Journal of Civil Engineering and Management*, [e-journal] 27(1), pp.1 - 13. https://doi.org/10.3846/jcem.2021.14105.

Yaakob, M., Ali, N.A. and Radzuan, K., 2016. *Identifying critical success factors (CSFs) of implementing building information modeling (BIM) in Malaysian construction industry*. In: 2016 International Conference on Applied Science and Technology. Kedah, Malaysia, 11-13 April 2016. AIP Conference Proceedings.

Zakaria, Z., Ali, N.M., Haron, A.T., Marshall-Ponting, A., and Hamid, Z.A., 2013. Exploring the adoption of Building Information Modelling (BIM) in the Malaysian construction industry: A qualitative approach. *International Journal of Research in Engineering and Technology*, [e-journal] 2(8), pp.384 - 395. https://doi.org/10.15623/ijret.2013.0208060.

APPENDICES

APPENDIX A: Questionnaire

EXPLORE THE ISSUES AND CHALLENGES TO ADOPT BUILDING INFORMATION MODELLING (BIM) LEVEL 3

Dear Sir/Madam,

I am a final year undergraduate student currently pursuing Bachelor of Science (Honours) Quantity Surveying in Universiti Tunku Abdul Rahman (UTAR). I sincerely invite you to participate in this research on "Explore the Issues and Challenges to Adopt Building Information Modelling (BIM) Level 3" by completing the following survey. The aim of this research is to explore the issues and challenges towards BIM Level 3 adoption. The following questionnaire will require approximately 5-10 minutes to complete. Thank you for taking your time in assisting me with this research. Under no circumstances are you obliged to answer any of the questions, however, in doing so will greatly assist me in completing my research and enhancing the understanding of this research focus. The data collected will remain confidential and used solely for academic purposes. Your support towards my following research will greatly help to conduct the study perfectly. If you have any queries regarding the survey questions, please do not hesitate to contact me at chancheehong1999@1utar.my.

Thank you for your participation.

Yours faithfully,
Chan Chee Hong
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Section A: Practices of BIM Adoption

To what extend do you agree or disagree with the following statements?

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Project teams are using traditional drafting tools and techniques to create paper-based drawings					
Project teams are using CAD tools to create 2D drawings					
Project teams are using CAD tools to create 3D drawings					
Project teams are using BIM tools to model building information in 3D					
Project teams are using Building Lifecycle Management (BLM) system					
Project files are being shared via paper					
Project files are being shared via digital file					
Project files are being shared via an online shared platform					
Project files are being shared via an open data file format					
Project teams operate on a single shared model via a cloud-based environment					
Project teams keep their own generated models					

The generated models are accessible to project team members only					
The generated models are accessible to all stakeholders					
The generated models are modifiable to all stakeholders					
Project teams are using BIM tools to visualise a building's structure in 3D					
Project teams are using site logistics model to support logistics planning and control					
Project teams are using equipment routing animation to visually track site readiness requirements					
Project teams are using project timeline stimulation to schedule construction sequences					
Project teams taking off quantities from paper printouts					
Project teams taking off quantities from CAD tools					
Project teams taking off quantities from BIM tools					
Project teams are using cost estimation to estimate construction cost					
Project teams are using real-time cost visualization to control construction cost					
Project teams are using energy estimation to analyse the energy consumption of a building					
Project teams using BIM to facilitate decision making related to component installation					
Project teams are using facility management to operate and maintain building					

Section B: Factors that Need for Initiating BIM Adoption

To what extend do you agree with the following statements?

	Not Important	Less Important	Neutral	Important	Very Important
A standardised processes and procedures					
An international set of standards					
Data can be exchanged between different software applications					
Data can be exchanged without compatibility problems					
Data can be accessed through the internet					
Data can be accessed regardless of time					
Data can be accessed regardless of location					
Data can be stored regardless of size					
An optimized work breakdown for construction					
Project status can be monitored in real time					
A virtual building for streamlining maintenance and operations					
An open standard and workflow					

Project stakeholders are using same design software					
Project stakeholders are able freely to choose their preferred design software					
A predictive life cycle management system for construction works					
A mindset shift to new ways of working					
Shaping skills and lifelong learning					
Leadership of senior management					
Support and enforcement by the government					
A single central model					
A federated model					

Section C: Issues and Challenges of BIM Adoption

How strongly do you agree or disagree with the following statements?

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Lack of government enforcement for implementing BIM industry standards as a contractual requirement					
Lack of common language in the BIM industry standards documents					
Lack of clear guidance for the use of BIM industry standards documents					
Loss of data during translation of the open data format					
Loss of parametric intelligence during translation of the open file format					
Loss of geometric properties during translation of the open file format					
Slow processing performance due to large size of open file format					
Lack of effort by software vendor to improve open file format					
Lack of incentive to use cloud computing					
Lack of legal and contractual implication of using cloud computing					
Lack of security and protection of data in cloud computing					

Lack of cloud specific standards					
Low bandwidth internet connection					
Lack of management of interactions within a model among multidisciplinary team					
Lack of support from project owners on open BIM implementation					
Lack of investment in a common data environment					
Lack of performance measurement systems for open BIM implementation					
Low level of cooperation between multidisciplinary team					
Lack of experts with relevant skills and knowledge					
Lack of proper training and learning resources					
Lack of awareness and involvement in the change					
Lack of financial resources to improve BIM-related technologies					
Lack of standardised definition on the scope of BIM Level 3					

Section D: Demographic Information

D1) Which of the following best describes your company's business activities?

- ○ Developer
- ○ Consultant
- ○ Contractor
- ○ Sub-contractor
- ○ Supplier
- ○ Other (Please specify): ________________

D2) Which of the following best described your profession?

- ○ Architect
- ○ Civil & Structural Engineer
- ○ Mechanical & Electrical Engineer
- ○ Quantity Surveyor
- ○ Other (Please specify): ________________

D3) How do you rate your knowledge and skills in BIM?

- ○ Do not know
- ○ Very Poor
- ○ Poor
- ○ Fair
- ○ Good
- ○ Very Good

D4) For how many years is your working experience in the construction industry?

- ○ Less than 2 years
- ○ At least 2 years, but less than 5 years
- ○ At least 5 years, but less than 10 years
- ○ At least 10 years, but less than 20 years
- ○ 20 years or more

Consent of Participation

By clicking submit of the online questionnaire, you are indicating that:

1. You understand that if you have any additional questions, you can contact chancheehong1999@gmail.com

2. You understand that Privacy Notice of UTAR is available at https://www2.utar.edu.my/PrivacyNotice_English.jsp

3. You understand that you can contact the Research Ethics Officers at +603 9086 0288 or aswini@utar.edu.my

4. You agree to participate in this survey voluntarily