THE FUTURE OF BUILDING INFORMATION MODELING: AN EXPLORATORY STUDY

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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

Building Information Modelling (BIM) has been widely adopted in the construction sector across various countries, including Malaysia, over the last decade. It is time to review how the industry has made use of BIM and explore its future. This research aims to explore the future of BIM adoption in the Malaysian construction industry by reviewing the changing narratives of BIM, exploring the current adoption of BIM in Malaysian construction industry, and anticipating its future adoption. The literature review identified 13 ways of BIM adoptions and 11 possibilities for the future of BIM. An online questionnaire survey was used to gather empirical data from industrial practitioners, and 206 valid responses were received. The questionnaire's internal consistency was assessed using Cronbach's alpha reliability analysis, and the randomness of the result was tested using the Chi-Square Test. The Kruskal Wallis H-test was used to determine significant differences in current practices and future BIM adoption according to companies' business activities, profession, and working experience. The results showed that authoring is the most common use of BIM in Malaysia, and BIM is viewed as an integral part of the construction sector's future. Architects are the most proactive in adopting BIM, while quantity surveyors perceive its importance to be higher than other professionals. The research findings can help the construction industry in creating, a strategic plan for the future BIM adoption. Regulatory bodies can implement necessary improvements to expedite the industry's maturity in BIM adoption and support academic advancements in research, innovation, and curriculum creation.

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LIST OF SYMBOLS / ABBREVIATIONS

BIM	Building Information Modeling
US	United States
UK	United Kingdom
AEC	Architecture, Engineering and Construction
NBIMS	National Building Information Modeling Standard
RICS	Royal Institution of Chartered Surveyors
ISO	International Organisation for Standardisation
IFC	Industry Foundation Classes
COBie	Construction Operations Building Information Exchange
AI	Artificial Intelligence
AR	Augmented Reality
VR	Virtual Reality
IoT	Internet of Things
bsDD	buildingSMART Data Dictionary
BCF	Building Collaboration Format
CLT	Central Limit Theorem
SPSS	Statistical Package for Social Sceinces

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CHAPTER 1

INTRODUCTION

1.1 Background

Construction projects are complex and require meticulous planning and coordination as there are numerous interdependent tasks involved (Tran, Tookey and Roberti, 2012). BIM is a digital tool that enables collaboration among project stakeholders on a single, shared platform to enhances coordination and communication between different parties. According to the US National Building Information Modeling Standard (NBIMS), BIM is “A digital representation of a facility’s physical and functional characteristics.” Throughout a facility's lifecycle, which is described as "lasting from original conception to demolition," a BIM is a shared knowledge resource for information about the facility that provides a reliable basis for decisions.

In recent years, the rate of BIM adoption in the construction and industrial sectors has accelerated. This is due to the widespread endorsement of digital construction as a means of advancing enhanced information interchange and management in the architecture, engineering and construction (AEC) sector. For instance, the UK Government Construction Strategy specified a variety of objectives, such as the creation of standards to enable supply chain participants to collaborate through BIM, with a minimum level of fully collaborative 3D BIM "Level 2" by 2016 (ERG UK, 2011). On the other hand, a roadmap for integrating BIM and IT-based technologies into the design and construction of significant infrastructure projects was also released by Germany’s Federal Ministry of Transport (BMVI Germany, 2015). According to the Malaysia Building Information Modelling Report 2019, published by the Construction Industry Development Board (CIDB) in 2020, there has been a significant increase in BIM adoption in the country's construction industry. The report shows that 49% of the survey respondents have implemented BIM in their construction projects, indicating a substantial rise from the adoption rate of 17% recorded in the previous study conducted in 2016.

Initially, the development of BIM was focused on design, construction, and the 3D model, with opportunities for 4D and 5D. However, the modelcentric workflow that relies on the appropriate type and quantity of information presented in a format that allows for collaborative decision-making at the first instance was supported and founded on national standards, norms, and procedures. These standards have recently been standardized internationally to cater to the requirements of the global market. As a result, this study aimed to commence a conversation regarding the future adoption of BIM in the Malaysian construction industry.

1.2 Problem Statement

The NBS 2019 survey found that BIM knowledge and implementation increased from 10% in 2011 to over 70% in 2019 at UK, based on responses from about 1,000 industry professionals. Additionally, the technology was specifically included in the Government Construction Strategy (GCS) as a remedy for managing and procuring public sector assets. In order to change work patterns and boost efficiency, BIM and digital technologies were cited as being crucial. BIM creates 3D models using sophisticated computer systems that can record data about the design, condition, and use of assets (Modelling and Plan, 2015).

BIM can be an acronym of Building Information Model/Building Information Modeling or Building Information Management. While most people who know BIM will refer to Building Information Modeling or the 'Model' dimension, the 'Management' part is at least as important. BIM plus (2020) noted there is a changing narrative in BIM, building information management should receive more attention in the construction industry. The ISO 19650 series being released under the UK BIM Framework provides a comprehensive internationally-agreed set of standards for information management using BIM. This enables the UK to move beyond 'BIM Level 2' and build a resilient foundation to be able to integrate with the future state Information Management Framework (IMF) being developed under the National Digital Twin programme. A project's success or failure depends on the prompt delivery of accurate information of high quality, as well as how that information is managed and disseminated within the project team. At its most basic level, building information management involves organising and carrying out duties related to the identification of information needs, information generation, verification, and distribution (Kocakaya et al., 2019). Besides, Dave et al. (2020) that examined the barriers to BIM adoption in the construction industry and noted that there was a need for more research on the future of BIM and its potential to transform the industry. Moreover, in a study by Ahmad et al. (2019) that explored the use of BIM for sustainable building design and noted that there was a lack of research on the future of BIM and its potential to support sustainable building practices. Therefore, this research attempts to explore the future of BIM adoption. The inquiries that this study aims to addressed are: What are the changing narratives of BIM? What are the current adoption of BIM in the Malaysian construction industry? What are the future of BIM adoption in the Malaysian construction industry?

1.3 Research Aim

BIM adoption is still relatively low in the Malaysian construction industry, despite the potential benefits of BIM. Understanding the future of BIM adoption can help to identify the potential barriers and opportunities for increasing BIM adoption in Malaysia. Therefore, this research aims to explore the future of BIM adoption in the Malaysian construction industry.

1.4 Research Objective

The following objectives have been established to achieve the research aim mentioned above:

i. To review the changing narratives of BIM.
ii. To explore the current adoption of BIM in the Malaysian construction industry.
iii. To anticipate the future of BIM adoption in the Malaysian construction industry.

1.5 Research Method

The adoption of BIM in the Malaysian construction industry is being investigated using an exploratory method to explore the future of BIM adoption. The questionnaire survey for this study was distributed via internet-based methods for data gathering. Both descriptive and inferential analysis were used to analyse all the information gathered from the questionnaire. Figure 1.1 depicts the research methods used to accomplish the research objectives.

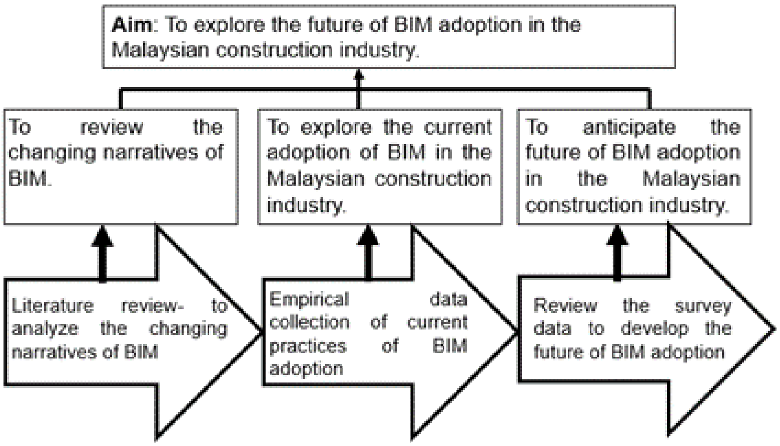

Figure 1.1: Research Methodology Framework

1.6 Research Scope

The research scope of the study is to explore current BIM adoption in the construction industry and explore the future of BIM adoption. After future of BIM adoption was deconstructed from the pertinent literature reviews, empirical data was gathered using a questionnaire design. Construction practitioners working in various supply chain operations make up the target respondents. For in-depth analysis and comparisons, the characteristics of respondents varied professional backgrounds and lengths of employment in the construction business were gathered. There are no limitations on the qualifications of the respondents because this research is exploratory in nature, other than the requirement that the participants be associated with the construction industry.

1.7 Report Structure

The five chapters that make up the organization of this research project report are Introduction, Literature Review, Methodology, Result and Discussion, and Conclusion and Recommendations. The following paragraphs provide an overview of each chapter.

Chapter 1 encompasses the study’s background and problem statement of future of BIM adoption along with the previous research. Besides, it outlines the research aim, objective, methodology, research scope and limitations, as well as the structure of the report.

Chapter 2 provides a succinct definition of BIM. The published literature and documentations on BIM were then reviewed with an emphasis on the current adoption of BIM. Subsequently, the future of BIM adoption is discussed in more detailed in this chapter. Finally, a conceptual framework is presented.

Chapter 3 explained the research methodology used in this study. The research approach, research strategies, sample methods, and data analysis methods are also highlighted in this chapter. To make inferences that can be generalised, methods of data analysis including reliability tests, descriptive statistics, and inferential statistics are used. This chapter includes a thorough justification and explanation of the questionnaire's design.

Chapter 4 evaluates and discuss the findings of the data analysis. The respondents' demographic data was presented using descriptive statistics' frequency distribution. Also, the reliability of the collected data was examined using the Cronbach's alpha reliability test. Moreover, inferential statistics tests like the Kruskal-Wallis H test are used to assess the perceptions among the various groups of respondents. Besides, the chi-square test is employed to establish if there exists a significant correlation between two categorical variables. By contrasting and comparing the results with the literature reviews, the conclusions are arrived upon.

Chapter 5 is the final chapter wraps up this research. It summarises the attainment of the research aim as well as the three research objectives. This chapter also discusses how the research will affect academics and research institutions, as well as industrial practitioners, regulators, and professional bodies. It also highlights the limitation of this study. Upon consideration of the lesson gained from this project, recommendations are given for the forthcoming research.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Building Information Modelling which involves the multidisciplinary of professional parties to design their project in a 3D model (Lorek, 2021). BIM always tends to be technology, but it is also about process, protocol, and information (BIM Learning Center, 2013). This chapter provided a succinct description of BIM. As BIM adoption moves forward, the process becomes more complicated and there is animosity against the future adoption of BIM. As a result, this chapter also discussed the current practices and future of BIM adoption. Lastly, this chapter suggests a conceptual framework for understanding the future of BIM adoption.

2.2 BIM

BIM sometimes referred to as n-D modelling or virtual prototyping technology, is quickly reviving the AEC industry. According to RICS (2020), BIM relies on technology and a cooperative strategy for producing and managing data throughout a project's lifespan.

According to the NBIMS committee of the US, BIM is a digital representation of a building's structural and functional attributes. A fundamental BIM idea is the cooperation of numerous stakeholders at different stages of a facility's lifecycle to enter, extract, update, or modify information in the BIM to support and reflect the role of stakeholders (NBIMS, 2010).

Generative design is a powerful tool that can significantly impact the adoption and implementation of BIM in the construction industry. Generative design allows for the rapid generation of multiple design options based on specified criteria and constraints. This enables architects and engineers to explore a wide range of possibilities and evaluate their performance, functionality, and aesthetics. By integrating generative design with BIM, stakeholders can visualize and analyze these options in a collaborative and interactive manner, fostering creativity and innovation .

According to Zhao and Enrico (2019), generative design algorithms leverage computational power to generate optimized design solutions. When combined with BIM, these solutions can be evaluated for various performance parameters, such as energy efficiency, structural integrity, and cost-effectiveness. This integration empowers design teams to make informed decisions based on data-driven insights, leading to the creation of more sustainable and high-performing buildings.

Leach and Turnbull (2012) asserted that BIM provides a digital representation of a building's physical and functional characteristics throughout its lifecycle. Generative design algorithms generate design alternatives that can be seamlessly incorporated into the BIM environment. This integration enables efficient data exchange and interoperability, streamlining workflows and reducing errors during the design, construction, and operation phases. As a result, the narrative shifts from BIM being seen as an additional burden to an invaluable tool for improved project coordination and collaboration.

2.3 Explore the Current Adoption of BIM

In recent years, BIM has gained significant traction in the AEC industry. BIM enables the creation of a collective knowledge pool of data regarding a facility, which can be utilized for design, construction, and operation purposes. It serves as a digital model of a building's physical and functional characteristics. The following sections elaborates the key current BIM adoption, which consists of authoring, standardisation, and accessibility.

2.3.1 Authoring

The usage of BIM tools for authoring is undoubtedly possible. Buildings can be created in detail using BIM tools, and these models can then be used to produce 2D drawings and plans for construction documentation (NBS, 2016). With the BIM tools, users can create 2D views from 3D models and annotate drawings by adding dimensions, annotations, and other details. By exporting views and sheets from the 3D model, Revit, a well-known BIM tool, can produce 2D drawings (Autodesk, 2023). Changes made to the 3D model will be reflected in the 2D drawings, which users can dimension and remark.

Hamzeh (2019) mentioned that as more clients demand the use of BIM in the design and construction process, BIM adoption can give architects a competitive edge. According to Sacks, Eastman, and Lee (2004), BIM tools may produce 3D models of buildings, giving architects, engineers, and other construction industry professionals a better visual representation of and more precise planning of the construction process. Eastman et al. (2011) stated that BIM tools enable industry practitioners to track and manage changes to building designs throughout their lifecycle, ensuring that different parties participating in the project has access to the most up-to-date information. The software can also provide information on the building's energy efficiency, construction costs, and material costs. According to Al-Momani and Al-Qawasmi (2020) before beginning actual construction, BIM enables contractors to develop a comprehensive virtual model of a building, which can help them find and fix any problems. In addition, by offering a common forum for communication and information sharing, BIM is able to assist all parties engaged in the project, including contractors, subcontractors, and clients to communicate more effectively (Kamara, Anumba, and Evbuomwan, 2018).

2.3.2 Standardisation

BIM standards are a set of guidelines or protocol that establish a uniform vocabulary, conceptual framework, and specifications for the application of BIM in construction projects. Across all phases of a construction project, from planning and design to construction and maintenance, these available standards provide a framework for the uniform and coordinated use of BIM.

An international standard for BIM-based information management is ISO 19650. ISO 19650 offers direction on the methods, processes, and information exchanges necessary for BIM-based information management (International Organization for Standardization, 2018). Besides, ASTM E1967 is a standard reference for BIM in facility management. It offers advice on how to use BIM to facility management tasks (ASTM International., 2016). On the other hand, IFC (Industry Foundation Classes) is a standard for facilitating communication between various BIM software programmes. According to National Institute of Building Sciences (2018), IFC establishes a neutral file format for the BIM data transmission. Furthermore, a standard for exchanging building data among several software programmes is COBie (Construction Operations Building Information Exchange). COBie offers a standard format for the interchange of building data, including information about the equipment, warranties, and maintenance (BuildingSmart International, 2013).

2.3.3 Accessibility

BIM is a digital representation of a building's physical and functional attributes that aids in the creation and management of building information throughout the life cycle of the project (Kumar, Jha and Kumar, 2019). According to Zawawi et al. (2019), the ease with which stakeholders can access, use, and exchange BIM data is referred to as its data accessibility. Moreover, BIM, which is used in various building projects to promote efficiency and decrease errors, has seen a considerable surge in use in recent years. However, the accessibility of current adoption of BIM is limited due to several factors.

Zawawi et al. (2019) mentioned that different software platforms may not be completely compatible with one another, making it difficult to transfer BIM data across stakeholders who use different software. According to Azhar et al. (2012), BIM data may be subject to licence and ownership agreements, which can restrict certain stakeholders access to it. In addition, working with BIM data requires a particular level of technical knowledge, which may prevent stakeholders without the required knowledge or training from accessing it (Kim et al., 2019). While BIM data for large or complicated projects may be quite complex, which may make it challenging to maintain and access (Abdul-Rahman et al., 2016).

2.4 Changing narrative of BIM adoption

The "changing narrative of BIM adoption" refers to the evolving perspective and discourse surrounding the use and implementation of BIM in the construction industry. It implies that there have been changes in the way practitioners talk about, perceive, and use BIM over time. These changes can be influenced by various factors, such as technological advancements, industry standards, regulatory requirements, and societal expectations. By reviewing the changing narrative of BIM adoption, practitioners can gain insights into how BIM has been adopted in the past, the current state of adoption, and the potential future trends. In the context of BIM adoption, the narrative can be influenced by various stakeholders, such as architects, engineers, contractors, clients, and policymakers, who have different perspectives and interests.

According to Miettinen, Paavola and Puttonen (2018), the narrative of BIM adoption has changed over time from a focus on technical aspects to a broader view of its potential benefits for the construction industry, such as improving collaboration, reducing errors and rework, and enhancing sustainability. They argue that this change in the narrative has led to a shift in the way BIM is perceived and used, from a tool for modeling and visualization to a platform for data integration and decision-making.

Similarly, Lim and Jang (2020) note that the narrative of BIM adoption has evolved from a top-down approach driven by government regulations to a bottom-up approach driven by industry practices and standards. They suggest that this change in the narrative has created opportunities for innovation and customization of BIM applications, but also challenges in terms of interoperability and data governance. These studies highlight the importance of understanding the changing narrative of BIM adoption in order to anticipate its future trends.

2.5 Future of BIM adoption

As the construction industry seeks to boost productivity, reduce cost, and improve outcomes of the project, the usage of BIM is anticipated to keep expanding in the future. The following sections elaborates eight categories of future of BIM adoption which consists of BIM is industry trends, connected BIM, BIM integration, Cloud-base BIM, skill up professionals, data accessibility, open BIM and ISO19650.

2.5.1 BIM is industry trends

According to Huang et al. (2017), BIM technology has the ability to enhance stakeholder engagement and communication, which could lead the consultants to improved project outcomes. Kiron et al. (2013) asserted that BIM use has risen quickly in recent years, with 50% of AEC businesses utilising it in 2012, up from only 28% in 2007. The survey also mentioned that larger companies adopted BIM most widely, with 70% of those with more than 100 employees doing so in 2012.

The way that buildings are designed, built, and managed is changing, making BIM an industry trend (MarketsandMarkets, 2019). According to Larsen and Sorensen (2016), BIM can make it easier to integrate different systems and procedures, such as project management, cost estimating, and scheduling, which can improve the efficiency of the entire project. Besides, BIM is going to become even more essential for the construction industry as technology develops. Eastman et al. (2011) stated that BIM technology is constantly developing, and new features and functionalities are frequently added. Project outcomes are improved by BIM by lowering errors and rework, enhancing cooperation and communication, and facilitating better cost control and risk management (Azhar, 2012). The capacity to deliver projects on schedule and under budget will be vital to survival as the construction industry becomes more competitive, and BIM can assist companies in achieving these goals.

2.5.2 Cloud-base BIM

Terol (2020) mentioned that one of the key elements that must be established for future of BIM deployment to realise multi-user access and collaborative engagement is a cloud-based BIM. This view is reinforced by Wong, et al. (2014), who claim that the developing cloud-BIM technology is viewed as an enabling technology to get beyond traditional BIM's stand-alone character. It promotes greater coordination and cooperation among project participants and offers a dependable platform for real-time communication.

Afsari, Eastman, and Shelden (2016) findings establish that BIM data and models are stored, shared, and accessed using cloud computing, which is referred to as cloud-based BIM. Cloud-based BIM eliminates the need for local servers or hardware by enabling users to view BIM data and models from any location with an internet connection using a variety of gadgets like laptops, tablets, and smartphones. According to a study by McGraw Hill (2020), the adoption of cloud-based BIM has dramatically expanded in recent years, with 74% of polled construction professionals reporting using cloud-based BIM in 2019, up from 55% in 2017. The adoption of cloud-based BIM is anticipated to increase due to more construction firms become aware of the advantages of this technology such as collaborative working, cost-effectiveness, scalability, security, and accessibility.

2.5.3 Data Accessibility

All project team members are anticipated to have much more access to integrated BIM in the future. Team members will be able to view and contribute on BIM models using their preferred software tools and devices from anywhere in the globe thanks to developments in cloud-based technology and the integration of BIM software with other construction software tools (Dodge data and analytics, 2020).

The growth of mobile devices and applications is one trend that is anticipated to contribute to BIM becoming more widely accessible (Autodesk, 2020). Construction professionals are increasingly embracing smartphones and tablets, which are getting more capable and affordable, to access BIM models and engage with team members while on the go. In addition, team members can view, edit, and share BIM models from their mobile devices thanks to the development of powerful and user-friendly mobile BIM applications (Global Market Insights, 2021). Golizadeh, Asadi and Honarvar (2019) stated that quantity surveyors required access to accurate and extensive data to assure the accuracy of their cost estimates, which BIM technology can supply. Autocase (2021) claimed that the utilization of artificial intelligence (AI) and machine learning represents a promising advancement that could enhance the accessibility of BIM. By automating the creation and maintenance of BIM models, these technologies could eliminate the need for manual data entry and upkeep. AI might also be used to examine BIM data and offer insights that could assist construction professionals in improving project outcomes and decision-making.

2.5.4 Connected BIM

In order to develop a connected and collaborative approach to construction and building management, connected BIM refers to the integration of BIM with other technologies, systems, and software programmes (Li et al., 2020). By employing BIM, a digital representation of a building's physical and functional attributes is created, and this model is then integrated with various systems and software programmes, including project management software, scheduling software, energy management systems, and building automation systems (Chen, Yang, and Li, 2019).

According to the study of Sacks, Goldschmidt, and London (2015), the purpose of connected BIM is to boost the effectiveness and efficiency of the building's ongoing management as well as the construction process. Stakeholders may access real-time data and cooperate more successfully across the entire lifecycle of the building, from design and construction to operations and maintenance, by integrating BIM with other systems and software applications. Kilinc, Ergen and Giritli (2018) asserted that quantity surveyors who are responsible for overseeing costs and spending on construction projects, have become increasingly aware of the benefits of BIM technology. Kim and Park (2017) mentioned that by giving quantity surveyors more precise and thorough information about the building and its systems, connected BIM also promotes improved decision-making. This can enhance overall performance and sustainability while minimising errors and waste.

2.5.5 BIM Integration

BIM integration is the process of integrating BIM with other software systems and technologies to enable a more collaborative and efficient approach to building design, construction, and management. By creating a centralised, digital model of the building and its systems that can be accessed and updated in real-time by all project stakeholders, BIM integration aims to increase the efficiency and effectiveness of building design, construction, and management.

According to the findings of Abdellatif and AbouRizk (2021), Augmented Reality (AR) and Virtual Reality (VR) technologies can be integrated with BIM to create immersive visualisations and simulations of the building design and construction process. In addition to allowing stakeholders to virtually tour and experience the building before construction starts, this integration can assist project teams in identifying potential problems and conflicts in the design (Boukamp, Roetzel and Haas, 2019). The usage of AR and VR technology can also help to increase safety by giving on-site employees access to real-time visual instructions and information about the construction process. According to the study of Calzada-Pérez, Becerik-Gerber, and Leite, 2021, by integrating BIM with AI technology, building designs, schedules, and resource allocation may be automatically analysed and improved. With this integration, project teams can shorten completion times and reduce costs by identifying and resolving possible issues and conflicts during the design and construction phases (Jia et al., 2021). AI can also be employed to evaluate data from sensors and other sources to find trends and insights that can help guide decisions and enhance the sustainability and performance of buildings. Chen and Wu (2021) asserted that real-time monitoring and management of building systems and equipment are made possible by the integration of BIM with IoT technology. This integration can assist building owners and operators in maximising energy efficiency, lowering maintenance expenses, and enhancing occupant safety and comfort (Li et al., 2021). Building performance and occupancy data can be gathered with IoT sensors, which can help with management and design decisions.

2.5.6 Open BIM

BIM is a collaborative process, and open BIM emphasises the use of open standards and processes to promote interoperability between various software programmes and project stakeholders. The usage of open standards, such as IFC and buildingSMART Data Dictionary (bSDD), that enable various software applications to communicate data in a uniform format is referred to as "open" in Open BIM (building SMART, 2021; Data Design System, 2020).

Choudhary (2020) investigated the concept of open BIM, which allows project stakeholders to access the information model while preserving the original design. Open BIM is a collaborative approach to designing, implementing, and managing buildings that utilizes open standards such as IFC, bSDD, and BCF. Baldwin (2018) claims that open BIM is a worldwide strategy based on open standards and procedures for collaborative building design, construction, and operation. Peters (2021) also urge open BIM to set universal standards and reduce the time designers must spend making sure their BIM model complies with these standards. According to Bakker, Boeykens and Truijen (2016), the Open BIM approach encourages project stakeholders, including as architects, engineers, contractors, and owners, to operate more transparently and cooperatively. This makes it possible for each stakeholder to use the software tools that best suit their needs while still sharing and working together on project data.

2.5.7 ISO 19650 and Building Information Management

BIM is used to manage information over a built asset's whole life cycle according to the international standards known as ISO 19650. The ISO created the standards in response to the expanding usage of BIM in the construction sector and the requirement for a consistent method of managing information across various projects and stakeholders (Messner, Anumba, and El-Masri, 2021).

ISO 19650 is a set of international standards that provide a framework for managing information over the entire lifecycle of a built asset using BIM. The six standards of ISO 19650 are: ISO 19650-1: Organization and digitization of information about buildings and civil engineering works, including BIM, ISO 19650-2: Delivery phase of the assets, ISO 19650-3: Operation and maintenance phase of the assets, ISO 19650-4: Collaborative production of information, ISO 19650-5: Security-minded approach to information management, and ISO 19650-6: Collaborative business relationships. Shillcock (2019) further explain that the organizations may make sure they are utilising BIM efficiently to support the construction projects by adhering to the rules outlined in the ISO 19650 standards. This can help to enhance project results, lower costs, and boost efficiency.

2.5.8 Skill Up Professionals

The involved parties in the construction industry must improve the skills of their employees, which calls for a mentality change that supports and promotes transparent and collaborative working (Terol, 2020). McGraw Hill (2020) claims that professionals in the architectural, engineering, and construction (AEC) sector nowadays require BIM as a fundamental competence (McGraw Hill, 2020). The creation and management of digital information about a building or infrastructure project, from design to construction to operation and maintenance, is known as BIM. It enables specialists to communicate more successfully, minimise errors, and enhance project results.

In accordance with Bataw, Kirkham, and Lou (2016), the adoption of BIM in the future will drastically alter the way professionals carry out their daily responsibilities. The transition will veer them away from the fragmented and paper-based approach towards a unified information model that requires continuous communication among various disciplines from the beginning. As a result, training and education are necessary for both new and seasoned professionals to fully understand their duties and responsibilities. According to Zakaria, et al. (2013), a successful BIM implementation requires that experts within the organisation have the necessary BIM expertise and training. Meanwhile, education is one method for arming people with knowledge and skills.

2.6 Proposed Conceptual Framework

The literature reviews revealed three categories that are crucial for current adoption of BIM. The conceptual framework for future of BIM adoption is shown in Figure 2.1. It is anticipated that early adopters' exposure to BIM techniques will increase awareness of the future of BIM adoption.

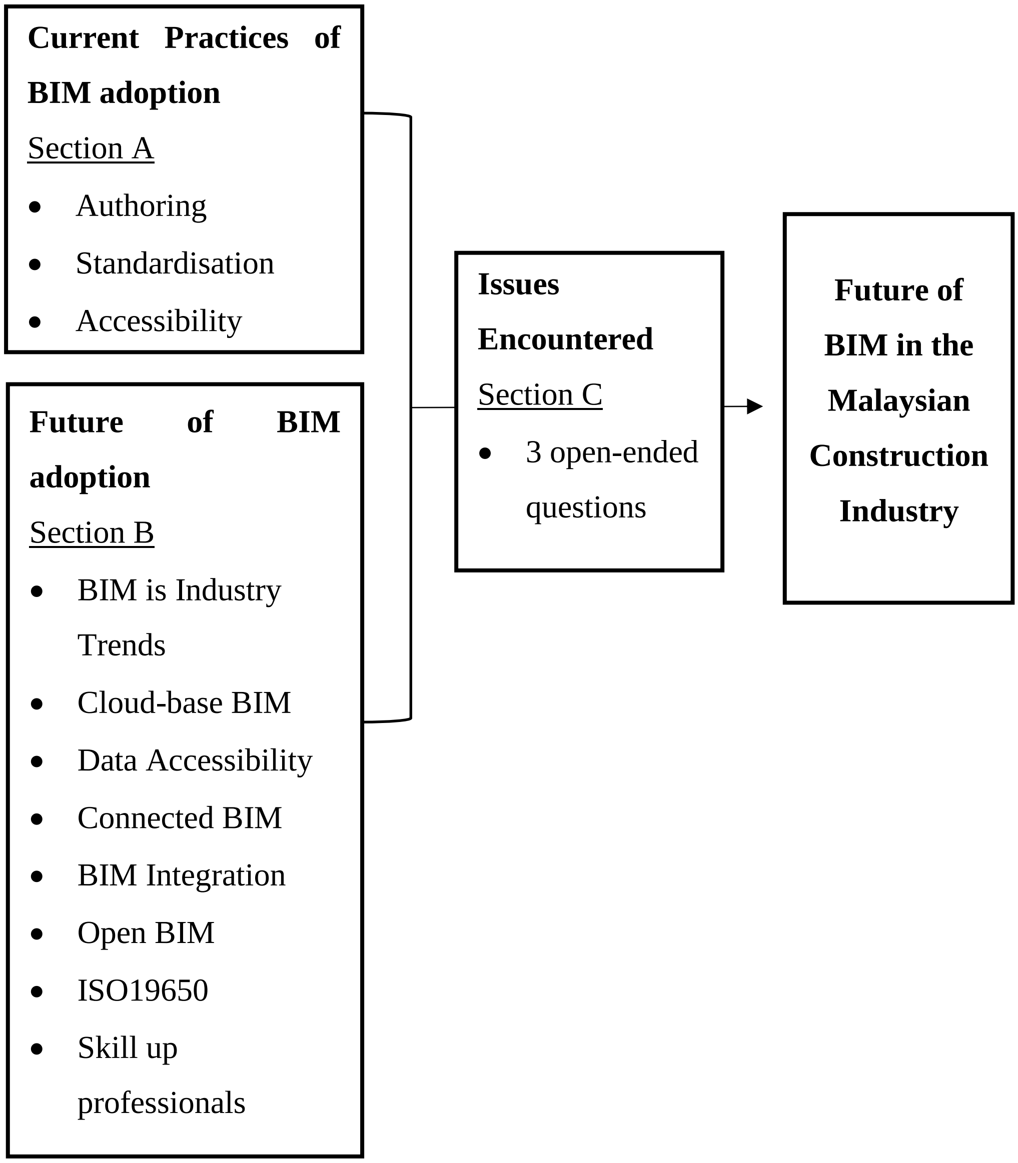

Figure 2.1: Conceptual Framework Proposal

CHAPTER 3

METHODOLOGY AND WORK PLAN

3.1 Introduction

This chapter outlines the methodology section of the research study. It commences with a discussion of the research approach, followed by an overview of the research strategies that include the questionnaire's purpose, design, and rationale. The sampling method is described, including the sample size and target respondents. Additionally, the proposed data analysis methods, which include the Cronbach's alpha reliability test, frequency distribution, mean rank, Kruskal-Wallis H test for determining significant differences, and Chi-Square test for testing the result's randomness are outlined. The chapter concludes with a section on research ethics, which explores the ethical considerations considered during the study, such as obtaining informed consent from participants and protecting their confidentiality.

3.2 Research Approach

According to Kumar (2019), exploratory research is often used in situations where there is limited existing research on a topic, where a researcher is seeking to gain a deeper understanding of a phenomenon, or where a researcher is seeking to generate hypotheses or ideas that can be tested in future research. The exploratory approach is being used to explore the current adoption of BIM and to anticipate the future of BIM adoption.

3.3 Research Strategies

Quantitative analysis method was adopted in this study to reveal the current adoption and the future of BIM adoption. The questionnaire was utilized and administered through online survey tools, such as Google Forms to collect the factual data from industrial practitioners. The details regarding the design and structure of the questionnaire are elaborated in subsequent sections.

3.3.1 Questionnaire Design

The main sections of the questionnaire were divided into four sections. Section A aimed to investigate the current BIM practices that are being implemented in the Malaysian construction industry, while Section B aimed to explore the future of BIM adoption in the industry. Section C was created to discover the issues of BIM's application in the industry and to exploring possible functions or features of BIM in future. Finally, the last section of the questionnaire covered the demographic information from the respondents. The design of the questionnaire was informed by the conceptual framework presented in Chapter 2, as depicted in Figure 3.1.

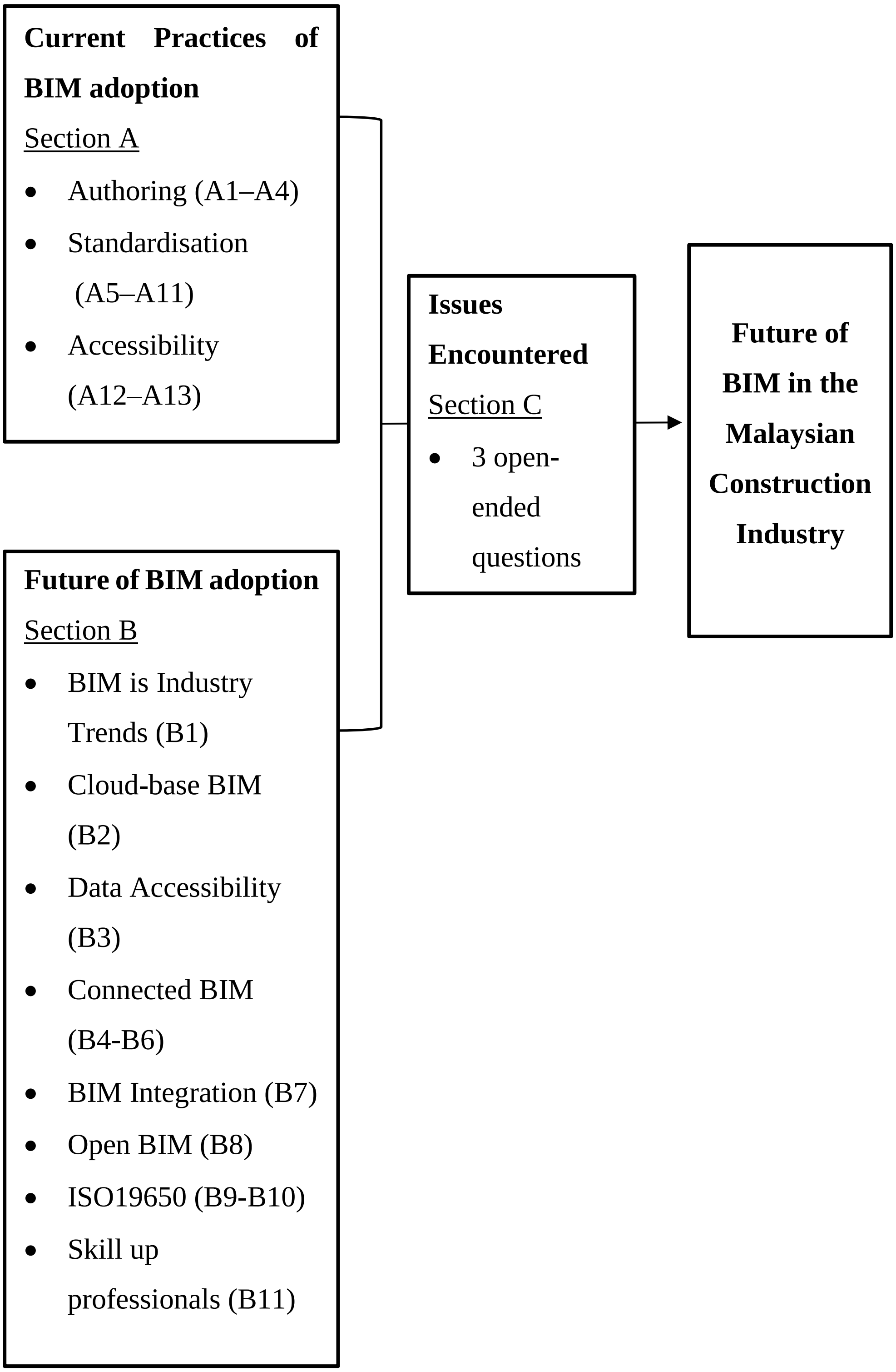

Figure 3.1: Structure of Questionnaire Design

3.3.2 Section A: Current Practice of BIM adoption

Section A of the questionnaire contained a series of statements related to the three categories of current practices of BIM adoption that were identified through a comprehensive review of published literature. Table 3.1 showed the statements for each category, and the extent of involvement of the statements varied within each category. The respondents were requested to express their level of agreement or disagreement concerning each of the 13 statements.

Table 3.1: Formulation of Question on Section A

Ref. Code	Statement	Categories	Reference
A1	We are using BIM tools to create 2D drawings	Authoring	Gunes (2019); Leidy (2020); Marty (2014)
A2	We are using BIM tools to create 3D drawings		
A3	We are using BIM tools to visualise a building in 3D		
A4	We are using BIM tools to monitor the entire building lifecycle		
A5	We are make use of available standards for project management involved with BIM (eg: ISO19650, BIM protocol, etc)	Standardisation	Mellado and Moreno (2019)
A6	We are using available standards to agree the appropriate remuneration regarding to BIM services		
A7	We are using available standards to consider the issue of contractual obligations		
A8	We are using available standards to define the information technology related obligations		
A9	We are using available standards to allow the creator has the right of ownership over information		
A10	We are using available standard to protect the valuable personal information		
A11	We are using available BIM standards (eg: ISO19650, BIM protocol, etc) to support BIM management		
A12	Our BIM models are accessible to project team members only	Accessibility	Interscale (2020); LetsBuild (2019)
A13	Our BIM models are editable by project team members only		

3.3.3 Section B: Future of BIM adoption

Section B of the questionnaire was created to assess respondents' agreement with the eight categories of future of BIM adoption that were identified through literature review. This section contained 11 statements about the future of BIM, as presented in Table 3.2. Respondents were asked to rate the level of importance they attributed to each statement on a scale from "not at all important" to "strongly important."

Table 3.2: Formulation of Question on Section B

Ref. Code	Statement	Categories	Reference
B1	BIM as an integral part of the construction sector's future	BIM is Industry Trends	Arayici et al. (2011)
B2	Cloud-based technologies connected to BIM	Cloud-base BIM	Terol (2020)
B3	Accessibility to connected BIM of all project team members	Data Accessibility	Interscale (2020)
B4	Connected BIM to be used in building operations and maintenance	Connected BIM	Bentley Systems (2020)
B5	Connected BIM to be used in facility management		
B6	Connected BIM to be used in building lifecycle		
B7	Integration of BIM with other emerging technologies such as AR, VR, AI, IoT, etc	BIM Integration	BIM Forum (2020);
B8	Collaboration among project stakeholders	Open BIM	Eastman (2015)
B9	Standardized processes and procedures of BIM implementation	ISO19650	Terol (2020); CIDB (2020); Azhar (2011)
B10	International set of standards to BIM application		
B11	Government's support in BIM applications	Skill up professionals	Abbas, Din & Farooqui (2016)

3.3.4 Section C: Issues Encountered

Section C of the questionnaire consisted of open-ended questions that gave respondents the option to share their ideas and experiences. This section had three questions concerning the issues encountered in BIM's application and possible functions or features of BIM in future for improving the BIM's application in the construction industry, as illustrated in Table 3.3.

Table 3.3: Formulation of Question on Section C

Ref. Code	Questions
C1	Do u think there is sufficient adoption of BIM in the construction industry now? If not, which areas is most underutilized?
C2	What are the most important issues of BIM's application in the industry?
C3	What are other functions/ features of BIM you wish to have in future?

3.3.5 Section D: Demographic Information

Section D of the questionnaire contained four questions aimed to gathering demographic information from the respondents. The questions included inquiring about the company's business activities, the respondents' profession, respondents' knowledge in BIM and working experience.

3.4 Sampling Design

Sampling design is the process of selecting a subset of the population for study and analysis. According to Kothari (2004), sampling design involves selecting a representative sample from a population to make inferences about the entire population. The next sub-sections explain the sampling method, sample size, and target respondents for this study.

3.4.1 Sampling Method

Convenience sampling was chosen as the method for data collection in this study. Convenience sampling is a non-probability sampling technique that involves selecting participants who are readily available and accessible to the researcher (Saunders et al., 2016). This method is often used in research where the population is difficult to reach or when there is limited time or resources available (Mackey & Gass, 2015).

3.4.2 Sample Size

This research utilized the Central Limit Theorem to determine an appropriate sample size. The CLT is a fundamental concept in statistics that states that as the sample size increases, the distribution of sample means approaches a normal distribution. Tennent (2013) suggestion that a minimum of 30 is a useful benchmark for the lowest number in any given category within a sample is a commonly accepted rule of thumb for statistical analysis. The study suggests that a sample size of 30 or more for each group is appropriate for independent variables such as the company's business activities, the profession of the respondents, respondent’s knowledge in BIM, and working experience.

3.4.3 Targeted Respondents

This study targeted construction practitioners from diverse business organizations, professions, work experience levels, and education levels who operate within the Malaysian construction industry. The research primarily focused on individuals who are based in Malaysia.

3.5 Data Analysis

Data analysis is a systematic and logical process of applying statistical procedures to interpret, evaluate, and model data. In this study, the collected data were quantitatively analysed using the Statistical Package for Social Sciences (SPSS) to identify meaningful relationships between variables. Various statistical methods, including the Cronbach's alpha reliability test, descriptive statistics, and inferential statistics, were employed to achieve this objective. Further elaboration of these methods will be provided in the subsequent subsection.

3.5.1 Reliability Test

The Cronbach's alpha reliability test was selected to assess the internal consistency and reliability of Section A and B of the questionnaire. This test computes a coefficient value between 0 and 1, and a value of 0.7 or above indicates that the items in the sections share covariance and are measuring the same underlying concept or construct.

3.5.2 Descriptive Statistics

Descriptive statistics is an approach used to summarize and present data in a more simplified and understandable form. Demographic data such as respondents' professions, main business activities, working experience, and BIM knowledge and skills were arranged using frequency distribution. Friedman's mean rank was used to determine the overall ranking of statements in each section of the questionnaire, based on their mean rank. Additionally, open-ended questions regarding issues encountered in BIM adoption in the Malaysian construction industry were presented graphically.

3.5.3 Inferential Statistics

Inferential statistics were used in this research to compare various groups, allowing for generalizations about the larger population of participants by using measures taken from a sample. This approach enables to make conclusions about the population based on a smaller sample by using statistical tests and procedures to estimate population parameters from sample data. As Cohen, Manion, and Morrison (2018) noted, inferential statistics help to infer or generalize from the sample to the population.

3.5.4 Chi-square test

The chi-square test is a statistical test used to determine whether there is a significant association between two categorical variables. It involves comparing observed frequencies with expected frequencies to see if any differences are statistically significant. The purpose of using the chi-square test for this research is to observe and compare the expected frequencies between (i) the agreement levels and the 13 current practice of BIM adoption and (ii) the importance levels and the 11 of future BIM adoptions. The chi-square test can be used for various purposes such as testing for independence, goodness of fit, and homogeneity. The formula for calculating the chi-square test:

$$\chi^2 = \Sigma (O - E)^2 / E$$

Where:

χ^2 = the chi-square test statistic

Σ = the sum of all observations

O = the observed frequency

E = the expected frequency

3.5.5 Kruskal Wallis H-Test

The Kruskal Wallis H-test is a statistical technique that examines whether there are significant differences in perceptions among multiple independent groups based on a continuous or ordinal dependent variable. In this study, the Kruskal Wallis H-test was utilized to investigate whether there were any significant differences in perceptions among different groups of participants based on their main business activities, professions, knowledge in BIM, and working experience. The null hypothesis is rejected and the research hypothesis is accepted with confidence if the p-value is less than 0.05. The results were then compared to prior literature to identify similarities, novel discoveries, or to reinforce established theories.

3.6 Research Ethics

Respondents were given the option to participate voluntarily in the questionnaire survey, and they have the right to withdraw their participation at any time. The confidentiality of respondents information is ensured, and their personal data will not be disclosed without their consent. The information collected will be solely used for this research. Prior to submitting the questionnaire survey, respondents were advised to review the consent of participation and UTAR privacy notice.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

This chapter begins with a brief summary of the background of the 206 respondents to the questionnaire survey. The reliability of the questionnaire construct is then tested using Cronbach's Alpha Reliability Test. The analyzed data are tested with the Friedman Test and Kruskal Wallis-H test to determine significant differences in current practices and the future of BIM adoption based on companies' business activities, profession, and working experience. The final section discusses the current practices of BIM adoption, the future of BIM adoption, and the issues associated with BIM adoption in the Malaysian construction industry based on the analysis of results.

4.2 Respondent’s background

The survey lasted about four weeks from 1 February 2023 to 27 February 2023. A total of 300 invitations to participate questionnaires survey were sent through email, MS teams and personal contacts and 206 sets of questionnaires were received. It is equivalent to 68.67%. Table 4.1 summarised the profile of the respondents. Majority of respondents (29%) are currently attached to consultant firms. Nearly half of the respondents (42%) are quantity surveyors by profession, almost two-thirds (67%) of the respondents have over two years of working experience in the construction industry. In addition, more than two-third (68.1%) of the respondents self-rated their knowledge and skills in BIM is fair and good.

Table 4.1: Demographic Information of Respondents (N=206)

Demographic Characteristics	Frequency (*n*)	Percentage (%)
Company's Business Activities		
Developer	35	16.9
Consultant	60	29.0
Contractor	44	21.3
Sub-contractor	36	17.4
Supplier	31	15.4
Profession		
Architect	39	20.2
Civil & Structural Engineer	34	16.4
Mechanical & Electrical Engineer	38	17.9
Quantity Surveyor	87	42.0
Charted Builder	8	3.5
Knowledge & Skills in BIM		
Very Poor	12	5.8
Poor	54	26.1
Fair	107	52.2
Good	33	15.9
Working Experience		
Less than 2 years	69	33.3
At least 2 years, but less than 5 years	115	55.6
At least 5 years, but less than 10 years	17	8.7
At least 10 years, but less than 20 years	5	2.4

4.3 Reliability Analysis

The Cronbach's alpha reliability test of the overall questionnaire show a reliability coefficient of 0.946 to both Section A and B of the questionnaire, which indicates high internal consistency among the 13 and 11 items in the questionnaire respectively. The result suggests that the questionnaire is a reliable measure and the items in each section of the questionnaire are consistent with one another in the questionnaire construct.

Table 4.2: Cronbach's Alpha Reliability Test

Section of Questionnaire	**Number of Items**	**Cronbach's Alpha**
Section A:		
Current Practice of BIM adoption	13	0.946
Section B:		
Future of BIM adoption	11	0.946

4.4 Current Practices of BIM adoption in the Construction Industry

Table 4.3 shows the three top BIM practices are "create 2D drawings" (mean rank = 7.78), "allow the creator has the right of ownership over information" (mean rank = 7.44), and "3D visualisation" (mean rank = 7.31). However, the three least BIM practices are "to appropriate remuneration regarding to BIM services" (mean rank = 6.28), "accessible to BIM model by project team members only" (mean rank = 6.56) and "using available standards (eg: ISO 19650, BIM protocol, etc) for project management involved with BIM" (mean rank = 6.62). The differences were tested statistically significant with Friedman test (χ^2 (12) = 46.173, ρ = 0.000).

Table 4.3: Friedman Test of Current Practices of BIM Adoption (N=206, df=12)

Ref Code	Statements	Mean Rank	Chi-square	Asymp. sig
A1	We are using BIM tools to create 2D drawings	7.78	46.173	0.000
A9	We are using available standards to allow the creator has the right of ownership over information	7.44		
A3	We are using BIM tools to visualise a building in 3D	7.31		
A7	We are using available standards to consider the issue of contractual obligations	7.26		
A8	We are using available standards to define the information technology related obligations	7.20		
A10	We are using available standard to protect the valuable personal information	7.18		
A2	We are using BIM tools to create 3D drawings	7.12		
A11	We are using available BIM standards (eg: ISO19650, BIM protocol, etc) to support BIM management	6.80		
A4	We are using BIM tools to monitor the entire building lifecycle	6.75		
A13	Our BIM models are editable by project team members only	6.70		
A5	We are make use of available standards for project management involved with BIM (eg: ISO19650, BIM protocol, etc)	6.62		
A12	Our BIM models are accessible to project team members only	6.56		
A6	We are using available standards to agree the appropriate remuneration regarding to BIM services	6.28		

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

4.4.1 Contracting Business Adopts BIM More than Others

Table 4.4 shows the extracts of statistically significant different items of BIM adoption according to the business activities tested with Kruskal Wallis-H test. The most using of BIM “to create 3D drawings” is consultant (mean rank = 115.53), while the most using of “3D visualisation and monitor the building life cycle is by contractor” (mean rank = 121.53 and 123.28 respectively). Other BIM adoption according to the company's business is available in Appendix B.

Table 4.4: Differences of Current Practices of BIM Adoption According Companies Business Activities

No	**Null Hypothesis**	**Mean Rank**					**Asymp. Sig.**
		Developer	**Consultant**	**Contractor**	**Sub-contractor**	**Supplier**	
A2	We are using BIM tools to create 3D drawings	113.78	115.53	113.70	90.97	68.74	0.001
A3	We are using BIM tools to visualise a building in 3D	113.35	115.23	121.53	83.58	67.27	0.000
A4	We are using BIM tools to monitor the entire building lifecycle	101.60	114.14	123.28	77.82	87.19	0.002

4.4.2 Architect Adopts BIM More than Others

Table 4.5 shows the extracts of statistically significant different items of BIM adoption according to the profession tested with Kruskal Wallis-H test. The most "using available standards to consider the issue of contractual obligations", "define the information technology related obligations", and "allow the creator has the right of ownership over information" is by architect (mean rank = 124.62, 120.87, and 118.50 respectively). Other BIM adoption according to the profession is available in Appendix C.

Table 4.5: Differences of Current Practices of BIM Adoption According Profession

No	Null Hypothesis	Mean Rank					Asymp. Sig.
		Architect	C&S Engineer	M&E Engineer	Quantity Surveyor	Chartered Builder	
A7	We are using available standards to consider the issue of contractual obligations	124.62	81.85	77.63	112.64	47.14	0.000
A8	We are using available standards to define the information technology related obligations	120.87	81.56	86.86	110.44	44.14	0.000
A9	We are using available standards to allow the creator has the right of ownership over information	118.50	83.69	83.58	112.02	43.43	0.000

4.5 Future of BIM adoption in the Construction Industry

The three top future of BIM adoptions are “BIM as an integral part of the construction sector’s future” (mean rank = 7.14), “connected BIM to be used in facility management” (mean rank = 6.29), and “connected BIM to be used in building lifecycle” (mean rank = 6.22). However, the least choices of future of BIM adoption is “Government's support in BIM applications” (mean rank = 5.39), “international set of standards to BIM application” (mean rank = 5.54), and “standardized processes and procedures of BIM implementation” (mean rank = 5.71). The differences were tested statistically significant with Friedman test (χ^2 (10) = 62.122, ρ = 0.000).

Table 4.6: Friedman Test of Future of BIM Adoption (N=206, df=10)

Ref Code	Statements	Mean Rank	Chi-square	Asymp. sig
B1	BIM as an integral part of the construction sector's future	7.14	62.122	0.000
B5	Connected BIM to be used in facility management	6.29		
B6	Connected BIM to be used in building lifecycle	6.22		
B7	Integration of BIM with other emerging technologies such as AR, VR, AI, IoT, etc	6.16		
B2	Cloud-based technologies connected to BIM	6.09		
B8	Collaboration among project stakeholders	5.94		
B3	Accessibility to connected BIM of all project team members	5.78		
B4	Connected BIM to be used in building operations and maintenance	5.74		
B9	Standardized processes and procedures of BIM implementation	5.71		
B10	International set of standards to BIM application	5.54		
B11	Government's support in BIM applications	5.39		

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

4.5.1 Consultants perceived Future of BIM Adoption is More Important than Others Business Sectors

Table 4.7 shows the extracts of statistically significant different items of future of BIM adoption according to the business activities tested with Kruskal Wallis-H test. Consultants perceived “BIM as an integral part of the construction sector's future” (mean rank = 122.59), “Cloud-based technologies connected to BIM” (mean rank = 120.80, “Accessibility to connected BIM of all project team members” (mean rank = 123.49), and “Connected BIM to be used in facility management” (mean rank = 122.30). Other future of BIM adoption according to the company's business is available in Appendix D.

Table 4.7: Differences of Future of BIM Adoption According Companies Business Activities

Null Hypothesis	Mean Rank				
	Developer	Consultant	Contractor	Sub-contractor	Supplier
BIM as an integral part of the construction sector's future	98.67	122.59	113.57	98.47	64.32
Cloud-based technologies connected to BIM	96.72	120.80	111.91	102.49	67.69
Accessibility to connected BIM of all project team members	93.76	123.49	109.57	102.76	69.00
Connected BIM to be used in facility management	99.08	122.30	114.18	97.32	64.87

4.5.2 Quantity Surveyors perceived Future of BIM Adoption is More Important than Others Profession

Table 4.8 shows the extracts of statistically different items of future of BIM adoption according to the profession tested with Kruskal Wallis-H test. Quantity Surveyors perceived "BIM as an integral part of the construction sector's future" (mean rank = 117.14), "Accessibility to connected BIM of all project team members" (mean rank = 116.00), and "Government support in BIM applications"(mean rank = 111.37) are more likely than other professionals. Other future of BIM adoption according to the profession is available in Appendix E.

Table 4.8: Differences of Future of BIM Adoption According Profession

No	Null Hypothesis	Mean Rank					Asymp. Sig.
		Architect	C&S Engineer	M&E Engineer	Quantity Surveyor	Chartered Builder	
B1	BIM as an integral part of the construction sector's future	104.38	91.06	73.41	117.14	67.71	0.000
B3	Accessibility to connected BIM of all project team members	100.53	95.37	73.95	116.00	76.79	0.002
B11	Government's support in BIM applications	120.76	71.12	90.38	111.37	64.64	0.000

4.5.3 Construction Practitioners with At least 6 years or More Working Experience perceived Future of BIM Adoption is More Important than Others

Table 4.9 shows the extracts of statistically significant different items of future of BIM adoption according to the working experience tested with Kruskal Wallis-H test. Those with 6-10 years of working experience perceived "Integration of BIM with other emerging technologies such as AR, VR, AI, IoT, etc" (mean rank = 139.42), and "Government's support in BIM applications" (mean rank = 137.28) are more likely than other groups.

Table 4.9: Differences of Future of BIM Adoption According Years of Experience

No	Null Hypothesis	Mean Rank				Asymp. Sig.
		Less than 2 years	2-5 years	6-10 years	11-20 years	
B7	Integration of BIM with other emerging technologies such as AR, VR, AI, IoT, etc	101.67	98.60	139.42	132.90	0.028
B11	Government's support in BIM applications	88.78	106.25	137.28	142.50	0.004

4.6 Issues Encountered

4.6.1 Design is most underutilized to BIM adoption

The top 5 construction areas underutilised BIM are design (36%), cost estimation (23%), site analysis (19%), supply chain management (13.5%) and operation and maintenance (9%).

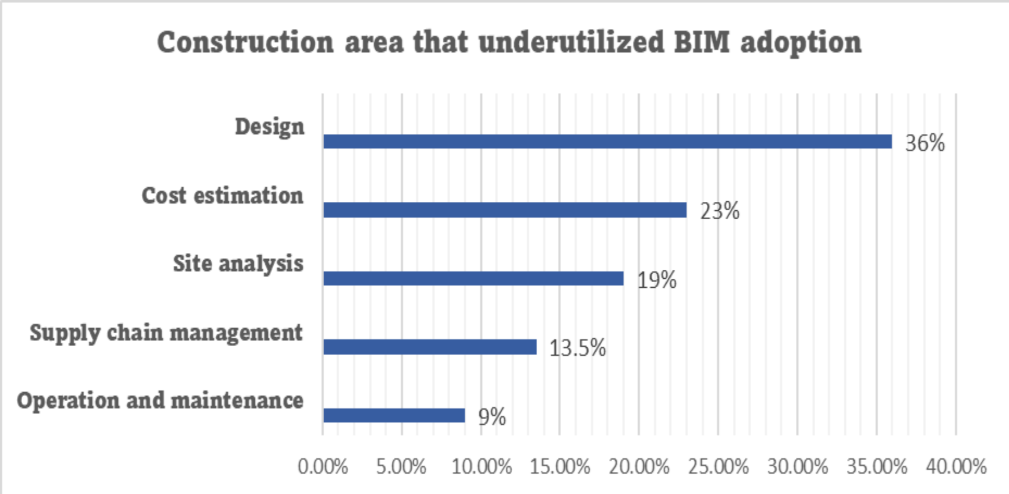

Figure 4.1: Top 5 Construction Areas that underutilized BIM adoption

4.6.2 High cost is most important issue to BIM’s application in the industry

The top 5 issues of BIM’s application are high cost (33.5%), lack of experience (28%), law issues (21.5%), resistance to change (10.5%), and project size (7%).

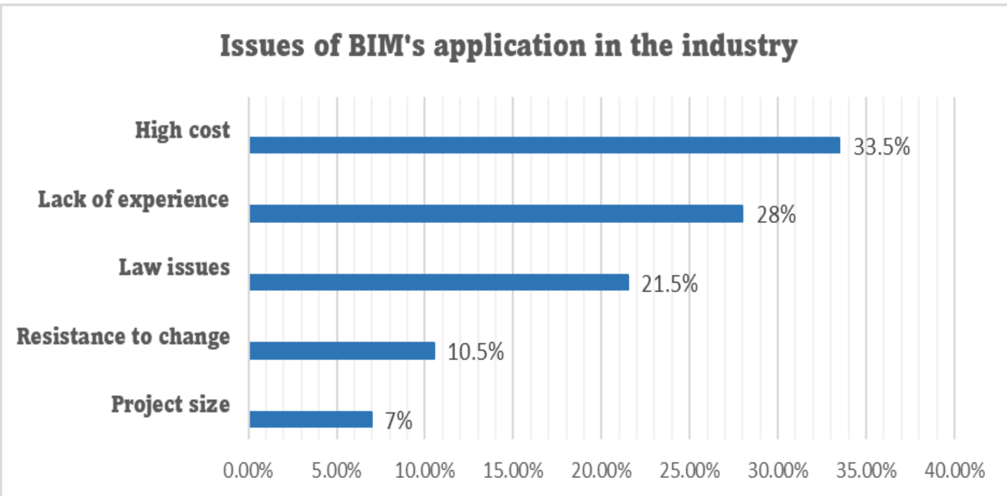

Figure 4.2: Top 5 Issues of BIM’s application in the Industry

4.6.3 More automation is most important functions to BIM in the future

The top 5 functions and features of BIM in the future are more automation (36%), cost control (27%), real time collaboration (19.5%), project visualization (13.5%), and safe constructionability (4.5%).

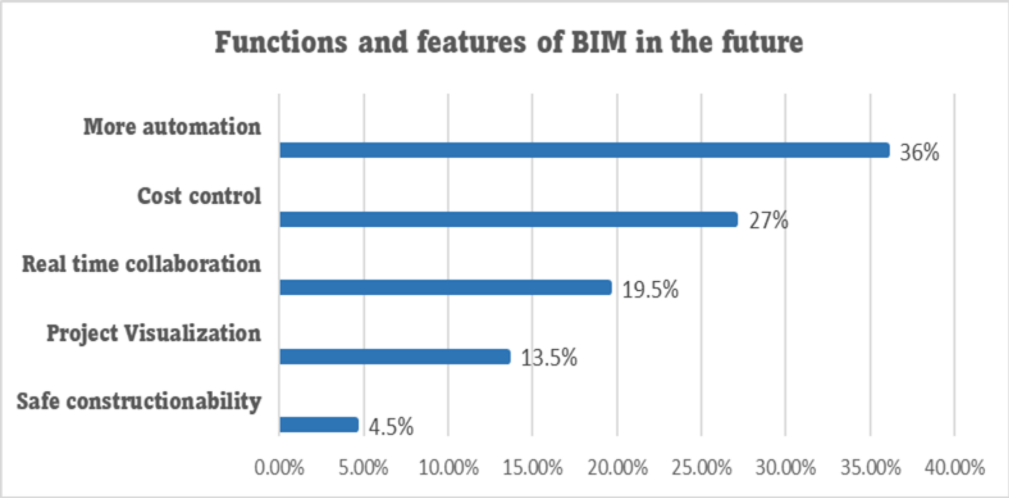

Figure 4.3: Top 5 of Functions and Features of BIM in the Future

4.7 Discussion

The following section presents the analysed result is discussed in three distinct sections. The first section encompasses the prevalent BIM practices employed by practitioners, with authoring being the most widely utilized, and contractors and architects primarily adopting BIM for current practices.. The second section scrutinizes the perception of consultants regarding the significance of BIM implementation, whereas quantity surveyors consider it crucial for the prospective adoption of BIM in the Malaysian construction industry. Finally, the last section addresses the issues linked with BIM adoption.

4.7.1 Current Practices of BIM Adoption in the Malaysian Construction Industry

(a) Authoring is the primary application for BIM

According to section 4.4 of the study, the most commonly used practice of BIM adoption among current practitioners is "using BIM tools to create 2D drawings."

Buildings can be created in detail using BIM tools, and these models can then be used to produce 2D drawings and plans for construction documentation (NBS, 2016) as literature reviewed in Section 2.3.1. These 2D drawings consists of floor plans, elevations, sections, and details. By exporting views and sheets from the 3D model, Revit, a well-known BIM tool, can produce 2D drawings (Autodesk, 2023) as literature reviewed in Section 2.3.1. It offers tools for producing 2D drawings and construction documents, as well as sophisticated 3D modelling capabilities. Eastman et al. (2011) discussed that BIM tools enable industry practitioners to track and manage changes to building designs throughout their lifecycle, ensuring that different parties participating in the project has access to the most up-to-date information as literature reviewed in Section 2.3.1. For instance, Navisworks is a BIM tools that is especially made for project management and collaboration during construction.

(b) The contracting business is the main adopter of BIM by business activities

In line with the overall findings of the Kruskal-Wallis H Test in Section 4.4.1, there was a significant difference, with respondents in the contracting services being rated higher than respondents in other business activities like development, consultation, subcontracting and supplying. This outcome demonstrates how BIM has an impact on contractor of construction goods in the industry.

Kumar, Jha, and Kumar (2019) claimed that BIM is a digital representation of a building's physical and functional attributes that aids in the creation and management of building information throughout the life cycle of the project as literature reviewed in Section 2.3.3. According to Al-Momani and Al-Qawasmi (2020), before beginning actual construction, BIM enables contractors to develop a comprehensive virtual model of a building, which can help them find and fix any problems as literature reviewed in Section 2.3.1. Therefore, BIM can assist contractors streamline the building process by allowing them to plan, manage, and execute projects more efficiently. In the end, this may result in cost savings and a quicker project completion time. Kamara, Anumba and Evbuomwan (2018) claimed that BIM is able to assist all parties engaged in the project, including contractors, subcontractors, and clients to communicate more effectively as literature reviewed in Section 2.3.1. This may result in wiser decision being made and a more fruitful building venture.

(c) Architect is the main adopter of BIM by profession

According to the Section 4.4.2, there are considerable disparities between architects, civil and structural engineers, mechanical and electrical engineers, quantity surveyors, and mechanical and chartered builder from a professional standpoint. The architects have reported a higher mean rank for the current practices of BIM adoption.

According to Sacks, Eastman, and Lee (2004), BIM tools may produce 3D models of buildings, giving architects, engineers, and other construction industry professionals a better visual representation of and more precise planning of the construction process as literature reviewed in Section 2.3.1. This indicates that the adoption of BIM can assist architects in producing visualisations of their designs that are more precise and lifelike. At the same time, BIM can assist clients in better understanding design concepts and making project-related decisions. Hamzeh (2019) mentioned that as more clients demand the use of BIM in the design and construction process, BIM adoption can give architects a competitive edge as literature reviewed in Section 2.3.1. BIM tool and process expertise may increase an architect's chances of winning projects and effectively completing them.

4.7.2 Future of BIM adoption in the Malaysian Construction Industry

(a) The importance of future BIM adoption was deemed significant by consultants by business activities

Based on the results from Section 4.5.1, consultants perceived future of BIM adoption as important compared to other professions. According to Huang et al. (2017), BIM technology has the ability to enhance stakeholder engagement and communication, which could lead the consultants to improved project outcomes as literature reviewed in Section 2.4.1. In addition, by giving more accurate and thorough information about a project, BIM can facilitate better decision-making, which can result in cost savings and enhanced project performance. Larsen and Sorensen (2016) acknowledged that BIM can make it easier to integrate different systems and procedures, such as project management, cost estimating, and scheduling, which can improve the efficiency of the entire project as literature reviewed in Section 2.4.1. Therefore, by enabling consultants to complete projects of a higher calibre on schedule and under budget, BIM adoption can also help consultants maintain their competitiveness in the market.

(b) The importance of future BIM adoption was deemed significant by Quantity Surveyors by profession

Based on the results of 4.5.2 quantity surveyors are perceived in terms of BIM is industry trends, and data accessibility are important in the future of BIM adoption. BIM adoption is seen as a crucial component in enhancing cooperation, communication, and project outcomes as the construction industry keeps evolving. Kilinc, Ergen and Giritli (2018) asserted that quantity surveyors who are responsible for overseeing costs and spending on construction projects, have become increasingly aware of the benefits of BIM technology as literature reviewed in Section 2.4.4. Quantity surveyors see the use of BIM as a significant industry trend with a number of advantages, such as greater quantity take-off accuracy, improved cost control, and better project coordination. On the other hand, Golizadeh, Asadi and Honarvar (2019) stated that quantity surveyors required access to accurate and extensive data to assure the accuracy of their cost estimates, which BIM technology can supply as literature reviewed in Section 2.4.3. Therefore, data accessibility is perceived as important by quantity surveyors.

Based on the results of 4.5.3, those practitioners with at least 6 years working experience perceived future of BIM adoption are more important. According to a study by Tah and Carr (2019), practitioners with moderate working experiences believed that BIM was a crucial technology for enhancing project outcomes and lowering risks. However, practitioners with less job experience may not be as conversant with BIM technologies. Giel, Issa and Olbina (2015) claimed that exposure to BIM technology frequently occurs through training and on-the-job experience, both of which may be more constrained for practitioners who are just entering the workforce.

4.7.3 Issues Encountered

(a) BIM adoption for design purposes is the most underutilized

Figure 4.1’s findings showed that design is most underutilized BIM adoption in the Malaysian construction industry. This finding supported by Zhang et al.

(2022) construction firms tend to use time-consuming and error-prone traditional design techniques like 2D drawings. Some construction firms might not fully comprehend how using BIM for design can increase design accuracy and decrease rework, for example, by enabling the creation and modification of 3D models in real-time.

On the other hand, construction firms could lack the knowledge or experience required to use BIM for design efficiently. BIM software can be complicated and call for specialised abilities and information that may not be easily accessible internally. The implementation of BIM in design may also face organisational and cultural obstacles. For instance, some construction firms could be averse to change or might not see the benefit in investing funds into new technologies.

(b) High Costing is perceived as the Most crucial challenge associated with BIM implementation

Figure 4.2's findings reveal that high costing is the most important issues of BIM's application in the industry. According to McGraw Hill (2020), due to the need for specialised technology, software, and skilled labour, BIM deployment can be expensive. Smaller firms or those with tighter finances may find it more difficult to cover these fees. McGraw Hill (2020) further discussed that there must be considerable adjustments made to current workflows and procedures in order to switch from conventional design and construction methods to BIM. However, this shift may be costly because it calls for either employing new staff with BIM expertise or providing existing staff with training. The expenses connected with this shift could increase the entire cost of implementing BIM.

Furthermore, although BIM has the potential to increase project efficiency and lower costs over time, the initial implementation expenses may discourage firms from implementing BIM in the short term. This may prevent BIM from being widely used and restrict the overall advantages it can bring to the industry.

(c) The most significant feature of BIM in the future is perceived to be its increased automation

Figure 4.3's findings indicate that more automation is indeed one of the most important functions of BIM in the future. The efficiency and precision of building design, construction, and operation might all be considerably increased with the use of BIM. By minimising manual tasks and errors, improving workflows, and boosting productivity, automation is essential to obtaining these advantages.

Fisher and Kunz (2019) asserted that BIM software can be used to automate repetitive operations and guarantee accurate and consistent drawings and blueprints. This minimizes the likelihood of mistakes and omissions, which might result in costly rework. Collaboration between various teams and stakeholders participating in a construction project is facilitated by BIM. Fisher and Kunz (2019) further explained that by ensuring that everyone is using the same accurate and current information, automation can help to further increase collaboration. Automation also can increase safety on construction sites by lowering the demand for physical labour and accident risk.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction

The findings and comments from the previous chapter are summarised and wrapped up in this chapter. It begins by taking a look at the achievement of the research's objectives and goals. Furthermore, the study's implications for academic, regulatory agencies, and the construction industry will be examined. The limitations of the research are then noted, and recommendations for future research are made in the concluding section.

5.2 Accomplishments

The following sections summarise the research objectives' accomplishments. These will serve as launching points for the conclusion in the following paragraph.

5.2.1 Objective 1 – To review the changing narratives of BIM

The first objective is achieved by scrutinizing literature reviews, standard documents, organizational reports, and documents to identify the current practices and future of BIM adoption. The literature reviews revealed three categories of current practices of BIM adoption, which consists of authoring, standardisation, and accessibility. In order to fully adhere to changing narratives of BIM, the literature reviews also revealed eight categories of future of BIM adoption, which includes BIM is industry trends, cloud-base BIM, data accessibility, connected BIM, BIM integration, open BIM, ISO 19650, and skill up professionals. In addition, the survey exposed that authoring is the most agreed by the practitioners to current practices BIM adoption. However, BIM is industry trends is perceived as the most important to future of BIM adoption among respondents.

5.2.2 Objective 2 - To explore the current adoption of BIM in the Malaysian construction industry

The second objective is accomplished by evaluating the level of agreement or disagreement of respondents regarding the three categories of current BIM adoption, which were identified through a thorough analysis of published literature. The outcome of the Friedman test uncovered that the current practices of BIM adoption is using BIM tools to create 2D drawings. Moreover, the construction practitioners are using available standards to allow the creator has the right of ownership over information. Besides, BIM tools are used by the construction practitioners to visualise a building in 3D. Conversely, the Kruskal Wallis-H test discovered that current of BIM adoption is most prominent among architects within the Malaysian construction industry. It is possible that this suggests current of BIM adoption are more impact on architects compared to other professions. On the other hand, the result show that contractors are less agreed with using BIM tools to create 3D drawings. Meanwhile, contractors are more agreed with using BIM tools to visualise a building in 3D and monitor the entire building lifecycle. This may imply that BIM allow contractors to overseeing construction projects more comprehensively and dynamically.

5.2.3 Objective 3 - To anticipate the future of BIM adoption in the Malaysian construction industry

The third objective is achieved by evaluating the levels of engagement of various statements about future of BIM adoption. The outcome of the Friedman test reveals that BIM as an integral part of the construction sector’s future. Besides, connected BIM to be used in facility management and building lifecycle are perceived as important in future of BIM adoption. Nevertheless, the Kruskal Wallis test uncovered that consultant perceived that accessibility to connected BIM of all project team members is most important in future of BIM adoption. Moreover, quantity surveyors perceived that government’s support in BIM applications is least important in the future of BIM adoption. Furthermore, construction practitioners with at least 6 years working experience perceived that BIM integration is also important in future of BIM adoption.

5.3 Conclusion

In a nutshell, all the research objectives were justified the achievement of the research aim: the future of BIM adoption are BIM as an integral part of the construction sector's future, cloud-based technologies connected to BIM and accessibility to connected BIM of all project team members.

5.4 Research Implications

The findings are anticipated to serve as an indicator of BIM adoption in the Malaysian construction industry, enabling a better understanding of the future of BIM adoption. Moreover, the research implications for the construction industry, regulatory bodies, and academia are examined.

The practical impact of this study is that it enables industry practitioners to foresee future of BIM adoption. In particular, this study enables construction firms the capacity to acknowledge and highlight the future of BIM adoption. Companies can utilise the findings in this way to address the current BIM adoption in order to uncovered the future. The findings of this study can also assist the top executives of construction firms in creating a strategic plan to advance the BIM adoption throughout their companies.

The findings will be useful to regulatory agencies in establishing policies that will make it easier for industry to adopt new technology, which will hasten national development. In addition, the study's findings assist regulatory bodies in determining the degree of skills and knowledge of BIM adoption in the Malaysian construction industry. This will make it easier to improve the BIM strategy plan and implement the necessary improvements to raise the industry's overall BIM adoption level.

On the other hand, the findings also enable academics to more fully comprehend practitioners' demands for better design and revised BIM-related training. As a result, a more pertinent educational programme can be created to provide the future workforce that the construction industry will require. This supports academic advancements in research, innovation, and curriculum creation.

5.5 Research Limitations

This research is completely exploratory as the future of BIM adoption is a relatively new concept. To predict future conditions, it is necessary to extrapolate from the available data and consult with relevant specialist groups. However, this may result in response bias and misunderstandings, where respondents provide inaccurate or misleading responses to questions due to a lack of complete understanding of BIM adoption. Moreover, the total number of chartered builder professionals is lower than the recommended sample size of 30. Lastly, the findings of this study are specific to the construction sector in Malaysia and cannot be generalised to other regions or industries.

5.6 Research Recommendations

The possibility of the following research was opened up by the reflection on the limitation depicted above. The lesson learnt from this was that future researchers should seek out more volunteers in order to collect a significant amount of data. In this manner, updated knowledge might be learned through the study. Furthermore, there is a need for further investigation to assess the level of significance of the identified issues from the perspective of various job roles, such as project managers, construction managers, site supervisors, and other relevant stakeholders. This would enable a more comprehensive understanding of the issues faced by different professionals in the construction industry, which could inform the development of targeted solutions and interventions to address these challenges. This analysis is crucial since each identified future of BIM adoption can be viewed as having a different degree by each stakeholder. In the future, it is advised to do an intensity analysis of the identified BIM adoption from the perspectives of various employment positions.

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APPENDICES

Appendix A: Questionnaire

THE FUTURE OF BUILDING INFORMATION MODELING: AN EXPLORATORY STUDY

Dear Sir/Madam/Mr/Ms,

Good day !

I'm a final year student from Bachelor of Science (Hons) Quantity Surveying in Universiti Tunku Abdul Rahman (UTAR). I wish to invite you to participate in my final year project entitled "The Future of Building Information Modeling: An Exploratory Study".

This questionnaire consists of 4 sections which may take you 10-15 minutes to complete.
Section A: Current practice of BIM
Section B: Future of BIM
Section C: Ideas or experience in application of BIM
Section D: Demographic data

Your contribution to this research is much appreciated. Thank you very much for your time to fill up this questionnaire as every single contribution would greatly mean a lot to this study. All the information that provided will be strictly keep private and confidential, without reveal to any third parties without consent. The information which includes personal information will be only used for this research study. Participant is voluntary participate in this research study, and you are allowed to withdraw your participation from this research study anytime. Participant may be contacted through the email provided if the information given has certain errors or issues.

Lastly, a copy of response will be delivered to the email that you provided.

If you have any inquiries, please do not hesitate to contact me at chuaxj@1utar.my.

Thank you.

Yours faithfully,

Chua Xin Jie
Bachelor of Science (Hons) Quantity Surveying
Universiti Tunku Abdul Rahman (UTAR) Sungai Long Campus

Section A: Current Practices of BIM Adoption

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

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
We are using BIM tools to create 2D drawings.					
We are using BIM tools to create 3D drawings.					
We are using BIM tools to visualise a building in 3D.					
We are using BIM tools to monitor the entire building lifecycle.					
We are make use of available standards for project management involved with BIM (eg: ISO 19650, BIM protocol, etc).					
We are using available standards to agree the appropriate remuneration regarding to BIM services.					
We are using available standards to consider the issue of contractual obligations.					
We are using available standards to define the information technology related obligations.					
We are using available standards to allow the creator has the right of ownership over information.					
We are using available standards to protect the valuable personal information.					
We are using available standards (eg: ISO 19650, BIM protocol, etc) to support BIM management.					
Our BIM models are accessible to project team members only.					
Our BIM models are editable by project team members only.					

Section B: Future of BIM Adoption

How important of the following statements?

	Not at all important	Slightly important	Important	Fairly Important	Strongly Important
BIM as an integral part of the construction sector’s future.					
Cloud-based technologies connected to BIM.					
Accessibility to connected BIM of all project team members.					
Connected BIM to be used in building operations and maintenance.					
Connected BIM to be used in facility management.					
Connected BIM to be used in building lifecycle.					
Integration of BIM with other emerging technologies such as AR, VR, AI, IoT, etc					
Collaboration among project stakeholders.					
Standardized processes and procedures of BIM implementation.					
International set of standards to BIM application.					
Government’s support in BIM applications.					

<u>Section C: Ideas or experience in application of BIM</u>

Building Information Modeling (BIM) has established itself to be a powerful process for design and construction teams. However, the industry's application of BIM throughout the construction lifecycle is still relatively fragmented.

Please share your ideas/ experience in the following questions.

C1) Do you think there is sufficient adoption of BIM in the construction industry now? If not, which areas is most underutilized?

C2) What are the most important issues of BIM's application in the industry?

C3) What are other functions/features of BIM you wish to have in future?

<u>Section D: Demographic Information</u>

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) 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 chuaxinjie00@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

Appendix B: Differences of Current Practices of BIM adoption According Companies Business Activities

No	Null Hypothesis	Mean Rank					Asymp. Sig.
		Developer	Consultant	Contractor	Sub-contractor	Supplier	
A1	We are using BIM tools to create 2D drawings	120.24	110.34	109.64	96.18	70.84	0.004
A2	We are using BIM tools to create 3D drawings	113.78	115.53	113.7	90.97	68.74	0.001
A3	We are using BIM tools to visualise a building in 3D	113.35	115.23	121.53	83.58	67.27	0.000
A4	We are using BIM tools to monitor the entire building lifecycle	101.6	114.14	123.28	77.82	87.19	0.002
A5	We are make use of available standards for project management involved with BIM (eg: ISO19650, BIM protocol, etc)	114.71	108.81	115.23	88.28	81.42	0.030
A6	We are using available standards to agree the appropriate remuneration regarding to BIM services	121.49	105.66	110.64	93.88	79.55	0.029

Appendix C: Differences of Current Practices of BIM adoption According Profession

No	Null Hypothesis	Mean Rank					Asymp. Sig.
		Architect	C&S Engineer	M&E Engineer	Quantity Surveyor	Chartered Builder	
A1	We are using BIM tools to create 2D drawings	121.69	82.87	78.96	110.86	71.36	0.001
A2	We are using BIM tools to create 3D drawings	119.21	83.22	85.95	108.75	70.00	0.008
A3	We are using BIM tools to visualise a building in 3D	118.09	90.06	80.93	110.76	44.43	0.001
A4	We are using BIM tools to monitor the entire building lifecycle	117.53	94.79	82.79	107.48	54.86	0.010
A5	We are make use of available standards for project management involved with BIM (eg: ISO19650, BIM protocol, etc)	115.94	85.19	88.79	108.37	65.57	0.024
A6	We are using available standards to agree the appropriate remuneration regarding to BIM services	122.68	79.71	93.93	106.67	52.71	0.002
A7	We are using available standards to consider the issue of contractual obligations	124.62	81.85	77.63	112.64	47.14	0.000
A8	We are using available standards to define the information technology related obligations	120.87	81.56	86.86	110.44	44.14	0.000

A9	We are using available standards to allow the creator has the right of ownership over information	118.50	83.69	83.58	112.02	43.43	0.000
A10	We are using available standard to protect the valuable personal information	121.56	85.13	85.64	108.61	52.64	0.002
A12	Our BIM models are accessible to project team members only	124.03	86.00	80.43	106.42	92.00	0.006
A13	Our BIM models are editable by project team members only	117.84	84.07	87.50	106.59	90.93	0.049

Appendix D: Differences of Future of BIM adoption According Companies Business Activities

No	Null Hypothesis	Mean Rank					Asymp. Sig.
		Developer	Consultant	Contractor	Sub-contractor	Supplier	
B1	BIM as an integral part of the construction sector's future	98.67	122.59	113.57	98.47	64.32	0.000
B2	Cloud-based technologies connected to BIM	96.72	120.80	111.91	102.49	67.69	0.001
B3	Accessibility to connected BIM of all project team members	93.76	123.49	109.57	102.76	69.00	0.001
B4	Connected BIM to be used in building operations and maintenance	98.68	115.69	119.69	97.28	70.13	0.002
B5	Connected BIM to be used in facility management	99.08	122.30	114.18	97.32	64.87	0.000
B6	Connected BIM to be used in building lifecycle	98.17	118.10	118.64	91.74	74.08	0.002
B11	Government's support in BIM applications	121.56	101.25	112.58	81.56	99.40	0.038

Appendix E: Differences of Future of BIM adoption According Profession

No	Null Hypothesis	Mean Rank					Asymp. Sig.
		Architect	**C&S Engineer**	**M&E Engineer**	**Quantity Surveyor**	**Chartered Builder**	
B1	BIM as an integral part of the construction sector's future	104.38	91.06	73.41	117.14	67.71	0.000
B2	Cloud-based technologies connected to BIM	103.07	98.31	77.99	113.10	64.21	0.008
B3	Accessibility to connected BIM of all project team members	100.53	95.37	73.95	116.00	76.79	0.002
B4	Connected BIM to be used in building operations and maintenance	118.84	84.38	84.28	108.67	76.29	0.012
B5	Connected BIM to be used in facility management	113.72	79.15	82.43	112.82	85.00	0.004
B6	Connected BIM to be used in building lifecycle	112.21	84.56	76.37	113.18	94.50	0.003
B7	Integration of BIM with other emerging technologies such as AR, VR, AI, IoT, etc	105.21	84.34	82.86	114.02	83.93	0.014
B8	Collaboration among project stakeholders	109.31	93.37	79.99	110.05	85.00	0.049
B9	Standardized processes and procedures of BIM implementation	115.51	84.13	85.87	110.55	61.64	0.007

B10	International set of standards to BIM application	117.87	73.99	91.21	110.32	73.29	0.003
B11	Government's support in BIM applications	120.76	71.12	90.38	111.37	64.64	0.000