BIM-ENABLED COLLABORATION AND COMMUNICATION IN THE CONSTRUCTION INDUSTRY: A COMPARATIVE STUDY OF THE PRACTICES AMONG CONSTRUCTION PRACTITIONERS

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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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ABSTRACT

Building Information Modelling (BIM) has reshaped the global construction industry, with strong adoption in countries like the UK, Germany, and Singapore. In Malaysia, BIM implementation is growing, especially in high-value public projects. However, challenges persist, particularly in stakeholder collaboration and communication. This study aims to compare the practices of various construction practitioners in BIM execution, focusing on how they engage in collaboration and communication. The literature review showed that construction professionals use BIM in different ways, highlighting the critical importance of integrated collaboration and effective communication across disciplines. This study adopts a pragmatist philosophy, emphasising a mixed-method approach through a questionnaire comprising both closed-ended and open-ended sections. Data was collected through an online survey, with a total of 137 valid responses from architects, engineers, quantity surveyors, and chartered builders across Malaysia. The data were analysed using descriptive statistics and inferential tests, including Cronbach's alpha, Kruskal-Wallis, and Spearman's correlation. Findings reveal that BIM is most used by quantity surveyors and junior-level practitioners. Collaboration is strongly prioritised by engineers and executive-level professionals, while communication is more common among junior practitioners, especially in design coordination. A moderate-to-strong correlation between collaboration and communication indicates their interdependence. Meetings and discussions were the most frequent BIM-enabled activities, and higher BIM proficiency corresponded with deeper BIM engagement. In conclusion, the study contributes to understanding how BIM is practised among Malaysian construction practitioners, highlighting the need for strategies to enhance collaboration and communication. Future research could explore BIM adoption in SMEs, infrastructure projects, and behavioural factors influencing implementation.

Keywords: Building Information Modelling; Collaboration; Communication; Malaysian Construction Industry; BIM Practices

Subject Area: TH1-9745 Building construction

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LIST OF SYMBOLS / ABBREVIATIONS

AEC	Architecture, Engineering and Construction
BIM	Building Information Modelling
CAD	Computer-Aided Design
CDE	Common Data Environment
CIDB	Construction Industry Development Board
CITE	Construction Industry Trading Electronically
FM	Facility Management
HVAC	Heating, Ventilation, and Air Conditioning
IFC	Industry Foundation Classes
ISO	International Organisation for Standardisation
MR	Mixed Reality
PWD	Public Works Department
QS	Quantity Surveyor
RFID	Radio Frequency Identification
RICS	Royal Institution of Chartered Surveyors
SME	Small and Medium Enterprise
SPSS	Statistical Package for Social Sciences
UK	United Kingdom

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CHAPTER 1

INTRODUCTION

1.1 Background

Building Information Modelling (BIM) originated from the early development of computer-aided design (CAD) systems in the 1960s (Eastman, 1975). These early CAD systems enabled the creation of digital drawings and geometric models, laying the foundation for BIM (Eastman, 1975). Over time, BIM further evolved with the advent of personal computing and 3D modelling technologies, which initially gained traction in the aerospace, automotive, and shipbuilding industries. A significant milestone in BIM's development occurred in the 1990s with the release of AutoCAD by Autodesk, incorporating solid modelling capabilities (Eastman, 2011). This allowed architects to express their creativity more freely. From 2000 onwards, the architectural, engineering, and construction (AEC) industry was transformed, largely driven by the technological advancements of Autodesk Revit, which enabled 3D modelling of building components (Eastman, 2011). Today, BIM is a standard practice in the AEC industry, addressing many challenges related to information sharing and coordination (Baddeley and Chang, 2015). Additionally, Holness (2008) describes BIM as a comprehensive database with fully integrated and interoperable information, accessible to construction practitioners, including owners, throughout a facility's lifecycle.

Globally, BIM adoption has progressed significantly in both developing and developed countries. In the UK, the use of at least BIM Level 2 is mandated for all state-funded projects since 2016. The adoption rate stands at 62% for small businesses and 80% for large businesses (Steers, 2021). Germany also shows strong adoption of BIM, with 70% of construction companies using it at various levels. Since 2017, the German government has required BIM for projects valued over €100 million, and starting from 2020, it has become compulsory for all public contracts, including federal infrastructure projects. France, while lacking a single BIM law, has seen 50 to 60% of leading companies achieve BIM Level 2. In Singapore, BIM e-submission has been mandatory for all project submissions since 2016. These trends reflect a broader shift within the construction industry towards integrating technology and transitioning from traditional methods to BIM-based approaches.

In Malaysia, the government has actively promoted the adoption of Building Information Modelling (BIM) through several strategic initiatives and official mandates. First of all, the Malaysian Public Works Department (PWD) has successfully integrated BIM into 455 projects across various stages of planning, design, and construction between 2021 and 2024 (Riza, 2024). Under the PWD Strategic Plan 2021-2025, the department aims to implement BIM in 90% of projects valued at more than RM10 million by 2025 (Riza, 2024). Additionally, beginning in August 2024, the National Development Action Council, with support from the Construction Industry Development Board (CIDB), has mandated the use of BIM for all major construction projects valued at RM10 million and above (Kaur, 2024). These efforts mark a significant step toward the digital transformation of the construction industry, leading to improvements in project delivery and quality.

Most projects currently use BIM Level 2, but this often proves insufficient due to its limitations in multidisciplinary coordination and integration. Azhar (2011) explains that BIM Level 2 can still result in fragmented information, as individual models are created by separate team members, leading to potential data loss during exchanges. Meanwhile, it can be seen that many countries are making significant efforts to achieve BIM Level 3, aiming to produce a fully integrated BIM environment. This allows multiple disciplines to work simultaneously, with changes made by one discipline being reflected in real-time for others. Achieving BIM Level 3 is a challenging journey requiring substantial investment, technological advancements, and a high level of communication and collaboration among all parties involved. This research aims to examine BIM-enabled communication and collaboration, along with the practices among construction practitioners.

1.2 Problem statement

Effective construction processes rely heavily on collaboration efforts among all parties (Tessema, 2008). Additionally, open, honest, and efficient communication is also crucial for the successful delivery of construction projects (Adnan, et al., 2012). However, in traditional project procurement, fragmentation often occurs due to the sequential process and the separation between the construction and design teams. This fragmentation leads to delayed response, misinterpretation, design clashes, and increased reworks. Migilinskas et al. (2013) added that the project information is usually shared through emails, phone calls, and face-to-face meetings, which increase the risk of information loss and misunderstandings. The absence of a centralised data environment further worsens this issue, as project information is scattered, and real-time updates cannot be efficiently managed.

In this context, BIM is intended to provide an integrated approach by enabling various stakeholders to contribute their works and communicate effectively throughout the entire project life cycle (Wang, et al., 2022). This is supported by features such as 3D visualization, clash detection, and cloud technology available in BIM, which enhance collaboration among multidisciplinary teams and reduce the likelihood of design errors (Cheng et al., 2016; Succar et al., 2012). Despite these advancements, BIM projects can still face collaboration and communication challenges, especially when stakeholders have different levels of BIM proficiency and use it without standardized protocols and processes (Cheng et al., 2016). For example, if the CDE is poorly managed or underutilized, it can lead to data inconsistencies, version control problems, and fragmented communication (Succar et al., 2012).

Although BIM offers clear benefits in improving collaboration and communication, its implementation remains challenging. Several studies show its barrier includes lacking education and training programs (Agirbas, 2020;). Other than lacking BIM programs, it was highlighted that reluctance to embrace change, adherence to traditional work habits, and insufficient organisational support can also discourage BIM adoption (Olanrewaju, 2020). Furthermore, the lack of uniformity across different construction practitioners and contexts can lead to inefficiencies and missed opportunities for enhanced project outcomes (Evans, 2021). Although BIM has been shown to enhance project coordination and optimise costs, many small companies face difficulties in adopting the technology due to high initial costs and financial concerns (Ismail et al., 2021).

Existing research such as Georgiadou (2019), Babatunde et al. (2018), Elghaish et al. (2019), Becerik-Gerber et al. (2012) and Oraee et al. (2021) has explored the theoretical advantages, application and challenges of the BIM; however, there are a few key questions that have not been answered by the above research such as Is there any difference in utilising BIM by different construction practitioners? Is there any different impediment faced by the different construction practitioners in BIM execution? How do construction practitioners engage in collaboration and communication during BIM execution?

1.3 Research Aim

This research aims to conduct a comparative study of the practices employed by various construction practitioners in BIM execution, particularly on the engagement of collaboration and communication.

1.4 Research Objectives

In order to achieve the above-mentioned research aims, this research has established the following objectives to be accomplished:

1. To compare the practices of different construction practitioners in BIM execution.
2. To examine how practices of different construction practitioners engage the collaboration in BIM execution.
3. To study how practices of different construction practitioners engage the communication in BIM execution.

1.5 Research Method

This study adopts a mixed-method research design by incorporating a questionnaire survey consisting of both open-ended and closed-ended questions targeted at construction practitioners, including architects, engineers, quantity surveyors, and chartered builders. The collected data will be analysed quantitatively using relevant inferential statistical methods for the close-ended questions, and qualitatively on the open-ended questions.

1.6 Scope of Study

This research is conducted within Malaysia. The targeted respondents are construction practitioners who are actively involved in construction projects in Malaysia.

1.7 Report Structure

The research report is structured into five main chapters: Introduction, Literature Review, Methodology and Work Plan, Results and Discussion, and Conclusions and Recommendations.

Chapter 1 begins with the background of the study, followed by the problem statement, which highlights the issues related to BIM based on previous studies. Besides, the chapter also delineates the research aim, research objectives, explains the research method, delimit scope of the study, and provides an overview of the research structure.

Chapter 2 covers a brief description of BIM, particularly in elucidating the maturity levels. It examines the BIM practices by the different construction practitioners at different stages of project developments and constructions. The chapter also peruse the necessity of collaboration and communication in BIM execution. Finally, the literature review is summarised to present the content of the chapter and to establish a foundation for the subsequent chapters.

Chapter 3 outlines the research methodology used in this study including research philosophy, research approach as well as research strategies. Besides, the sampling design and process are discussed, explaining how various construction practitioners will be selected and how data will be collected to ensure a representative sample. The chapter also discusses the data analysis method, detailing any statistical methods used for analysis. Lastly, it also considers research ethics, discussing how confidentiality will be managed.

Chapter 4 presents and analyses the research findings. It begins with the demographic information of the respondents, followed by a reliability test to ensure the reliability of the collected data. Additionally, other statistical tests are used to assess the views of different respondent groups and the valuable relationships between variables. Finally, the discussion section explores the implications of these findings, considering their relevance to the research questions and existing literature.

Chapter 5 is the final chapter, which summarises the research and offers conclusions based on the findings. The chapter further connects the findings to the research objectives and aims. Furthermore, it also explores the implications of the research, discussing its theoretical contribution, practical applications and potential policy impacts. Lastly, the chapter acknowledges the limitations of the study and provides recommendations for future research including directions for those who wish to build upon this study.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The construction industry is witnessing a transformation with the advent of BIM, a technology designed to enhance project collaboration, communication, and overall productivity. This chapter examines the critical aspects of BIM, starting with its definition and progressing through BIM maturity levels, from basic to fully integrated processes. Following this, the chapter explores BIM practices among construction practitioners, including owners, architects, engineers, contractors, quantity surveyors, building merchants, specialist and facility managers, comparing their BIM workflows across different project phases. The collaboration and communication in BIM execution are discussed in terms of their application and benefits, followed by a summary of the literature review presented in a tabular format.

2.2 Building Information Modelling

Building Information Modelling (BIM) is a digital representation of physical and functional properties of a facility like buildings, bridges, roads, and others. BIM combines visual models with detailed project information, enabling the stakeholders to work on a shared platform that updates in real time and make informed decision (Wang et al., 2022). If a change is made to a building component, it will automatically update across all the disciplines such as architectural, structural, and M&E. Wang and Liu (2020) clarified that BIM goes beyond 3D modelling by integrating additional dimensions such as time (4D), cost (5D), sustainability (6D), and facility management (7D). These capabilities provide a comprehensive platform that supports the whole project lifecycle from initiation to completion.

Although BIM has roots tracing back to the 1970s (Eastman, 1975), many experts have realised that technology alone is not enough to ensure project success (RICS, 2014). As emphasised by RICS (2014), it is important to integrate technology with evolving interrelationships between people and processes for effective implementation. It requires project teams to communicate clearly, collaborate efficiently, and ensure proper coordination of project workflows.

2.3 BIM Maturity Level

In 2008, Mark Bew and Mervyn Richards developed the BIM maturity model to provide a structured framework addressing these critical interrelationships, leading to a more effective adoption of BIM in the industry (Richards, 2010; RICS, 2014). This Bew-Richards BIM maturity model defines BIM into four levels (0-3), starting with a paper-based, isolated approach and evolving into a fully collaborative, integrated, and interoperable model-based method (Richards, 2010; RICS, 2014).

2.3.1 BIM Maturity Level 0

At Level 0, projects and assets are operated and delivered using paper-based and two-dimensional (2D) information, resulting in inefficiencies (RICS, 2014). Additionally, Zieliński and Wójtowicz (2019) explain that this level involves using unmanaged Computer-Aided Design (CAD) to produce drawings and documents, relying on paper-based documentation, such as paper drawings or digital PDFs, to share project information.

2.3.2 BIM Maturity Level 1

This stage involves a combination of paper-based (2D) and 3D environments, including some type of Common Data Environment (CDE) to facilitate the storage and sharing of construction project information among the project team (Chudy and Gasparek, 2017; Dowd and Marsh, 2020). In this context, 2D CAD is used for drafting statutory approval documents and production information, while 3D CAD is used for conceptual work (Zieliński and Wójtowicz, 2019). Furthermore, CIDB (2016) emphasises that the use of 3D modelling is limited to a single discipline, without integration with other disciplines.

2.3.3 BIM Maturity Level 2

At Level 2, each discipline independently produces its own project information within a 3D environment, a concept known as discipline-centric proprietary BIM, or 'pBIM' (Dowd and Marsh, 2020). These models are enriched with additional data, such as specifications and dimensions for each component (Dowd and Marsh, 2020). This level is distinct from Level 1 as collaboration and exchange of information can be achieved between stakeholders through the use of middleware software that allows various models to interface with one another within the CDE, as well as perform monitoring or checking (Dowd and Marsh, 2020; Chudy and Gasparek, 2017; RICS, 2014).

2.3.4 BIM Maturity Level 3

Sackey et al. (2013) describe Level 3 as fully integrated 'iBIM', where a single collaborative model is shared among project stakeholders, enabling multiple disciplines to work on it at the same time. After that, Chudy and Gasparek (2017) explains that this approach allows stakeholders to access and modify the shared model in real-time, thereby reducing the possibility of errors. Figure 2.1 illustrates the four levels of BIM maturity, which represent the progression of BIM development from Level 0 to Level 3.

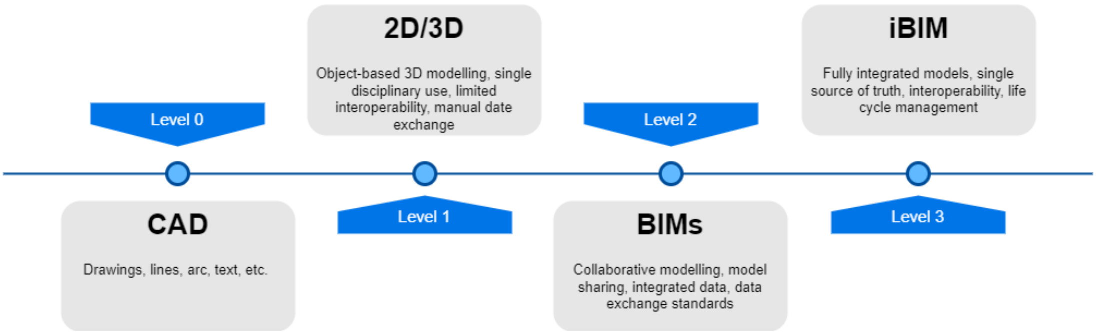

Figure 2.1: The BIM maturity levels (Adapted by author from Mervyn Richards' from Building Information Management: A Standard Framework and Guide to BS 1192

2.4 Practitioners in Construction Industry

In the construction industry, a practitioner is described as a professional involved in the entire project lifecycle, from planning through to handover and maintenance. This includes various roles such as owner, architect, engineer, contractor, quantity surveyor, specialist, and facility manager, all of which are interdependent. Each role is equipped with specialised knowledge and expertise that is crucial for the successful delivery of the project. Griffith and Watson

(2004) explain that practitioners must apply their technical knowledge, problem-solving skills, and management abilities to ensure that project objectives related to time, cost, and quality are achieved.

2.5 BIM Applications Among Construction Practitioners

Since each construction project is unique and involves various practitioners working together, effective collaboration and communication among these professionals are essential. The adoption of BIM facilitates the integration of these diverse roles, enhancing collaboration and communication, which in turn reduces errors and improves project outcomes. This collaborative environment is crucial in the journey toward achieving BIM maturity level 3, where the industry transitions from isolated processes to a fully integrated workflow. The following discussion will explore BIM practices among various construction practitioners who are Owners, Architects, Engineers, Contractors, Specialists, Quantity Surveyors, and Facility Managers across different project phases and examine how BIM enables collaboration and communication.

2.5.1 Owner

The project owner initiates the project and provides the financial resources required for its completion. Additionally, they serve as the key decision-maker, approving designs, scope changes, and other major project decisions (PMI, 2021). Moreover, they are responsible for appointing key stakeholders, such as contractors, consultants, and engineers, to execute and manage various aspects of the project (PMI, 2021).

2.5.1.1 Design

In planning phase, the owner is concerned about the feasibility and scope of the project. However, BIM provides owner with an environment that enables the visualisation of various project aspects in real time (Eastman et al., 2018). Shafiq (2021) explains that visualisation provided by BIM allows the owner to have comprehensive view of the project, aiding owner in understanding the proposed design, layout and functionality of the project. This helps the owner better understand the spatial relationships and design intent.

Since cost is a significant concern for the owner, BIM can reduce financial risks by providing reliable estimates at an early stage (Latiffi et al., 2016). Eastman et al. (2018) explains that this early and reliable estimate is useful for owner in assessing predicted cash flows and securing financing. With the aid of BIM, it enables owners to receive quick cost feedback on various design scenarios.

In terms of time, project delays or extended durations can lead to additional costs for the owner, such as interest payments on loans, labor costs, and equipment rentals. However, BIM can ensure reliable on-time project delivery by enabling early coordination and analysis, including aspects of manufacturing, shipping, and field installation (Eastman et al., 2018). These 3D models can be shared with and visualised by stakeholders, allowing the owner to gather feedback and make informed decisions on project feasibility.

2.5.1.2 Construction

Since BIM models continuously reflect the actual on-site conditions, owners can use BIM to monitor construction progress in real-time, ensuring that all construction activities adhere to the project timeline (Azhar, 2011). Additionally, BIM facilitates visualisation, allowing owners to better understand ongoing construction and ensure alignment between the design and the actual build. This capability enables effective communication with contractors and other team members, allowing the owner to address issues and implement changes immediately (Volk et al., 2014). By monitoring these changes effectively, owners can maintain control over the project's progress and budget, thereby reducing the risk of time and cost overruns.

2.5.1.3 Post-construction

BIM promotes creation of 3D model and simulation which aiding in the assessment of operational productivity. Once the facility is operational, BIM helps owners monitor energy consumption and compare real-time usage against design expectations (Latiffi et al., 2016). Additionally, visualisation in BIM enables rapid evaluation and response to the impact of maintenance issues on the facility. For example, an integrated BIM-FM system can visually identify areas affected by events such as fires and power loss, determining which spaces are impacted (Eastman et al., 2018).

2.5.2 Architect

The architect is the one who produce the design that meets the owner’s requirements. Beyond design, architects must ensure that the building complies with national regulations, such as the Uniform Building By-Laws 1984 (UBBL), as well as safety, environmental, and zoning laws (Chong and Siong, 2023). In addition, they coordinate with other construction professionals, such as contractors and engineers, to ensure that the design is both buildable and compatible with other building systems. Architects also serve as contract administrators, particularly under the PAM Contract, managing the contractual relationship between the client and contractor. Their duties include certifying progress payments, certifying project completion, and ensuring that all aspects of the project meet the client’s expectations (PAM 2018).

2.5.2.1 Design

BIM requires architects to take the lead in developing and refining building programs (Eastman et al., 2018). The program, typically defined by the owner, outlines specific requirements such as room dimensions, space allocation, spatial relationships, necessary equipment, and the budget (Autodesk, 2018). Based on the developed building programs, BIM helps architects produce quick massing models and conceptual sketches (Eastman et al., 2018). BIM’s 3D visualisation capabilities enable architects to present ideas to clients and stakeholders effectively.

In this phase, architects translate the building program and concept design into architectural and spatial designs. BIM tools assist architects in developing initial floor plans, sections, and elevations, ensuring the design aligns with the client’s desires and regulatory requirements (Eastman et al., 2018). The 3D visualisation capabilities of BIM help architects explore multiple design ideas and options, achieving the best possible design solutions (Succar, 2009). Additionally, this enables architects to effectively communicate design concepts to the client.

Once the schematic design is finalised, BIM assists architects in conducting detailed designs by incorporating technical information into the model. This information includes exterior and interior layouts, space sizes, and materials, leading to a fully designed building (Azhar, 2011). Furthermore, BIM allows for the integration of HVAC, plumbing, mechanical, and electrical systems into the architectural model (Azhar, 2011). The data-enriched model enables architects to simulate the functional aspects of the building, such as energy performance, temperature control, and ventilation airflow (Becerik-Gerber & Kensek, 2010). Latiffi et al. (2016) explain that architects can even use BIM to determine the building’s location, impacting electricity and water consumption costs. Additionally, BIM integrates design processes with big data, enabling the production and optimisation of building models (Eastman et al., 2018). This allows architects to define a range of design alternatives and use plug-ins to explore these options (Eastman et al., 2018). The process involves optimising façade design, natural ventilation, solar gain, and energy efficiency (Eastman et al., 2018).

With the aid of BIM, architects can efficiently produce construction documentation, including plans, sections, and elevations (Latiffi et al., 2016). BIM technology, equipped with placement and composition rules, enables architects to create standard construction documentation effectively (Latiffi et al., 2016). These BIM-generated documents can serve as legal and contractual sources of building information (Eastman et al., 2018). In this context, architects produce drawings that meet contractual obligations and satisfy building code requirements for other stakeholders, making these documents essential for communication between designers and construction teams.

2.5.2.2 Construction

In this phase, architects use BIM to document and monitor modifications. According to Bynum et al. (2013), architects can regularly update the BIM model to accurately reflect on-site changes and maintain the overall design integrity. This practice ensures that drawings and specifications remain up to date, facilitating clear communication with contractors and adherence to design standards (Krygiel and Nies, 2008). In this way, architects can ensure that the design intentions are realised, and the construction process is streamlined

2.5.2.3 Post-construction

Architects can use BIM to make informed decisions during the post-occupancy evaluation process. Integrating BIM with the Building Management System (BMS) provides valuable, detailed information within the BIM model, which is essential for monitoring real-time building performance (Azhar et al., 2012). This integration enables architects to track various aspects such as functionality, energy consumption, temperature control, and occupancy levels. In this way, architects can identify areas that require adjustments to achieve better project outcomes.

2.5.3 Engineer

Engineers are professionals trained in various disciplines such as civil, structural, mechanical, or electrical engineering, each contributing unique expertise to the construction process. They typically possess specialised knowledge and skills in the design, analysis, and implementation of construction systems. In this way, they ensure the structural integrity and safety of their designs and address technical issues that arise during construction. Furthermore, their responsibilities extend to overseeing testing processes, conducting site inspections, and verifying adherence to safety and industry standards.

2.5.3.1 Design

In the design phase, engineers utilise BIM to create detailed 3D models representing the physical structural elements of the project, such as columns, beams, walls, and slabs. These objects in the model are often simplified to basic linear representations and connection points (Eastman et al., 2018). Eastman et al. (2018) explain that BIM allows engineers to specify the locations of connection points, the constraints on these connections, and to define and model various structural loads and scenarios. This capability enables engineers to conduct structural analysis and simulations effectively. Additionally, BIM's visualisation features allow engineers to experiment with different structural systems and design options within the model (Latiffi et al., 2016; Azhar, 2011). Furthermore, BIM enables clash detection, allowing engineers to identify potential conflicts between various building elements and systems, ensuring they are well-coordinated (Eastman et al., 2018).

In this phase, engineers can produce detailed and precise construction documentation, including shop drawings, directly from clash-free models (Dossick and Neff, 2011). Meanwhile, BIM ensures that all documents and drawings are updated to reflect the most current project information, even as changes occur. This process is helpful for the accurate fabrication and installation of engineering components and systems, reducing onsite issues and rework (Eastman et al., 2018).

2.5.3.2 Construction

Additionally, BIM models can be updated to reflect as-built conditions. (Latiffi et al., 2016). By comparing the as-built model with the as-designed model, engineers can verify that construction aligns with the original specifications (Kymmel, 2008). This facilitates real-time management and quality control. Eastman et al. (2018) explain that the as-built model helps engineer to manage installed systems and components, as well as maintenance activities as the model contains all the necessary information about the building (Eastman et al., 2018).

2.5.3.3 Post-construction

BIM assists engineers in recording and tracking changes made during the post-construction phase. By using BIM, engineers ensure that the model remains up-to-date, accurately reflecting the building's real condition (Volk et al., 2014). Maintaining an as-built model enables facility managers to plan future maintenance or upgrades using a precise digital representation of the building (Eastman et al., 2018). Additionally, the integration of BIM with the Internet of Things (IoT) allows engineers to monitor critical structural components in real-time. According to Kassem et al. (2015), sensors can track stress, strain, and vibration, providing real-time information on the building's structural condition. This allows engineers to use the model to evaluate the situation, identify anomalies, and take preventative actions.

2.5.4 Contractor

The contractor is responsible for executing and overseeing the physical construction of a project. They are typically appointed by the project owner to carry out the building work according to the details provided by architects and engineers. Additionally, contractors must fulfill their obligations concerning project timelines, payment schedules, variation orders, budget, quality standards, and other requirements (PAM, 2018; CIDB, 2021). Beyond managing on-site construction activities, contractors often coordinate with subcontractors, suppliers, and other stakeholders to ensure that all aspects of the project are completed efficiently and smoothly. They are also tasked with managing risks, addressing unforeseen site conditions, and resolving challenges that may arise during construction.

2.5.4.1 Design

With the aid of BIM, the contractor can build digital model to address constructability issue before construction starts (Azhar et al., 2012). In this way, contractors can simulate construction processes to determine potential outcomes and identify issues that may affect project costs, timelines, and quality, hence enhancing overall project efficiency (Reddy, 2011). Azhar (2011) and Hardin (2009) explains that the contractor can utilises BIM to perform an analysis that evaluates key performance metrics, including structural loads, maximum shear forces, and moments. This simulation is valuable for ensuring the construction plan is feasible, efficient and constructable.

At the same time, BIM allows the construction schedule to be linked with 3D representation of building components, enabling visual simulation of construction sequence (Crowther and Ajayi, 2019). In advance, BIM can take this further by incorporating detailed construction methods and optimise the sequence of activities. This BIM tools incorporate information including spatial information, resource management, productivity data and they even support time-based clash detection (Eastman et al., 2018). In this context, the contractor not only can identify spatial conflicts between different building system but also between permanent and temporary elements used during construction such as cranes, trucks, scaffolding, etc (Eastman et al., 2018). With the aid of BIM, contractor can visually convey the detailed construction planning and scheduling to the team members.

Not only that, but the BIM can also assist the contractor to assess safety risk and explore different scenarios before construction begins. Lee et al. (2019) explain that BIM-based automated safety checking systems is advantageous for contractor to identify potential safety hazards early in the project. In this way, it can minimise the risk of accident on-site during construction, by implementing preventive measures.

Additionally, BIM enhances accuracy in material quantity estimation, which is a significant advantage for contractors, particularly during the bidding process (Lu et al., 2016). With the aid of BIM, the contractor can calculate number of components, areas and volumes, and material quantities from the model, which can then be compiled into various schedules (Eastman et al., 2018). This enhanced precision tends to reduce uncertainty regarding the amount of materials required, enabling contractors to produce more competitive and reliable bids.

2.5.4.2 Construction

During construction, BIM is useful for contractor to effectively manage the site operation and delivery (Politi, 2018). By comparing different construction schedule within the BIM model, it allows the contractor to determine whether the project is moving along as planned or experiencing delays that need to be addressed (Azhar, 2011 ; Bryde et al., 2013 ; Hardin, 2009). Meanwhile, contractor is allowed to frequently create, review, and update the model, which result in more accurate and reliable construction sequences (Eastman et al., 2018).

Furthermore, contractor can utilise BIM tools to manage site logistics including determining laydown areas, equipment placement, and site access (Eastman et al., 2018). For example, BIM can help contractor to identify if a mobile crane has enough space to operate within the constraint site area or for a truck to move around the site without blocking (Eastman et al., 2018). In this way, this can facilitate coordination of different trades, ensuring the tasks in constraint area are effectively planned and executed, in term of time and space.

2.5.4.3 Post-construction

The contractor utilises BIM to create as-built documents, which provide precise and updated representations of the completed construction (Eastman et al., 2018). This information is valuable for facility managers, as it offers comprehensive details on building systems and components. Additionally, BIM assists contractors in managing defects by enabling them to track the performance of installed systems and components (Krygiel and Nies, 2008). In this way, this capability allows contractors to address issues during the defect liability period and provide necessary resolutions. Consequently, it facilitates a smoother handover process that aligns with contractual requirements and quality standards.

2.5.5 Quantity Surveyor

Quantity Surveyor is a professional responsible for managing project costs to ensure the project is financially reliable. They are skilled in cost estimation and control throughout the project lifecycle, effectively preventing cost overruns. Additionally, they prepare tender documents, evaluate bids, and are familiar with contract administration, helping to resolve disputes and ensuring that both parties adhere to contract terms (BQSM, 2024). Furthermore, they certify payments to contractors based on work progress and prepare the final account, including any variations from the original contract sum (Ashworth et al., 2013).

2.5.5.1 Design

In the early stage, Quantity Surveyors (QS) engage in feasibility study to estimate initial building cost. By using BIM, QS can extract quantities and produce accurate cost estimates, enabling them to assess the potential risk of cost overruns during early cost advice (Nagalingam, et al., 2013). This involves integrating cost data with the BIM model, which is useful for automated cost analysis (Boon & Prigg, 2012; Perera et al., 2019; Zhou et al., 2012). This approach allows QS to provide more accurate cost advice to the owner, highlighting potential risks of cost overruns.

BIM assists QS in preparing detailed cost estimates based on the comprehensive information provided by the designers (RICS, 2014; Fung et al., 2014). In this case, if the owner disagrees with the proposed cost estimate, QS can advise on alternative design solutions with the client and design team through the 3D visualisation of the building (Fung et al., 2014; Mayouf et al., 2019; Thurairajah and Goucher, 2013). Lai et al. (2010) explain that this visualisation also enables QSs to evaluate different scenarios, such as material choices, thereby enhancing life cycle costs over the building's lifespan (Lai et al., 2010). Meanwhile, QS can also advice on different procurement methods or construction techniques to ensure the cost efficiency is optimised (Society of Chartered Surveyors Ireland, 2016). This helps keep the project within the client's budget, enabling the client to make the best possible decisions.

Furthermore, BIM model can lead to development of detailed cost plan with a detailed breakdown of project costs (Kim & Park, 2017). This breakdown helps QS to identify areas where the potential budget overruns may occur, while clients can gain a better understanding of the project's financial aspects (Mitchell, 2012). Even with design changes occur, whether through additions or omissions, BIM can automatically update the cost plan to reflect these changes (Nagalingam et al., 2013). In this way, the need for manual remeasurement can be eliminated and saving time.

BIM facilitates the measurement process by providing an accurate and automated quantity takeoff from various drawings (Zhou et al., 2012). This significantly reduces manual errors and improves overall efficiency. As BIM automatically updates quantities in response to changes in the drawings, it enhances the efficiency of QS in preparing the Bill of Quantities (Li et al., 2014). Perera et al. (2019) explain that if a design is revised and an element is changed or replaced, BIM notifies the user of this change, ensuring that QS use the most current version of the design to perform all calculations and assessments

Additionally, BIM promotes e-tendering through web-based platforms, enabling the online execution of tasks (Seah, 2008). Tan and Suhana (2016) explain that tender documents can be prepared in the Construction Industry Trading Electronically (CITE) format to facilitate the tendering process. In this context, contractors can download the digital tender documents, pay electronically, and submit their Bill of Quantities (BQ) with pricing back to the QS for evaluation. Additionally, QSs can use BIM to compare submitted bids from contractors based on detailed quantity takeoffs and cost breakdowns (RICS, 2014).

2.5.5.2 Construction

During the construction phase, QS is responsible for cost control and management. By linking cost data with on-going construction activities, BIM enables QS to monitor actual costs against the budget in real time (Olatunji et al., 2010). Besides, QS must assess variations and their impact on the overall project budget (RICS, n.d.). With the aid of BIM, QS can instantly visualise changes and their cost implications (Hardin & McCool, 2015). Potential claims due to such variations can be identified early, helping to mitigate their impact on the final contract sum.

2.5.5.3 Post-construction

With the aid of BIM, QS can effectively manage financial tasks throughout the project. Jung and Joo (2011) explain that BIM provides up-to-date records of project data, including quantities, costs, and changes throughout the project lifecycle. This detailed record helps QS in the release of retention funds by verifying that all defects have been resolved and contractual obligations have been met. Additionally, BIM supports lifecycle management by allowing QS to monitor the condition and performance of building elements over time (Succar, 2009). This capability is valuable for predicting future maintenance needs and budgeting for repairs or replacements.

2.5.6 Building Merchants

Building merchants play a vital role in the supply chain by providing critical building materials, including cement, steel, glass, timber, and other essentials, to builders or developers. Meanwhile, they must ensure the availability of these materials to support construction progress. They also offer services such as material sourcing, transportation, credit options, and technical advice to facilitate efficient project execution (Agapiou et al., 1998).

2.5.6.1 Design

During the design stage, BIM is valuable for building merchants as it provides precise product information and specifications, facilitating collaboration with design teams. According to Eastman et al. (2018), BIM allows merchants to integrate product catalogues—encompassing pricing, technical details, visuals, and specifications—directly with the design model. This integration supports informed decisions on material selection, considering factors such as building performance, waste reduction, and alignment with design intent. Furthermore, building merchants can use BIM to offer digital twins of their products, enabling design teams to create more accurate and realistic models (Miettinen and Paavola, 2014). This capability enhances the overall design process by improving the representation and integration of products into the project design.

2.5.6.2 Construction

By utilising BIM, building merchants can effectively manage the supply chain and coordinate material deliveries according to the construction schedule. Additionally, merchants can use BIM to track material installations in real time, enhancing coordination with contractors and reducing the risk of rework (Shou et al., 2015). Eastman et al. (2018) explain that this real-time tracking can be achieved by integrating RFID data with the BIM model. This ensures that all materials are delivered and used as planned, allowing any defects to be quickly identified and resolved. Moreover, timely deliveries help avoid unnecessary on-site space wastage and minimise the risk of material damage.

2.5.6.3 Post-construction

During this phase, building merchants provide detailed information about the materials used in construction, including product data sheets, warranties, maintenance guidelines, and contact details. By utilising BIM, this information can be integrated into the BIM model, aiding in the efficient maintenance of the building and extending its lifespan (Kassem et al., 2015). The integration of additional technologies with BIM can further enhance the data within the model. As Eastman et al. (2018) explain, technologies such as RFID tags and sensors can be employed to gather up-to-date lifecycle data and incorporate them into the BIM model. This allows facility managers to monitor the performance of building systems and components in real time (Cavka et al., 2017), enabling preventative maintenance actions to be taken before issues become serious.

2.5.7 Specialist

Specialists are professionals with expertise and skills in specific areas. They are typically engaged in specialised tasks that require a high level of precision, such as mechanical, electrical, and plumbing (MEP) services, HVAC systems, and interior fittings. Their involvement is crucial throughout various stages of the project to ensure the proper design, installation, inspection, and maintenance of complex systems, while also ensuring compliance with required standards and specifications.

2.5.7.1 Design

During the design stage, specialists create detailed models to visualise building systems and services. These specialists may include mechanical engineers, electrical engineers, plumbing engineers, and HVAC (heating, ventilation, and air conditioning) engineers, and others. However, BIM facilitates the integration of these models with architectural and structural designs within a unified environment (Eastman et al., 2018). Specialists can utilise BIM's clash detection features to identify potential conflicts between components and report them to the users (Succar, 2009). Eastman et al. (2018) explain that potential conflicts may involve ducts clashing with structural beams or slabs, or electrical wiring interfering with plumbing pipes. Addressing these issues before construction helps reduce the need for timely and costly rework.

Additionally, BIM provides automated detailing features that handle many of the detailed design tasks that specialists would otherwise perform manually (Eastman et al., 2018). This allows specialists to adjust and refine specific details of how individual parts, like ductwork or pipes, fit and connect with each other. BIM uses pre-made custom components, known as families, to handle these detailed adjustments (Eastman et al., 2018). This approach reduces the time and effort required for manual detailing and ensures that all systems and services fit correctly within the building structure.

BIM can automate the production of detailed construction documentation, including drawings, specifications, and material takeoffs, all derived from the BIM model (Azhar, 2011). With the aid of BIM, specialists can ensure the accuracy and consistency of construction documents, as the BIM model automatically updates to reflect any changes made (Eastman et al., 2018).

This automation eliminates the need for specialists to engage in repetitive and time-consuming drafting of construction documents, particularly shop drawings.

2.5.7.2 Construction

BIM "Big Rooms" provide a collaborative working environment where specialists can work together with other key stakeholders in the same space, enabling them to coordinate their efforts effectively (Eastman et al., 2018). In this setting, specialists can adjust their designs in real time, directly responding to the ongoing progress of the fabrication and installation of plumbing, HVAC, water distribution, electrical conduits, and other systems on-site (Succar, 2009). This coordination ensures that their respective systems are well-integrated, leading to smooth project delivery.

2.5.7.3 Post-construction

BIM serves as an important tool for specialists to monitor and maintain installed building systems and services. The detailed models developed during the early phases provide extensive information about various building systems and services (Becerik-Gerber et al., 2021). By leveraging these BIM models, specialists can perform retrofits and upgrades effectively, ensuring that systems function as intended, which improves building efficiency and comfort (Parn and Edwards, 2017). This approach helps prolong the building's lifecycle and prevents it from deteriorating prematurely.

2.5.8 Facility managers

A facility manager’s role is to ensure the effective maintenance, operation, and management of a building throughout its lifecycle. They often oversee day-to-day operations, including building maintenance, energy optimisation, and tenant services, to ensure smooth functioning and occupant satisfaction. Besides, their responsibilities also involve planning for long-term sustainability while ensuring compliance with local regulations and industry standards, such as the National Occupational Skills Standard (NOSS) (Hamid et al., 2021).

2.5.8.1 Design

BIM serves as a robust knowledge repository, storing detailed and evolving information about a facility throughout its lifecycle. This central repository provides facility managers with essential building information, such as details of components, manufacturers, assembly sequences, maintenance instructions, and repair histories (Pärn and Edwards, 2017; Volk et al., 2014; Kassem et al., 2015). Meanwhile, this data-enriched model enables facility managers to simulate building operations, study maintenance and repair access, and verify that the MEP systems are optimally located for ease of maintenance or repair through 3D visualisation (Akcamete et al., 2010; Volk et al., 2014). It is important to ensure that all the works not only meets current requirements but also anticipates long-term challenges.

2.5.8.2 Construction

Since BIM provides a digital representation of building systems and components, including their precise locations (Eastman et al., 2018), it enhances communication between facility managers and contractors. This collaborative approach ensures that each part of the building is installed correctly and in the right location, facilitating easier maintenance access (Sabol, 2008). BIM also offers detailed layouts of emergency equipment, such as fire extinguishers and sprinklers, as well as escape routes including exits, emergency signage, and stairwells (Kelly, 2013). This visualisation helps facility managers coordinate with project teams to ensure that all the critical facility components are accessible and do not conflict with other building elements. Consequently, BIM enables the early identification and resolution of potential issues, preventing problems before the building becomes operational.

2.5.8.3 Post-construction

BIM allows for real-time monitoring of building performance by integrating models with various building system controls, enabling facility managers to optimise equipment performance and energy use (Smith and Tardif, 2009). Additionally, BIM enables recording and tracking changes to the building’s as-is condition and monitoring the facility over time (Golabchi and Akula, 2013; Akcamete et al., 2010). Ani et al. (2015) explains that BIM provides facility managers with quick and reliable information whenever needed. In this way, this enables them to perform instant maintenance, thereby reducing downtime and costly maintenance. In short, researchers like Teicholz (2013), Volk et al. (2014) and Alwan (2016) emphasise that integrating BIM into FM practices brings significant advantages, such as reduced energy and space management costs, improved system integration, and enhanced building performance.

2.6 BIM-enabled Collaboration

Collaboration in construction projects involves multiple parties working together with the aim of completing tasks and ultimately reaching common goals (Um and Kim, 2019). In this context, BIM has been recognised as a platform that facilitates collaboration among different disciplines (Golabchi et al., 2013). User-defined elements in BIM can be enriched with specific data attributes such as costs, specification and schedules. The data-enriched elements are then exported in Industry Foundation Classes (IFC) format (Levy, 2011). This format enables all the data to be shared and analysed across various software platform, enabling all stakeholders to perform analysis, simulation and visualisation. In regions like America and Europe, architects and engineers have succeeded in integrating their work within the same BIM model (Onungwa and Uduma-Olugu, 2017). In other words, a BIM shared model enables different stakeholders to share their knowledge and expertise (Onungwa and Uduma-Olugu, 2017).

RICS (2014) defines BIM as a powerful technological tool to achieve fully integrated processes. A central model server enables project stakeholders to work collaboratively in real-time, thus improving the development and progression of the model (RICS, 2014). Additionally, RICS (2014) claims that cloud computing can further enhance BIM's collaborative capabilities. In this context, a central model server hosted on cloud platforms provides secure and seamless access to the 3D model for all project stakeholders (Amarnath et al., 2011; Sawhney and Maheswari, 2013). Furthermore, a study conducted by El Ammari and Hammad (2019) developed a collaborative framework using BIM-based mixed reality (MR) to enhance facilities management. This framework facilitates collaboration by bridging the gap between field and office tasks, while enabling real-time consultation and coordination through interactive visual tools.

2.7 BIM-enabled Communication

According to the research done by Goh et al. (2014), BIM provides a definitive solution to communication challenges, which is much better than traditional methods. In traditional methods, each project stakeholder uses their own fully coordinated model to handle their tasks, and information is typically shared through 2D drawings (RICS, 2014). An integrated BIM environment has been introduced to enhance or replace traditional methods of communication. This environment includes BIM tools, servers, repositories, and workflows within the project or organisation (Eastman et al., 2018). Instead of relying on separate models for each project stakeholder, a single central model is created and maintained throughout the project (RICS, 2014). This central model acts as a single source of information for the entire project team (RICS, 2014). Central to this environment is the concept of a common data environment (CDE), which is used to manage information flows (RICS, 2014).

RICS (2014) defines a common data environment as an information storage system on a project server used for gathering, storing, organising, and distributing all authorised project documents, including models and drawings. Through this single information repository, efficient and timely information transfer between project stakeholders is ensured, driven by the client’s clear and value-based information requirements (Dowd and Marsh, 2020; RICS, 2014). Not only does it extend beyond just model data, but it also incorporates a broader range of information, including videos, images, audio recordings, and emails, all of which are integral to project management (Eastman et al., 2018). Furthermore, cloud platforms enable new forms of communication, essential for globally distributed project teams (RICS, 2014). In practice, BIM can enhance the interaction between the client and the contractor by serving as a platform for both parties to have effective discussions and facilitating the seamless execution of changes in the project plan (Goh et al., 2014). In other words, BIM enables all parties to clearly describe and solve issues throughout the design process, unlike traditional methods that rely on paper-based documents to convey information (Partridge et al., 2007).

2.8 Summary of Literature Review

This chapter has reviewed literature related to the evolution of BIM, its maturity levels, and the different roles of construction practitioners involved in BIM execution. In summary, BIM execution is categorised into three stages namely, design, construction, and post-construction, as shown in Table 2.1 below.

Table 2.1: BIM Applications Among Construction Practitioners Across Three Key Phases

	Design	**Construction**	**Post-Construction**	**References**
Owner	Real-Time Visualisation, Feasibility Assessment	Progress Monitoring, Issue Resolution	Facility Management, Energy Monitoring, Maintenance Planning	Shafiq (2021); Latiffi et al. (2016); Eastman et al. (2018); Azhar (2011); Volk et al. (2014)
Architect	Develops Design, Integrates systems, Simulates Performance Generates Compliant Documentation	Design Updates, Construction Coordination	Performance Tracking, Evaluation, Building Management	Eastman et al. (2018); Becerik-Gerber and Kensek (2010); Latiffi et al. (2016); Bynum et al. (2013); Azhar et al. (2012)
Engineer	Structural Design and Analysis, Clash Detection, Structural Simulations, Generates fabrication-ready documentation	As-built Checking, Quality Control,	- Maintains as-built records - Tracks structural health	Latiffi et al. (2016); Azhar (2011); Eastman et al. (2018); Dossick and Neff (2011); Kymmel (2008); Volk et al. (2014); Kassem et al. (2015)
Contractor	Constructability Analysis, Planning and Scheduling, Safety Assessment	Progress Tracking, Site Logistics Management,	Creates As-built Documentation, Defect Tracking	Azhar (2011); Hardin (2009); Crowther and Ajayi (2019); Eastman et al. (2018); Lee et al. (2019); Bryde et al. (2013); Krygiel and Nies (2008)

Quantity Surveyor	Cost Estimation and Planning, Quantity Takeoff, Value Management E-Tendering	Cost Control, Variation Impact Assessment, Early claim Verification	Financial Tracking, Lifecycle Cost Management	Nagalingam, et al. (2013);RICS (2014); Fung et al. (2014); Mayouf et al. (2019); Thurairajah and Goucher (2013); Kim and Park (2017); Zhou et al. (2012); Tan and Suhana (2016); Olatunji et al. (2010); Hardin and McCool (2015) Succar (2009)
Building Merchants	Material Selection, Product Catalogues, Integration and Representation	Supply chain Management, Installation Tracking, Material Usage Monitoring	Performance Monitoring, Maintenance Planning	Eastman et al. (2018); Shou et al. (2015); Kassem et al. (2015); Cavka et al. (2017)
Specialist	MEP/HVAC System Design, Clash Detection, Detailing, Shop Drawing and Specs Production	Design Adjustments, Installation/Fabrication Coordination	System Monitoring, Maintenance Planning	Eastman et al. (2018); Succar (2009); Parn and Edwards (2017)
Facility Manager	Maintenance Access and Operations Simulation	Installation checking, Emergency Layout Coordination	Facility Monitoring and Optimisation, As-Built Condition Tracking Maintenance Execution	Akcamete et al. (2010); Volk et al. (2014); Sabol (2008); Kelly (2013); Smith and Tardif (2009); Golabchi and Akula (2013); Akcamete et al. (2010)

CHAPTER 3

METHODOLOGY AND WORK PLAN

3.1 Introduction

This chapter begins by exploring the research philosophy, which guides the development of the research approach and questionnaire design. It then details the sampling design, including the sampling method, sample size, and targeted respondents. Next, the chapter discusses data collection, covering aspects such as the time horizon, questionnaire design, and pilot study. The data analysis process is then outlined, incorporating methods such as Cronbach's alpha reliability Test, frequency distribution analysis, mean rank, the Kruskal-Wallis H test, and Spearman correlation. Finally, the chapter concludes with a discussion on research ethics.

3.2 Research Philosophy

This study adopts a pragmatist research philosophy, which emphasises practical outcomes through a mixed-method approach to investigate BIM practices among practitioners, at the same time how they engage in collaboration and communication during BIM execution. However, the Malaysian construction industry continues to face significant challenges in this area, particularly due to fragmentation and limited integration between stakeholders. One of the important principles of pragmatism is known as reflexivity, which involves continuous reflection on the research process to discover new findings and enhance understanding. Additionally, pragmatism is chosen for this study because it allows the integration of both quantitative and qualitative methods, providing deeper insights into the phenomenon of how collaboration and communication challenges emerge and are managed within fragmented project environments.

Research philosophies are structured around three elements: epistemology, ontology, and axiology (Saunders et al., 2019). From an epistemological perspective, pragmatism recognises that both objective facts and subjective insights are essential for building knowledge. In this study, the collected data represent objective facts, while the subsequent discussion and interpretation provide subjective insights. The questionnaire responses are divides into close-ended and open-ended types. Close-ended responses provide quantitative data, offering measurable trends and patterns across different practitioners. On the other hand, open-ended responses provide qualitative data by capturing practitioners' experiences and perspectives subjectively, revealing insights that may not emerge through structured questions.

In terms of ontology, pragmatism views reality as complex and multifaceted, meaning that no single solution or viewpoint can fully address the challenges in the construction industry. Therefore, no objective facts exist but it is shaped by subjective interpretation. To address this, the study engages construction practitioners from various fields, allowing for diverse perspectives that capture the multiple layers of reality in the construction industry.

Lastly, axiology addresses the role of values, ethics, and personal judgments in research. It is recognised that the interpretation of the study is inherently subjective, as it is based on personal knowledge and experience. However, to enhance objectivity, the study incorporates existing research and literature to support these subjective insights. Interpretations without supporting research or literature will remain purely subjective.

3.3 Sampling Design

The sampling design involves managing the data collection process by focusing on a subset of the population rather than examining every possible case or elements. In this process, the samples are ensured to accurately represents the larger population, enabling the statistical inferences and analysis to be made (Becker, 2008). The sampling method, sample size, and targeted respondents will be discussed in the following sections.

3.3.1 Sampling Method

Convenience sampling will be employed for the effective collection of data in this study. According to Saunders et al. (2019), convenience sampling is a non-probability sampling technique where the sample is selected based on ease of access and availability. Rather than selecting a sample that is representative of the entire population, participants who are readily available and willing to participate will be chosen for this study. Additionally, this method is preferred due to its practicality, especially when time, resources, or access to larger populations are limited (Etikan et al., 2016). In this study, the questionnaire was distributed via Google Forms to construction practitioners who were easily accessible through internship networks, personal contacts, and social media platforms such as LinkedIn, WhatsApp, and email.

3.3.2 Sample Size

In this study, the Central Limit Theorem (CLT) guides the determination of an appropriate sample size. The CLT determined that, given a sufficiently large sample, the distribution of the sample mean will approximate a normal distribution, even if the original population distribution is non-normal, as long as the population has a finite mean and variance. Based on this principle, a minimum sample size of 30 or more is recommended for each group within the overall sample. Since this study involves four groups of practitioners, a minimum of 120 respondents are required to ensure the reliability and validity of the statistical inferences.

3.3.3 Executing the Sample Process

The questionnaire was in Google Form and was distributed through various online platforms, including Email, WhatsApp, LinkedIn, and XiaoHongShu. Meanwhile, the survey primarily targeted respondents in the Klang Valley, with some distributions extending to other regions, including Johor, Penang, Sabah, and Sarawak.

3.3.4 Targeted Respondent

The study focuses on the individual unit, where individual respondents serve as the primary level of observation. Data will be collected from individual practitioners in the Malaysian construction industry, representing diverse professional backgrounds. These individuals include architects, engineers, quantity surveyors, and chartered builders, with variations in their profession, position level, working experience, company's business activities, and BIM proficiency levels. Additionally, the targeted respondents must have at least basic experience in using BIM tools in their professional work, ensuring they are qualified to address the research objectives based on their practical exposure to BIM.

To identify suitable respondents, a combination of strategies was used. First of all, the profession of each individual was first confirmed through direct communication before distributing the questionnaire. Besides, respondents' profiles were reviewed to ensure their relevance to the targeted respondents. Additionally, some respondents were obtained through academic or internship experience, where their professional background was already known.

3.4 Data Collection

Data collection is a crucial strategy for acquiring reliable and valid data. This section discusses the time horizon, questionnaire design, and pilot test, all of which are essential to ensuring data quality and completeness. Additionally, selecting appropriate distribution channels and optimising response rates further strengthen the process.

3.4.1 Time Horizon

The time horizon in research refers to the timeframe over which data is collected, and it is typically divided into two categories: cross-sectional and longitudinal. Due to the nature of this study, a cross-sectional time horizon is implemented, where data is collected over a specified period. Specifically, the survey will be conducted over a few months, from 1 January 2025 to 31 March 2025. This approach provides an understanding of the current state of the BIM-related phenomena under investigation, which is sufficient to address the research objectives of this study.

3.4.2 Questionnaire Design

The questionnaire is designed based on the principle of 'mutually exclusive, collectively exhaustive,' ensuring that each statement is grouped logically and cover all possible groups without overlaps or overlooks (Rasiel, 1999). It is structured into both close-ended and open-ended sections to gather comprehensive insights.

The close-ended portion is divided into four sections: Section A focuses on understanding the practices of different construction practitioners in utilising BIM across various project phases; Section B delves into how these practices engage the collaboration in BIM execution; Section C explores how these practices engage the communication in BIM execution; and Section D assesses how importance of both collaboration and communication for a business organisation.

Section E includes open-ended questions to gather respondents' perceptions of collaboration and communication in the construction industry, along with insights into how they engage in these activities in their daily work.

Section F collects demographic information to contextualise the responses and support data analysis. By placing these demographic questions at the end of the survey, the design prioritises the research objectives, ensuring that the most critical data is collected. Additionally, to ensure that the questionnaire reaches the intended respondent, it is distributed one by one directly to construction practitioners, thereby maintaining the accuracy and relevance of the responses.

The questionnaire adopts a 5-point Likert scale, ranging from 1 = Strongly Disagree to 5 = Strongly Agree, to measure respondents' opinions related to BIM. This scale is useful for capturing the intensity of respondents' opinions and converting subjective data into quantifiable, ordinal data. Since the data collected is ordinal, it can be analysed using descriptive statistics such as mean, median, and frequency distribution. Additionally, the data enables more advanced analyses, such as non-parametric tests (e.g., Kruskal-Wallis Test) and correlation analyses (e.g., Spearman Correlation).

3.4.3 Pilot Test

A pilot test was conducted with 10 respondents comprising a variety of construction practitioners, including a Project Manager, Quantity Surveyor, Contractor, Engineer, and Construction Personnel, and the results have led to several recommendations. It is recommended that the linear scale be reduced from a range of 1-10 to a more concise 1-5, as the original scale was found to be too lengthy and potentially overwhelming for respondents. Additionally, based on feedback from the pilot test, it is suggested that an introduction to BIM be included on the first page of the questionnaire. This introduction aims to provide respondents with a clear understanding of BIM before they begin answering.

3.5 Data Analysis

Data analysis involves describing, demonstrating, consolidating, reviewing, and evaluating the data to discover useful information and draw conclusions. In this study, data analysis is conducted using the Statistical Package for Social Sciences (SPSS) to analyse collected data. It involves several statistical techniques, such as the Cronbach's Alpha Reliability Test, descriptive statistics, and inferential statistics to support interpretation of the research findings. These methods will be further explained in the following section.

3.5.1 Reliability Test

Cronbach's Alpha reliability test is used to assess the internal consistency of the statements in Sections A, B, C, and D of the questionnaire. This test produces a coefficient ranging from 0 to 1, indicating how closely related the statements are as a group. According to Taber (2018), a coefficient of 0.7 or above signifies strong reliability, meaning the items consistently measure the same underlying construct.

3.5.2 Descriptive Statistics

Descriptive statistics are used to provide a clear and interpretable summary of collected datasets. In this study, frequency distribution is used to determine the frequency of demographic data for each respondent, including profession, position level, working experience, company’s business activities, and BIM proficiency level. Additionally, mean ranking is applied to rank each statement in the questionnaire from highest to lowest, highlighting general trends and tendencies in the data. Furthermore, responses to the open-ended question regarding practitioners’ perspectives on collaboration and communication are presented using bar charts.

3.5.3 Inferential Statistics

Inferential statistics is useful for making generalisations about a broader population based on a sample of data. As Guetterman (2019) highlights, inferential statistics involves key methods such as hypothesis testing, analysing relationships between variables, and estimating population parameters. These techniques enable researchers to draw conclusions and make inferences about the broader population.

3.5.3.1 Kruskal-Wallis H Test

The Kruskal-Wallis H test is a non-parametric statistical test used to determine whether there are statistically significant differences in opinions among multiple independent groups of respondents. In this study, the test is applied to compare responses across different demographic groups, including profession, position level, working experience, company's business activities, and BIM proficiency level, to identify significant variations in their perceptions or behaviours.

3.5.3.2 Spearman Correlation Test

The Spearman Correlation is a non-parametric statistical test used to assess the strength and direction of the relationship between two variables. In this study, Spearman Correlation is adopted to evaluate the how well the relationship between collaboration and communication in BIM execution. It helps determine whether higher levels of collaboration are associated with better communication practices among construction practitioners during BIM execution, and vice versa. Additionally, the test identifies significant pairwise correlations between relevant variables, offering deeper insights into the interconnected aspects of collaboration and communication.

3.5.4 Research Ethics

Throughout the research process, maintaining confidentiality is crucial; respondents' identities and personal information must not be disclosed. Additionally, conflicts of interest should be avoided by not disclosing personal biases and ensuring fairness in the representation of findings (Creswell, 2017). Furthermore, the research proposal must be submitted to the UTAR Research Ethics Committee (REC) for review and approval. This process ensures the protection of respondents' rights and guarantees that the research is conducted in accordance with research principles and university policies.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

This chapter presents the analysis of the collected data, beginning with a summary of the respondents' profiles to establish context. The reliability of the questionnaire constructs is then assessed using Cronbach's Alpha. The mean ranking of multiple variables is tabulated, followed by the Kruskal-Wallis H test to identify any significant differences in BIM practices, collaboration, communication, and their perceived importance based on respondents' profession, position level, working experience, company business activities, and BIM proficiency. The Spearman correlation test is subsequently used to examine the relationship between collaboration and communication. The final section provides a detailed discussion of the findings derived from each analysis.

4.2 Respondents' Background

A total of 430 survey forms were distributed through online platforms such as WhatsApp, email, and LinkedIn. A total of 137 responses were collected, with a response rate of 31.86%. Table 4.1 presents the demographic profile of the respondents. Engineers (33.6%) and Architects (29.2%) represented the largest professional groups among respondents, with executives constituting the majority at 47.4%. Approximately two-thirds of respondents had over two years of experience, and consultancy (56.2%) emerged as the primary business sector. While 39.4% reported average BIM proficiency, only 6.6% rated their skills as very good.

Table 4.1: Frequency Distribution and Percentages of Respondents' Demographic Data

Demographic Variable	**Frequency (*n*)**	**Percentage (%)**
Profession		
Architect	40	29.2
Engineer	46	33.6
Quantity Surveyor	38	27.7
Chartered Builder	13	9.5
Position Level		
Non-executive	27	19.7
Executive	65	47.4
Manager	24	17.5
Upper Management	21	15.3
Working Experience		
Less than 2 years	42	30.7
2 years but not more than 5 years	30	21.9
5 years but not more than 10 years	27	19.7
10 years and above	38	27.7
Company's business activities		
Construction Businesses	44	32.1
Consultancy	77	56.2
Property Development	16	11.7
Proficiency Level in BIM		
Don't Know	11	8.0
Poor	31	22.6
Average	54	39.4
Good	32	23.4
Very Good	9	6.6

4.3 Reliability Analysis

All survey items were assessed for reliability using Cronbach's alpha, as shown in Table 4.2. The results demonstrated excellent internal consistency, with all sections achieving a coefficient of 0.9 or higher. These consistently high values confirm the instrument's robustness for measuring the targeted constructs and its appropriateness for data collection.

Table 4.2: Cronbach's Alpha Reliability Test

Section Name	Number of Items	Cronbach's Alpha
Section A: Practices of Different Construction Practitioners in BIM Execution	10	0.938
Section B: How Different Construction Practitioners Engage Collaboration in BIM Execution	10	0.939
Section C: How Different Construction Practitioners Engage Communication in BIM Execution	10	0.940
Section D: Importance of Collaboration and Communication in BIM Execution	8	0.900

4.4 Practices of Different Construction Practitioners in BIM Execution

Table 4.3 shows the mean rankings of BIM practices among construction practitioners, where the "enable detailing for the project" (mean rank = 6.64) is the highest-ranked practice, followed by "detect potential issues" (mean rank = 5.95) and "perform quantity takeoff" (mean rank = 5.78). In contrast, "monitor project cost" (mean rank = 4.43) and "perform tendering" (mean rank = 5.06) were ranked lowest.

Table 4.3: Mean Rank of Practices of Different Construction Practitioners in BIM Execution

Item Code	Statement	Mean Rank	Chi-square	Asymp. Sig.
A3	To enable detailing for the project	6.64	71.629	<0.001
A1	To detect potential issues of the project	5.95		
A4	To perform quantity takeoff	5.78		
A5	To prepare the construction documentations	5.59		
A8	To track the construction progress	5.43		
A10	To perform quality checking	5.42		

A7	To track the project variation	5.35
A2	To enable scheduling for the project	5.34
A6	To perform tendering	5.06
A9	To monitor the project cost	4.43

4.4.1 Quantity Surveyors Lead in BIM Practices

The Kruskal-Wallis test resulted in Table 4.4 reveal statistically significant differences in BIM practice across professions ($p < 0.05$). Quantity Surveyors demonstrated significantly higher engagement in using BIM to “perform quantity takeoff” (mean rank = 87.59) compared to other professions, especially Chartered Builders (mean rank = 43.27). Architects showed the strongest emphasis on “perform tendering” (mean rank = 80.43), whereas Chartered Builders ranked it lowest (mean rank = 39.69) in BIM practices. Similarly, “monitor project cost” was most prevalent among Quantity Surveyors (mean rank = 83.80) and least prioritised by Chartered Builders (mean rank = 55.69).

Table 4.4: Significant Differences of Practices of Different Construction Practitioners Based on Profession

Item Code	Null Hypothesis	Mean Rank				Asymp. Sig.
		Architect	Engineer	Quantity Surveyor	Chartered Builder	
A4	To perform quantity takeoff	63.83	65.41	87.59	43.27	0.001
A6	To perform tendering	80.43	62.17	75.26	39.69	0.004
A9	To monitor the project cost	56.11	71.74	83.80	55.69	0.008

4.4.2 Non-Executives Lead in BIM Collaboration

The Kruskal-Wallis test shown in Table 4.5 reveal statistically significant differences in how practitioners engage in BIM collaboration across position levels ($p < 0.05$). Non-executives had the highest engagement in using BIM to “perform tendering” (mean rank = 85.39), followed by executives (mean rank = 69.59) and managers (mean rank = 59.98), while upper management showed substantially lower engagement in BIM practices (mean rank = 56.40).

Table 4.5: Significant Differences of Practices of Different Construction Practitioners Based on Position Level

Item Code	Null Hypothesis	Mean Rank				Asymp.
		Non-executive	Executive	Manager	Upper Management	Sig.
A6	To perform tendering	85.39	69.59	59.98	56.40	0.039

4.4.3 Practitioners With Less Than 2 Years of Experience Lead in BIM Practices

The Kruskal-Wallis test reveals significant differences in BIM practice based on years of experience ($p < 0.05$), as shown in Table 4.6. Practitioners with less than 2 years of experience consistently assigned the highest rankings in using BIM to: “perform quantity takeoff” (mean rank = 78.95), “prepare construction documentation” (mean rank = 79.02), and “perform tendering” (mean rank = 81.60). In contrast, these three practices received the lowest rankings from those over 10 years of experience: “perform quantity takeoff” (mean rank = 55.49), “prepare construction documentation” (mean rank = 57.70), and “perform tendering” (mean rank = 58.46).

Table 4.6: Significant Differences of Practices of Different Construction Practitioners Based on Years of Experience

Item Code	Null Hypothesis	Mean Rank				Asymp. Sig.
		Less than 2 years	2 years but not more than 5 years	5 years but not more than 10 years	10 years and above	
A4	To perform quantity takeoff	78.95	75.15	65.70	55.49	0.038
A5	To prepare the construction documentations	79.02	78.30	58.98	57.70	0.021
A6	To perform tendering	81.60	73.73	58.98	58.46	0.023

4.4.4 'Very Good' Proficiency Groups Lead in BIM Practice

The Kruskal-Wallis test resulted in Table 4.7 confirm statistically significant differences in all BIM practices across proficiency levels ($p \leq 0.005$). Practitioners with ‘Very Good’ proficiency consistently assigned the highest rankings to most BIM practices, particularly for “detect potential issues of the project” (mean rank = 115.17) and “enable scheduling for the project” (mean rank = 111.94). However, three exceptions emerged where ‘Good’ proficiency ranked slightly higher: “perform quantity takeoff” (mean rank = 90.52), “track construction progress” (mean rank = 84.70), and “monitor project cost” (mean rank = 89.50). Obviously, the gap between ‘Very Good’ and ‘Don’t Know’ proficiency was large. For example, “detect potential issues of the project” was ranked 115.17 by ‘Very Good’ users versus just 26.36 by ‘Don’t Know’ users.

Table 4.7: Significant Differences of Practices of Different Construction Practitioners Based on Current Proficiency Levels in BIM Tools

Item Code	**Null Hypothesis**	**Mean Rank**					**Asymp. Sig.**
		Don't Know	**Poor**	**Average**	**Good**	**Very Good**	
A1	To detect potential issues of the project	26.36	54.23	72.90	78.41	115.17	<0.001
A2	To enable scheduling for the project	33.86	48.97	72.53	82.45	111.94	<0.001
A3	To enable detailing for the project	17.64	54.50	72.52	86.36	98.89	<0.001
A4	To perform quantity takeoff	25.95	48.87	74.79	90.52	79.72	<0.001
A5	To prepare the construction documentations	23.36	46.15	76.64	85.91	97.56	<0.001
A6	To perform tendering	26.86	45.00	77.72	85.83	91.00	<0.001
A7	To track the project variation	32.73	44.37	78.90	83.14	88.50	<0.001
A8	To track the construction progress	38.32	54.21	72.73	84.70	79.22	0.001
A9	To monitor the project cost	31.82	50.56	74.04	89.50	74.83	<0.001
A10	To perform quality checking	34.09	57.10	71.94	79.80	96.61	<0.001

4.5 How Different Construction Practitioners Engage Collaboration in BIM Execution

Table 4.8 shows the mean rankings of BIM collaboration methods among practitioners, where the “to visualise the impact of design modifications on construction tasks before implementation” (mean rank = 6.37) was the highest-ranked collaboration practice, followed closely by “to identify potential design conflicts by clash detection tools” (mean rank = 6.36) and “to align client requirements across multiple disciplines” (mean rank = 6.00). In contrast, the lowest-ranked collaboration practices were “to facilitate off-site prefabrication” (mean rank = 4.70) and “to facilitate remote access to the project model between on-site and off-site teams” (mean rank = 4.77).

Table 4.8: Mean Rank of How Different Construction Practitioners Engage Collaboration

Item Code	Statement	Mean Rank	Chi-square	Asymp. Sig.
B8	To visualise the impact of design modifications on construction tasks before implementation	6.37	94.056	<0.001
B1	To identify potential design conflicts by clash detection tools	6.36		
B2	To align client requirements across multiple disciplines	6.00		
B3	To enable simultaneous updates from different team members on a shared model	5.92		
B6	To improve site coordination by providing real-time access to construction models	5.42		
B7	To enable shared access to up-to-date construction schedules	5.36		
B9	To reduce response time in addressing defects and maintenance issues	5.11		
B10	To enable real-time monitoring of building systems for predictive maintenance and operational efficiency	5.00		

B5	To facilitate remote access to the project model between on-site and off-site	4.77
B4	To facilitate off-site prefabrication.	4.70

4.5.1 Engineer Lead in BIM Collaboration

The Kruskal-Wallis test resulted in Table 4.9 show statistically significant differences in how practitioners engage in BIM collaboration across professions ($p < 0.05$). In collaboration, Engineers tend to "align client requirements across multiple disciplines", which ranked at the highest (mean rank = 78.25) compared to other professions such as architects (mean rank = 70.81), quantity surveyors (mean rank = 65.14), and chartered builders (mean rank = 41.96). Similarly, for "enable simultaneous updates from different team members on a shared model," engineers showed the highest engagement (mean rank = 78.80) while chartered builders ranked lowest in BIM collaboration (mean rank = 45.54).

Table 4.9: Significant Differences of How Different Construction Practitioners Engage Collaboration Based on Profession

Item Code	**Null Hypothesis**	**Mean Rank**				**Asymp. Sig.**
		Architect	**Engineer**	**Quantity Surveyor**	**Chartered Builder**	
B2	To align client requirements across multiple disciplines	70.81	78.25	65.14	41.96	0.020
B3	To enable simultaneous updates from different team members on a shared model	67.69	78.80	66.54	45.54	0.042

4.5.2 Executives Lead in BIM Collaboration

The Kruskal-Wallis test shown in Table 4.10 reveal statistically significant differences in how practitioners engage in BIM collaboration across position levels ($p < 0.05$). In collaboration, Executives prioritised “identify potential design conflicts by clash detection tools” most strongly (mean rank = 76.66), followed by non-executives (mean rank = 71.57) and managers (mean rank = 60.81), while upper management showed substantially lower engagement (mean rank = 37.35). Similarly, for “improve site coordination by providing real-time access to construction models”, executives again ranked highest (mean rank = 76.87), closely followed by non-executives (mean rank = 72.94) and managers (mean rank = 65.85), while upper management demonstrated relatively lower engagement in BIM collaboration (mean rank = 43.17).

Table 4.10: Significant Differences of How Different Construction Practitioners Engage Collaboration Based on Position Level

Item Code	**Null Hypothesis**	**Mean Rank**				**Asymp. Sig.**
		Non-executive	**Executive**	**Manager**	**Upper Management**	
B1	To identify potential design conflicts by clash detection tools	71.57	76.66	60.81	51.33	0.036
B6	To improve site coordination by providing real-time access to construction models	72.94	76.87	65.85	43.17	0.005

4.5.3 Practitioners with Less Than 2 Years of Experience Lead in BIM Collaboration

The Kruskal-Wallis test shown in Table 4.11 reveal statistically significant differences in how practitioners engage in BIM collaboration based on years of experience ($p < 0.05$). Practitioners with less than 2 years of experience ranked “enable shared access to up-to-date construction schedules” highest in BIM collaboration (mean rank = 83.10), showing decreasing engagement as experience increase: 2-5 years (mean rank = 73.53), 5-10 years (mean rank = 57.17), and over 10 years (mean rank = 58.25).

Table 4.11: Significant Differences of How Different Construction Practitioners Engage Collaboration Based on Years of Experience

Item Code	Null Hypothesis	Mean Rank				Asymp. Sig.
		Less than 2 years	2 years but not more than 5 years	5 years but not more than 10 years	10 years and above	
B7	To enable shared access to up-to-date construction schedules	83.10	73.53	57.17	58.25	0.009

4.5.4 'Very Good' Proficiency Groups Lead in BIM Collaboration

The Kruskal-Wallis test presented in Table 4.12 confirm statistically significant differences in all BIM collaboration engagement among practitioners based on proficiency levels ($p \leq 0.005$). Overall, practitioners with ‘Very Good’ proficiency consistently assigned the highest rankings to most engagement in BIM collaboration, particularly for “align client requirements across multiple disciplines” (mean rank = 105.78) and “enable simultaneous updates from different team members on a shared model” (mean rank = 103.78). However, one exception observed where ‘Good’ proficiency ranked slightly higher: “improve site coordination by providing real-time access to construction models” (mean rank = 83.02). Obviously, the gap between ‘Very Good’ and ‘Don’t Know’ proficiency was large. For example, “align client requirements across multiple disciplines” was ranked 90.06 by ‘Very Good’ users versus just 24.14 by ‘Don’t Know’ users.

Table 4.12: Significant Differences of How Different Construction Practitioners Engage Collaboration Based on Current Proficiency Levels in BIM Tools

Item Code	Null Hypothesis	Mean Rank					Asymp.
		Don't Know	Poor	Average	Good	Very Good	Sig.
B1	To identify potential design conflicts by clash detection tools	26.50	54.52	74.44	80.86	96.61	<0.001
B2	To align client requirements across multiple disciplines	29.18	52.19	72.33	83.00	105.78	<0.001
B3	To enable simultaneous updates from different team members on a shared model	29.91	58.06	68.46	84.16	103.78	<0.001
B4	To facilitate off-site prefabrication	45.18	49.88	75.66	78.23	90.83	0.001
B5	To facilitate remote access to the project model between on-site and off-site	37.32	57.69	72.80	79.94	85.00	0.005
B6	To improve site coordination by providing real-time access to construction models	36.68	58.52	71.19	83.02	81.61	0.003
B7	To enable shared access to up-to-date construction schedules	41.64	54.58	72.16	79.42	96.11	0.002
B8	To visualise the impact of design modifications on construction tasks before implementation	30.41	50.90	74.33	84.84	90.17	<0.001

B9	To reduce response time in addressing defects and maintenance issues	33.95	48.95	79.36	79.56	81.17	<0.001
B10	To enable real-time monitoring of building systems for predictive maintenance and operational efficiency	47.77	51.87	74.96	79.47	80.94	0.007

4.6 How Different Construction Practitioners Engage Communication in BIM Execution

Table 4.13 shows the mean rankings of BIM communication methods among practitioners, where the "enhance stakeholder understanding of the design concept via 3D visualisation" (mean rank = 6.81) had the highest mean rank in communicating using BIM, followed by "share design models, drawings, and specifications efficiently among stakeholders" (mean rank = 6.46) and "communicate construction issues to relevant stakeholders for timely resolution" (mean rank = 6.17). In contrast, "generate automated reports, including progress updates and task lists, for project tracking" (mean rank = 4.83) and "convey safety protocols and risks visually to the site workers" (mean rank = 4.24) were located at the lowest in BIM communication.

Table 4.13: Mean Rank of How Different Construction Practitioners Engage Communication

Item Code	Statement	Mean Rank	Chi-square	Asymp. Sig.
C2	To enhance stakeholder understanding of the design concept via 3D visualisation	6.81	148.390	<0.001
C1	To share design models, drawings, and specifications efficiently among stakeholders	6.46		
C4	To communicate construction issues to relevant stakeholders for timely resolution	6.17		
C5	To keep all stakeholders informed about project progress, variations, and milestones.	5.72		
C3	To enable instant notifications of design changes to on-site team members	5.40		
C8	To manage Requests for Information (RFIs) and responses efficiently through a centralised system	5.34		
C9	To maintain organised project documents, logs, and communication records	5.05		

C10	To facilitate repair works by sharing accurate building data from the BIM model	4.99
C7	To generate automated reports, including progress updates and task lists, for project tracking	4.83
C6	To convey safety protocols and risks visually to the site workers	4.24

4.6.1 Non-Executives Lead in BIM Communication

According to Table 4.14, the Kruskal-Wallis test proves statistically significant differences in how practitioners engage in BIM communication across position levels ($p < 0.05$). For “share design models, drawings, and specifications efficiently among stakeholders”, non-executives (mean rank =77.54) and executives (mean rank = 78.65) were most engaged in BIM communication, while “manage Requests for Information (RFIs) and responses efficiently through a centralised system” saw non-executives most active (mean rank = 79.76). For “maintain organised project documents, logs, and communication records”, it displayed the largest gap where non-executives ranking highest (mean rank = 85.20) versus upper management (mean rank = 52.45). Executives ranked “facilitate repair works by sharing accurate building data from the BIM model” highest in BIM communication (mean rank = 76.53)

Table 4.14: Significant Differences of How Different Construction Practitioners Engage Communication Based on Position Level

Item Code	Null Hypothesis	Mean Rank				Asymp. Sig.
		Non-executive	Executive	Manager	Upper Management	
C1	To share design models, drawings, and specifications efficiently among stakeholders	77.54	78.65	52.15	47.40	<0.001
C8	To manage Requests for Information (RFIs) and responses efficiently through a centralised system	79.76	75.45	58.38	47.36	0.006
C9	To maintain organised project documents, logs, and communication records	85.20	71.77	57.75	52.45	0.011
C10	To facilitate repair works by sharing accurate building data from the BIM model	73.46	76.53	55.69	55.17	0.033

4.6.2 Practitioners with Less Than 2 Years of Experience Lead in BIM Communication

According to Table 4.15, the Kruskal-Wallis test proves statistically significant differences in how practitioners engage in BIM communication based on years of experience ($p < 0.05$). In communication, practitioners with 2-5 years' experience showed the highest engagement in "share design models, drawings, and specifications efficiently among practitioners" (mean rank = 82.98), and "manage Requests for Information (RFIs) and responses efficiently through a centralised system" (mean rank = 79.65), while with less than 2 years were most active in "generate automated reports, including progress updates and task lists, for project tracking" (mean rank =81.55) and "maintain organised project documents, logs, and communication records" (mean rank = 81.75). Notably, engagement levels consistently decreased with increasing experience, with those over 10 years group showing the lowest participation across all communication activities (mean rank = 49.07-61.38).

Table 4.15: Significant Differences of How Different Construction Practitioners Engage Communication Based on Years of Experience

Item Code	Null Hypothesis	Mean Rank				Asymp. Sig.
		Less than 2 years	2 years but not more than 5 years	5 years but not more than 10 years	10 years and above	
C1	To share design models, drawings, and specifications efficiently among stakeholders	79.52	82.98	65.15	49.07	<0.001
C7	To generate automated reports, including progress updates and task lists, for project tracking	81.55	72.05	56.81	61.38	0.031
C8	To manage Requests for Information (RFIs) and responses efficiently through a centralised system	76.39	79.65	64.85	55.37	0.029
C9	To maintain organised project documents, logs, and communication records	81.75	74.10	61.91	55.92	0.015
C10	To facilitate repair works by sharing accurate building data from the BIM model	78.43	76.72	65.06	55.29	0.028

4.6.3 'Very Good' Proficiency Groups Lead in BIM Communication

According to Table 4.16, the Kruskal-Wallis test confirms statistically significant differences in nearly all BIM communication engagement among practitioners based on proficiency levels ($p \leq 0.005$). Practitioners with ‘Very Good’ proficiency consistently scored the highest among the most engagement in BIM communication, especially for “generate automated reports, including progress updates and task lists, for project tracking” (mean rank = 99.94) and “manage Requests for Information (RFIs) and responses efficiently through a centralised system” (mean rank = 103.28). However, two exceptions emerged where ‘Good’ proficiency scored slightly higher: “share design models, drawings, and specifications efficiently among stakeholders” (mean rank = 90.98) and “keep all stakeholders informed about project progress, variations, and milestones” (mean rank = 79.20). Meanwhile, it was clear that the gap between ‘Very Good’ and ‘Don’t Know’ proficiency was large. For example, users rating ‘Very Good’ assigned a mean rank of 103.28 to “managing Requests for Information (RFIs) and responses efficiently through a centralised system,” compared to only 33.68 from ‘Don't Know’ users.

Table 4.16: Significant Differences of How Different Construction Practitioners Engage Communication Based on Current Proficiency Levels in BIM Tools

Item Code	**Null Hypothesis**	**Mean Rank**					**Asymp. Sig.**
		Don't Know	**Poor**	**Average**	**Good**	**Very Good**	
C1	To share design models, drawings, and specifications efficiently among stakeholders	31.05	52.85	70.56	90.98	83.50	<0.001
C2	To enhance stakeholder understanding of the design concept via 3D visualisation	29.23	55.98	71.26	83.55	97.17	<0.001
C3	To enable instant notifications of design changes to on-site team members	39.77	55.81	77.69	71.80	88.11	0.004
C4	To communicate construction issues to relevant stakeholders for timely resolution	45.59	57.65	75.20	72.84	85.83	0.033
C5	To keep all stakeholders informed about project progress, variations, and milestones.	41.55	56.02	74.89	79.20	75.67	0.009
C6	To convey safety protocols and risks visually to the site workers	47.91	54.16	75.61	75.22	84.11	0.020
C7	To generate automated reports, including progress updates and task lists, for project tracking	40.14	53.27	70.83	82.36	99.94	<0.001
C8	To manage Requests for Information (RFIs) and responses efficiently through a centralised system	33.68	51.03	74.08	80.33	103.28	<0.001

C9	To maintain organised project documents, logs, and communication records	50.95	48.32	74.44	78.03	97.50	<0.001
C10	To facilitate repair works by sharing accurate building data from the BIM model	40.91	59.85	68.57	80.83	95.33	0.004

4.7 Relationship Between Collaborative and Communicative Practices in BIM Execution

Based on Table 4.17, the pairwise correlations between collaboration and communication practices in BIM execution were obtained through Spearman's rank-order correlation analysis. Notably, several significant relationships were discovered involving key collaborative practices, particularly "to enable shared access to up-to-date construction schedules" (B7), "to reduce response time in addressing defects and maintenance issues" (B9), and "to enable real-time monitoring of building systems for predictive maintenance and operational efficiency" (B10), where these practices have significant correlations with multiple communication practices.

The three key collaborative practices have been examined using the Kruskal-Wallis test on respondents' profiles, as presented in the previous Section 4.5. The analysis revealed that the practice "to enable shared access to up-to-date construction schedules" showed statistically significant differences across experience levels, with practitioners having less than two years of experience demonstrating the highest mean ranks. Additionally, significant differences were also found across BIM proficiency levels. Respondents with very good BIM proficiency consistently recorded the highest mean ranks for all three collaborative practices (B7, B9, and B10).

Similarly, Table 4.18 presents the pairwise correlations between communication and collaboration practices. Three key communication practices were identified as having significant relationships with multiple collaboration functions: "to enable instant notifications of design changes to on-site team members" (C3), "to keep all stakeholders informed about project progress, variations, and milestones" (C5), and "to generate automated reports, including progress updates and task lists, for project tracking" (C7).

These communication practices have also been tested using the Kruskal-Wallis test in the previous Section 4.6. The results showed that "to generate automated reports, including progress updates and task lists, for project tracking" differed significantly across experience levels, with the highest mean rank reported among practitioners with less than two years of experience. Furthermore, all three communication practices exhibited significant differences across BIM proficiency levels, where respondents with very good proficiency demonstrated the highest engagement in BIM communication.

In short, the collaboration practices (B7, B9, B10) and communication practices (C3, C5, C7) were found to have significant relationships across multiple variables, as indicated by their higher number of pairwise correlations. Overall, Spearman’s rank-order correlation analysis demonstrated medium-to-strong positive correlations between collaboration and communication engagement in BIM execution, ranging from 0.600 to 0.720, with all coefficients statistically significant ($p < 0.01$).

Table 4.17: Significant Pairwise Correlations Between Collaboration and Communication Practices in BIM Execution

Collaboration		Communication		Correlation Coefficient
Item Code	**Statement**	**Item Code**	**Statement**	
B2	To align client requirements across multiple disciplines.	C8	To manage Requests for Information (RFIs) and responses efficiently through a centralised system.	0.605**
B3	To enable simultaneous updates from different team members on a shared model.	C4	To communicate construction issues to relevant stakeholders for timely resolution.	0.613**
		C2	To enhance stakeholder understanding of the design concept via 3D visualisation.	0.635**
B5	To facilitate remote access to the project model between on-site and off-site.	C3	To enable instant notifications of design changes to on-site team members.	0.611**
		C7	To generate automated reports, including progress updates and task lists, for project tracking.	0.631**
B7	To enable shared access to up-to-date construction schedules.	C3	To enable instant notifications of design changes to on-site team members.	0.605**
		C10	To facilitate repair works by sharing accurate building data from the BIM model.	0.623**

		C5	To keep all stakeholders informed about project progress, variations, and milestones.	0.674**
		C9	To maintain organised project documents, logs, and communication records.	0.682**
		C7	To generate automated reports, including progress updates and task lists, for project tracking.	0.720**
B9	To reduce response time in addressing defects and maintenance issues.	C7	To generate automated reports, including progress updates and task lists, for project tracking.	0.601**
		C6	To convey safety protocols and risks visually to the site workers.	0.605**
		C5	To keep all stakeholders informed about project progress, variations, and milestones.	0.607**
		C3	To enable instant notifications of design changes to on-site team members.	0.615**
B10	To enable real-time monitoring of building systems for predictive maintenance and operational efficiency.	C10	To facilitate repair works by sharing accurate building data from the BIM model.	0.601**

	C9	To maintain organised project documents, logs, and communication records.	0.614**
	C5	To keep all stakeholders informed about project progress, variations, and milestones.	0.635**
	C3	To enable instant notifications of design changes to on-site team members.	0.645**
	C7	To generate automated reports, including progress updates and task lists, for project tracking.	0.684**
	C6	To convey safety protocols and risks visually to the site workers.	0.707**

Table 4.18: Significant Pairwise Correlations Between Communication and Collaboration Practices in BIM Execution

Communication		Collaboration		Correlation Coefficient
Item Code	**Statement**	**Item Code**	**Statement**	
C2	To enhance stakeholder understanding of the design concept via 3D visualisation.	B3	To enable simultaneous updates from different team members on a shared model.	0.635**
C3	To enable instant notifications of design changes to on-site team members.	B7	To enable shared access to up-to-date construction schedules.	0.605**
		B5	To facilitate remote access to the project model between on-site and off-site.	0.611**
		B9	To reduce response time in addressing defects and maintenance issues.	0.615**
		B10	To enable real-time monitoring of building systems for predictive maintenance and operational efficiency.	0.645**
C4	To communicate construction issues to relevant stakeholders for timely resolution.	B3	To enable simultaneous updates from different team members on a shared model.	0.613**
C5	To keep all stakeholders informed about project progress, variations, and milestones.	B9	To reduce response time in addressing defects and maintenance issues.	0.607**
		B10	To enable real-time monitoring of building systems for predictive maintenance and operational efficiency.	0.635**

		B7	To enable shared access to up-to-date construction schedules.	0.674**
C6	To convey safety protocols and risks visually to the site workers.	B9	To reduce response time in addressing defects and maintenance issues.	0.605**
		B10	To enable real-time monitoring of building systems for predictive maintenance and operational efficiency.	0.707**
C7	To generate automated reports, including progress updates and task lists, for project tracking.	B9	To reduce response time in addressing defects and maintenance issues.	0.601**
		B5	To facilitate remote access to the project model between on-site and off-site.	0.631**
		B10	To enable real-time monitoring of building systems for predictive maintenance and operational efficiency.	0.684**
		B7	To enable shared access to up-to-date construction schedules.	0.720**
C8	To manage Requests for Information (RFIs) and responses efficiently through a centralised system.	B2	To align client requirements across multiple disciplines.	0.605**
C9	To maintain organised project documents, logs, and communication records.	B10	To enable real-time monitoring of building systems for predictive maintenance and operational efficiency.	0.614**

		B7	To enable shared access to up-to-date construction schedules.	0.682**
C10	To facilitate repair works by sharing accurate building data from the BIM model.	B10	To enable real-time monitoring of building systems for predictive maintenance and operational efficiency.	0.601**
		B7	To enable shared access to up-to-date construction schedules.	0.623**

4.8 Importance of Collaboration and Communication in BIM Execution

Table 4.19 presents the mean rankings of collaboration and communication importance in BIM execution, with “improves quality control” (mean rank = 4.96) achieved the highest, followed closely by “enhances decision-making” (mean rank = 4.93) and “reduces costly errors and rework” (mean rank = 4.90). The least prioritised items were “engages non-technical stakeholders (e.g., clients) effectively” (mean rank = 4.22) and “enhances site safety” (mean rank = 3.83).

Table 4.19: Mean Rank of Importance of Collaboration and Communication

Item Code	Statement	Mean Rank	Chi-square	Asymp. Sig.
D8	Improves quality control	4.96	43.427	<0.001
D4	Enhances decision-making	4.93		
D1	Reduces costly errors and rework	4.90		
D3	Improves resource management and allocation	4.49		
D7	Enhances commitment to sustainability	4.37		
D5	Reduces project delays	4.31		
D6	Engages non-technical stakeholders (e.g., clients) effectively	4.22		
D2	Enhances site safety	3.83		

4.8.1 Architect Lead in Valuing Collaboration and Communication

The Kruskal-Wallis test resulted in Table 4.20 show statistically significant differences in how practitioners prioritise collaboration and communication benefits by professions ($p < 0.05$). Architects ranked “reduces project delays” highest (mean rank = 80.80), followed by engineers (mean rank = 73.55), while quantity surveyors (mean rank = 56.11) and chartered builders (mean rank = 54.27) assigned it lower importance to collaboration and communication in BIM execution.

Table 4.20: Significant Differences of Importance of Collaboration and Communication Based on Profession

Item Code	Null Hypothesis	Mean Rank				Asymp.
		Architect	Engineer	Quantity Surveyor	Chartered Builder	Sig.
D5	Reduces project delays	80.80	73.55	56.11	54.27	0.013

4.8.2 Non-Executives Lead in Valuing Collaboration and Communication

The Kruskal-Wallis test resulted in Table 4.21 reveal statistically significant differences in how practitioners prioritise collaboration and communication benefits by position level ($p < 0.05$). Obviously, non-executives assigned the highest priority to collaboration and communication to "improve quality control" (mean rank = 85.43), significantly more than executives (mean rank = 67.95), managers (mean rank = 53.67), and upper management (mean rank = 68.67).

Table 4.21: Significant Differences of Importance of Collaboration and Communication Based on Position Level

Item Code	**Null Hypothesis**	**Mean Rank**				**Asymp. Sig.**
		Non-executive	**Executive**	**Manager**	**Upper Management**	
D8	Improves quality control	85.43	67.95	53.67	68.67	0.025

4.8.3 Practitioners with Less Than 2 Years of Experience Lead in Valuing Collaboration and Communication

The Kruskal-Wallis test shown in Table 4.22 reveal statistically significant differences in how practitioners value collaboration and communication benefits by experience ($p < 0.05$). Practitioners with less than 2 years of experience consistently ranked the importance highest: “reduces project delays” (mean rank = 82.37), “engages non-technical stakeholders” (mean rank = 82.88), and “improves quality control” (mean rank = 79.13). These ratings declined progressively with experience, with the most experience over 10 years of assigned lowest priorities (mean rank = 60.04; mean rank = 56.93; mean rank = 57.20). The steepest decline was observed in “engages non-technical stakeholders (e.g., clients) effectively” with a difference of 25.95 between less than 2 years and over 10 years.

Table 4.22: Significant Differences of Importance of Collaboration and Communication Based on Years of Experience

Item Code	Null Hypothesis	Mean Rank				Asymp. Sig.
		Less than 2 years	2 years but not more than 5 years	5 years but not more than 10 years	10 years and above	
D5	Reduces project delays	82.37	68.72	61.13	60.04	0.038
D6	Engages non-technical stakeholders (e.g., clients) effectively	82.88	72.67	60.31	56.93	0.011
D8	Improves quality control	79.13	75.57	62.56	57.20	0.035

4.9 Practitioners' Perspectives on Collaboration and Communication

This section presents the qualitative findings obtained through the open-ended questionnaire. It captures practitioners' perspectives and experiences regarding collaboration and communication in the context of BIM execution. These insights are illustrated graphically and further discussed in the following sections.

4.9.1 Efficiency and Productivity as Major Advantages of Collaboration in BIM Execution

Bar chart 4.1 illustrates the key advantages of collaboration in BIM execution, as reported by practitioners in the survey. Efficiency and productivity emerge as the most significant benefits, making up 28% of responses, followed closely by errors and clashes reduction at 25.5%. Coordination and communication represent 20% of the advantages, while cost and time savings are agreed by 15% of respondents. Multi-disciplinary integration and problem-solving, and innovation are less prominent at 10% and 1.5% respectively.

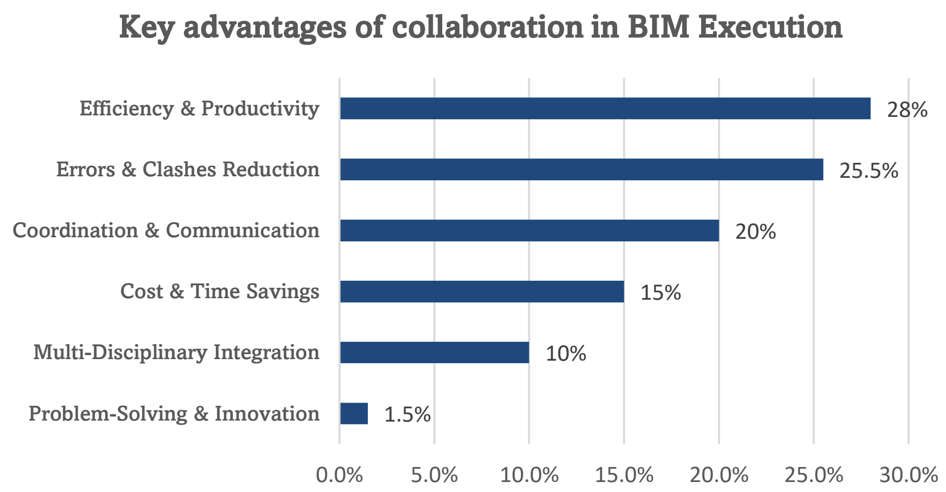

Figure 4.1: The 6 Key Advantages of Collaboration in BIM Execution

4.9.2 Meetings and Discussions as the Most Common Activities in Collaboration

Bar chart 4.2 shows how practitioners primarily collaborate using BIM, with meetings and discussions being the most common activity (25%), followed closely by clash detection and resolution (20.5%). Design coordination and review and model and data sharing, each contribute to 15%. Project documentation and RFIs represent 10% of responses, while 8% for tender and cost management. Problem-solving and brainstorming (5%), as well as site coordination and progress tracking (2%) are the least reported methods.

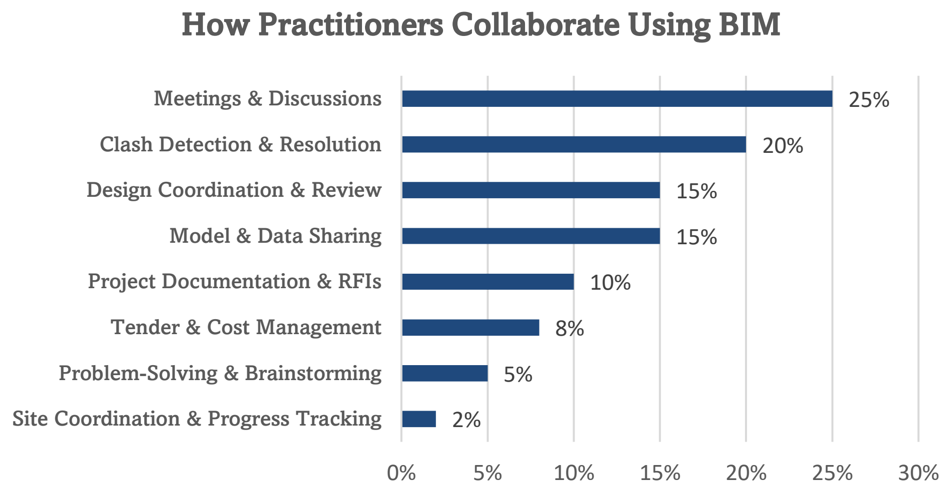

Figure 4.2: Practitioner Preferences for BIM Collaboration Activities

4.9.3 Misunderstandings and Errors Prevention as Major Advantages of Communication in BIM Execution

Bar chart 4.3 highlights the key advantages of communication in BIM execution, with survey responses showing that misunderstandings and errors prevention is the most significant benefit (33%), followed by team alignment (25.5%). Efficiency and productivity account for 18% while problem-solving and coordination contribute 15.5%. Only 9% of respondents identified rework and cost overruns mitigation as a key benefit.

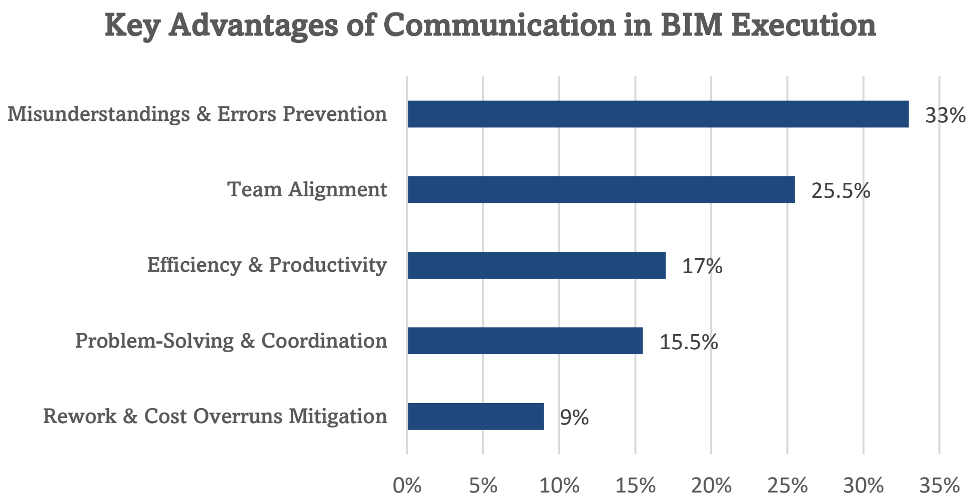

Figure 4.3: The 5 Key Advantages of Communication in BIM Execution

4.9.4 Meetings and Discussions as the Most Common Activities in Communication

Bar chart 4.4 illustrates how practitioners primarily communicate using BIM, with meetings and discussions agreed as the most common method (40%), followed by model sharing and coordination (30%). Documentation and reporting and digital communication, each contribute 15% of communication activities. Less frequent activities involve problem-solving and clarifications (10%) and site coordination and inspections (5%).

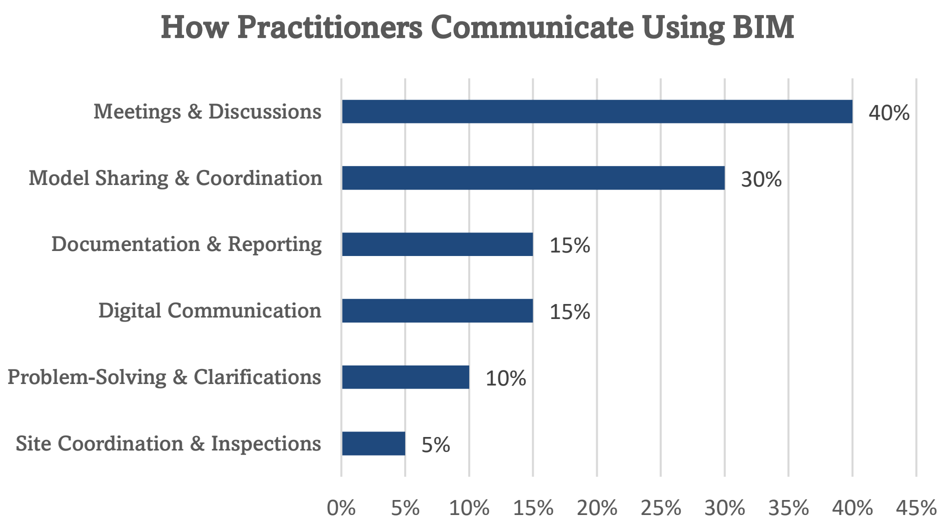

Figure 4.4: Practitioner Preferences for BIM Communication Activities

4.10 Discussion

This section highlights and interprets the main findings of the study to the research objectives. It provides deeper insights into BIM practices, particularly in the aspects of collaboration and communication, and how these practices differ across various demographic profiles. The following discussion will further explore these aspects.

4.10.1 BIM Practices Driven by the Quantity Surveying Field and Junior-Level Engagement

The findings in Section 4.4 identify project detailing, issue detection, and quantity takeoffs as the most prevalent BIM applications among practitioners. These functions directly align with core quantity surveying responsibilities, where BIM integration reduce errors and streamlines cost estimation processes. Building on this, Section 4.4.1 reveals statistically significant differences in BIM practices by professions, with quantity surveyors demonstrating leadership across all measured BIM practices, particularly in quantity takeoffs and cost monitoring, when compared to other disciplines.

As reported by Wu et al. (2014), BIM can automatically generate quantity takeoffs and measurements from a digital model, streamlining the cost preparation process compared to the manual method. By allowing automation in quantity extraction and measurement, BIM minimises human errors and enhances accuracy (Advenser, 2019). This capability is particularly crucial in the quantity surveying area where precise estimations are important. In this highly competitive bidding environment, a slight miscalculation or estimation error can result in the loss of a project.

Further analysis in section 4.4.2 demonstrates there was significant difference between BIM practices across position levels, with non-executives showing the strongest engagement with BIM in tendering activities. This suggests that BIM tasks are primarily being led by junior-level practitioners. The pattern becomes even more apparent when considering experience levels, where practitioners with less than two years of experience reported the highest involvement in BIM practices across key activities such as quantity takeoffs, documentation preparation, and tendering, with significant differences observed based on experience as presented in section 4.4.3.

Fung et al. (2014) highlighted that integrating BIM into quantity surveying education could effectively improve students' skills and knowledge related to BIM, preparing them for industry demand. It is believed that recent graduates are often exposed to BIM technology during their studies. Therefore, this aligns with why junior quantity surveyors utilise BIM more extensively than their senior colleagues.

A study by Mustapa and Jamaluddin (2022) reveals that despite being knowledgeable about BIM, many quantity surveyors hesitate to adopt it due to significant barriers, including reluctance to change. This phenomenon is particularly visible among senior-level professionals, who often perceive BIM as a threat to traditional QS practices. In contrast, younger quantity surveyors are more adaptable to technology and willing to integrate BIM into their work.

4.10.2 Collaboration Practices in BIM Execution Across Roles, Hierarchies and Experience Levels

(a) Design Coordination Is Central to BIM Collaboration

According to Section 4.5 of the findings, the most highly rated BIM collaboration practice is "visualise the impact of design modifications on construction tasks before implementation." Supporting this, Paik et al. (2020) discovered 1,662 validation and coordination issues in a real-world BIM project, highlighting that design conflicts, especially those between disciplines such as architectural, structural, and mechanical, are among the most critical challenges to project success. BIM's clash detection features allow the project team to verify conflicts between various building systems. Addressing these issues in the digital model early in the design process helps to prevent unnecessary rework during construction.

(b) Engineers Place More Emphasis on BIM Collaboration

According to Section 4.5.1 of the findings, there is a statistically significant difference indicating that engineers report the highest mean rank for collaboration practices in BIM execution, with "align client requirements across multiple disciplines" and "enable simultaneous updates from different team members on a shared model" being prioritised the most. As mentioned by Eadie et al. (2013), engineers often drive BIM adoption in projects as their work inherently requires detailed and accurate coordination across disciplines to ensure consistency and structural integrity. This is particularly relevant given the nature of engineering roles, where systems such as structural, mechanical, and electrical must be seamlessly integrated into the building's overall design framework.

(c) Executives Lead in Valuing BIM Collaboration

As shown in Section 4.5.2, the findings indicate statistically significant differences where executives consistently rated BIM collaboration practices more highly than other position levels. Due to the hierarchical structure of organisations, executives play a crucial role in shaping strategic decisions and overseeing the entire project lifecycle. This position enables them to fully appreciate BIM’s capacity to reduce errors, optimise processes, and improve overall project outcomes.

To further support this, a study by McKinsey (2021) found that 90% of executives involved in digital transformation initiatives reported that BIM adoption significantly enhances collaboration and communication. This reflects how executives perceive these practices not just as operational tools, but as essential strategies for achieving project success. When they prioritise collaborative BIM practices, it sets a precedent for the entire organisation, fostering a collaborative environment that benefits all levels of the project team.

(d) Less Experienced Practitioners Value BIM Collaboration the Most

Based on the findings from Section 4.5.3, less experienced practitioners reported the highest mean ranks in valuing BIM collaboration, with statistically significant differences observed across different experience levels. This trend could be attributed to their familiarity with BIM, early exposure through education or industrial training, and greater adaptability to emerging technologies. This is supported by a study conducted by Harris et al. (2024), which found that Malaysian Polytechnic students demonstrated moderately positive attitudes toward the use of BIM, suggesting that BIM awareness is being cultivated from the academic stage. Additionally, the study noted that young professionals with less than 10 years of experience showed a higher willingness to embrace BIM technology (Wu et al., 2021). This highlights that newer generations entering the construction industry are more inclined to leverage BIM for collaborative practices.

4.10.3 Communication Practices in BIM Ranging from Design Focus to Practitioner Experience

(a) Communication of Design Information is the Central Focus of BIM-Related Communication Practices

The findings show that design-related communication is the most prioritised aspect of BIM communication among practitioners. This is evident as the statement “to enhance stakeholder understanding of the design concept via 3D visualisation” was rated the highest overall, as shown in Section 4.6. Similarly, the statement “to share design models, drawings, and specifications efficiently” was ranked second and consistently prioritised across different professional roles and levels of experience, as presented in Sections 4.6, 4.6.1 and 4.6.2.

This trend reflects the industry’s recognition of the importance of effective communication of data and information, particularly those related to design as a key component of BIM execution. This is aligned with a study by Succar et al. (2012), which highlights that one of BIM’s greatest advantages is its ability to enhance the communication of design intent through digital models and 3D visualisations, allowing project teams to better understand and interpret design concepts.

Azhar (2011) further explains that BIM’s visualisation features enable project stakeholders, especially clients, to understand spatial relationships and key design components more easily during the early stages of the project. In this way, BIM aids in reducing misinterpretation and enables all parties to remain aligned with the design objectives.

(b) Junior-Level Practitioners Prioritise BIM Communication More Highly

According to Sections 4.6.1 and 4.6.2, the findings show a statistically significant difference, where junior-level practitioners across both position and experience levels place greater emphasis on BIM communication than senior practitioners. According to Sotelino et al. (2020), young professionals skilled in BIM are more likely to embrace digital communication tools, as they understand how to strategically utilise them to support coordination, share ideas, and clarify project goals. Their proficiency with digital platforms enables them to function effectively in multidisciplinary teams. Junior practitioners tend to exhibit these behaviours more frequently, which are essential for successful information sharing in BIM projects (Che Ibrahim et al., 2019).

4.10.4 Collaboration and Communication

(a) Moderate-to-Strong Correlation Between Collaborative and Communicative Practices in BIM Execution

The findings in Section 4.7 underscore a significant interdependence between collaborative and communicative practices within BIM execution. This is evidenced by a moderate-to-strong relationship, suggesting that better communication practices are likely to strengthen collaboration, and vice versa. This is consistence with research by RICS (2014), highlighting that BIM-enhanced communication, such as real-time updates, can contribute significantly to more collaborative project teams.

The Kruskal-Wallis test further revealed that practitioners with less than two years of experience exhibited the highest mean ranks in engaging with certain collaborative and communication practices. This suggests that younger professionals may be more willing to adopt digital technologies such as BIM, as discussed previously. Additionally, respondents with very good BIM proficiency consistently recorded the highest mean ranks across all practices, indicating that greater BIM skills are linked to stronger engagement in both collaboration and communication, which will be further discussed in the following section.

Put simply, these results emphasised the reinforcing nature of collaboration and communication when using BIM. As construction projects grow more complex and involve multiple disciplines, proficiency in utilising BIM and professional with adaptability to technology become essential in ensuring seamless coordination, faster decision-making, and improved project outcomes.

(b) Differences in BIM Benefits Arising from Collaboration, Communication, and Their Combined Implementation

Findings from the open-ended questionnaire highlighted that efficiency and productivity are perceived as the most significant benefits of using BIM for project collaboration, as shown in Section 4.9.1. One of the key contributors to this perception is BIM's ability to improve planning and design quality, thereby reducing the likelihood of rework. According to the McGraw-Hill SmartMarket Report (2014), 60% of BIM users reported shorter project durations. Barlish and Sullivan (2012) further emphasised that when the design and construction processes can be fully visualised and simulated, project teams are able to make decisions more quickly and with greater confidence. These insights suggest that BIM is not merely viewed as a design tool, but also as a collaborative platform that streamlines project delivery.

In terms of communication, Section 4.9.3 presents additional findings from the open-ended responses indicating that respondents view BIM as most useful in reducing misunderstandings and errors. This aligns with research by Huang et al. (2022), which highlights that BIM facilitates real-time interaction and information sharing among professionals in the AEC industry. Through the centralisation of project data, BIM ensures that all stakeholders are working with consistent and up-to-date information. This reduces miscommunication and allows the project team to resolve early potential conflicts, such as design clashes, before they escalate into costly problems during construction.

When examining both collaboration and communication together, the results from the closed-ended questionnaire highlight a strong emphasis on quality control as a key benefit, as presented in Sections 4.8. This benefit was recognised consistently across various roles, hierarchies, and experience levels, suggesting that quality is a highly prioritised concern in construction projects, and it relies heavily on clear coordination and communication between project teams.

Supporting this perspective, Francom and El Asmar (2015) emphasised that projects with BIM experience fewer design changes, higher-quality outcomes and long-term cost savings by reducing defects and warranty issues. Further reinforcing these findings, Ramadan (2023) highlights that BIM creates a unified platform for all professionals involved in a project, ensuring alignment with quality standards and expectations. By integrating BIM into project workflows, it allows for validation and compliance checks at the early stages.

The differences in benefits between collaboration, communication, and their combined application in BIM arise as each plays a unique role in project execution. Collaboration centres on shared goals, mutual engagement and decision making, but can be ineffective as not everyone stays informed in real time (Um and Kim, 2019). In contrast, communication ensures information is clear and up to date (RICS, 2014) yet may lead to misalignment without collaboration. When both are integrated, BIM not only facilitates teamwork but also supports well-informed decisions, leading to better project outcomes. This perspective is supported by Gu and London (2010), who emphasised that projects lacking either aspect often face fragmented workflows, while combining both fosters alignment, reduces misunderstandings, and improves overall performance.

(c) Architects Prioritise the Importance of Collaboration and Communication

The result presented in 4.8.1 indicates that architects place a higher value on collaboration and communication in BIM execution compared to other practitioners. Typically, architects serve as lead consultants, a role that necessitates continuous communication with a wide range of stakeholders, including clients, engineers, contractors, and local authorities, to align the design intent, building regulations, and project schedules.

Meanwhile, it is also observed that architects tend to prioritise its importance in terms of reducing project delays. This can be attributed to the iterative nature of the design process, where architects rely on timely feedback from other disciplines to effectively develop and finalise the design. If the design is not well-coordinated, it may lead to revisions, which can delay approvals.

(d) Junior-Level Practitioners Have Greater Reliance on Collaboration and Communication

The findings in Sections 4.9.2 and 4.9.3 indicate that junior-level practitioners, both in terms of position and years of experience, place more importance on collaboration and communication in BIM execution compared to their upper-tier practitioners, with statistically significant differences. As observed by Chen et al. (2022), junior practitioners demonstrate a stronger willingness to adopt digital tools like BIM and actively seek feedback and guidance from senior colleagues or mentors to improve their understanding. By getting input from more experienced team members, they can compensate for their limited experience with complex project scenarios.

(e) Meetings & Discussions Are Being Prioritised in BIM Collaboration and Communication

According to Sections 4.9.2 and 4.9.4, the findings indicate that meetings and discussions are the most frequently practiced activities in both collaboration and communication when using BIM. Effective BIM implementation does not rely solely on technology; however, human interaction like regular face-to-face or virtual interactions is essential to enable the proactive use of BIM for problem-solving and reducing miscommunication.

These findings align with research by Dossick et al. (2009), who highlight that in BIM-enabled projects, co-location and regular meetings play a critical role in fostering team alignment and open communication, which in turn enhance collaboration. Through regular meetings and discussions, project teams can identify and resolve potential clashes or design conflicts, track project progress, and discuss changes more effectively, particularly with the aid of BIM's visual and interactive models.

(f) BIM Proficiency as a Determinant of BIM Practices, Collaboration, and Communication

Based on Sections 4.4.4, 4.5.4, and 4.6.3, the findings reveal statistically significant differences in all BIM practices, collaboration engagement, and communication engagement. This collectively suggests that the level of BIM proficiency is an important factor for better practices, collaboration, and communication in the construction industry.

The findings are consistent with past research by Gerges et al. (2017), who found that professionals with strong BIM skills are more likely to utilise BIM tools effectively, adopt integrated workflows, and collaborate efficiently across multidisciplinary teams. Additionally, effective collaboration and communication are fundamental to BIM-driven projects, where real-time updates and accurate information exchange among stakeholders are critical to successful project delivery (Azhar, 2011). If BIM features are underutilised by those with limited BIM skills, it may lead to fragmented workflows and communication barriers that hinder project coordination.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction

This chapter presents the overall conclusions drawn from the study and highlights the extent to which the research objectives have been achieved. It further discusses the research implications for the industry, education, research, and policymakers. In addition, this chapter outlines the limitations encountered during the study, provides recommendations for future improvements, and suggests possible directions for further research, building upon this study.

5.2 Accomplishments of Objective

BIM has been identified as a critical tool in improving collaboration and communication within the construction industry, addressing challenges associated with fragmented information and poor coordination. However, this research was conducted to examine how different construction practitioners apply BIM in their practices. Through a comprehensive literature review and data analysis, all three research objectives were successfully achieved, which are summarised in the following sections.

5.2.1 Objective 1 - To compare the practices of different construction practitioners in BIM execution

The first objective was achieved through a comprehensive literature review, which identified BIM practices adopted by various construction practitioners across the design, construction, and post-construction phases. Eight key practitioner groups were examined, including owners, architects, engineers, contractors, quantity surveyors, building merchants, specialists, and facility managers. The results revealed that "to enable detailing" was the most agreed-upon BIM practice among practitioners. Additionally, statistically significant differences in BIM practices were found across several demographic profiles, particularly profession, position level, years of experience, and BIM proficiency. For example, quantity surveyors, less experienced practitioners, and those with higher BIM proficiency tended to place greater importance on BIM practices.

This indicates that while BIM practices are widely implemented, the extent and manner of their application different depending on the practitioner's role and background. Therefore, demographic factors play a crucial role in shaping how BIM is perceived and executed across the industry.

5.2.2 Objective 2 - To examine how practices of different construction practitioners engage the collaboration in BIM execution

The second objective was accomplished through a literature review that explored how construction practitioners engage in BIM-enabled collaboration. The review identified key collaborative tools and methods such as Industry Foundation Classes (IFC), central model servers, cloud computing, and mixed reality tools, with benefits including interdisciplinary integration, improved simulation, analysis, and visualisation, enhanced model progression, exchange of expertise, and better coordination between field and office tasks. The analysed data revealed that the most frequently practised form of collaboration was “visualising the impact of design modifications on construction tasks before implementation.” Statistically significant differences in collaboration practices were observed across roles, hierarchies, and levels of experience. This form of collaboration tended to be valued particularly by engineers, executive-level staff, less experienced practitioners, and those highly proficient in BIM tools. Another finding is that collaboration showed significant correlations with communication, particularly in “enabling shared access to up-to-date construction schedules,” “reducing response time in addressing defects and maintenance issues,” and “enabling real-time monitoring of building systems for predictive maintenance and operational efficiency,” with these elements pairing closely with several communication practices. These correlations suggest that for BIM environment to support effective collaboration, communication must be timely, accessible, and well-integrated. Efficiency and productivity were perceived as the primary advantages of collaboration using BIM, and practitioners agreed that meetings and discussions were the most commonly practised collaborative activities within BIM environments.

5.2.3 Objective 3 - To study how practices of different construction practitioners engage the communication in BIM execution

The third objective was achieved through a literature review that identified how construction practitioners engage in BIM-enabled communication. Through these reviews, key communication applications found include integrated BIM environments, central models, common data environments, and cloud platforms, along with its benefits such as centralised communication, enhanced information transfer, accommodation of various data types, improved issue resolution, better discussion processes, reduced paperwork, real-time updates, clearer project coordination. The results highlighted that the most common communication practice was "enhancing stakeholder understanding of the design concept via 3D visualisation," indicating a strong focus on design-related communication. Statistically significant differences were observed across position levels, years of experience, and BIM proficiency, suggesting that less experienced practitioners and those having higher BIM proficiency appreciated the communication practices in BIM execution. The findings also show that communication has significant relationships with multiple collaboration practices, including "enabling instant notifications of design changes to on-site team members," "keeping all stakeholders informed about project progress, variations, and milestones," and "generating automated reports, including progress updates and task lists, for project tracking." Meanwhile, collaboration and communication showed a moderate-to-strong correlation, ranging from 0.600 to 0.700, indicating that they require to reinforce each other throughout the BIM execution. Among these advantages, practitioners rated the prevention of misunderstandings and errors as the most significant benefit of communication, while meetings and discussions were the most commonly practised activities, similar to collaboration. When examined together, the findings conclude that the integration of collaboration and communication in BIM execution leads to enhanced project quality control, demonstrating their joint role in supporting more successful project outcomes.

5.3 Research Implications

This research provides meaningful implications across several key areas, which are industry, university, research and policymaker. For the construction industry, firms are encouraged to invest more in BIM adoption through training programs, workshops, and seminars that focus not only on improving software proficiency but also on strengthening collaboration and communication practices. The research suggests that firms should actively train younger practitioners, who have shown a greater tendency to embrace BIM technologies, while also providing continuous support for senior practitioners to overcome resistance to digital tools. Practising collaboration and communication in daily BIM workflows, where team members work in synergy, can significantly transform project delivery and improve overall project outcomes.

The research serves as an indicator for tertiary education institutions to update and expand BIM-related content within built environment programs. While universities currently teach students how to use BIM tools, they should also incorporate collaborative and communication-based assignments where students from different programs, such as architecture, engineering, quantity surveying, and construction management, jointly solve problems using BIM platforms. This approach prepares graduates with practical, real-world experience, where interdisciplinary teamwork and digital collaboration are essential. It is believed that graduates will be better equipped to transition smoothly into the workplace, minimising the gap between academic learning and industry practice.

Furthermore, the research provides valuable insights into how different construction practitioners apply BIM in their work, particularly for collaboration and communication. By examining demographic profiles such as profession, position, experience, company’s business activities, and proficiency, the research indicates that not all practitioners use BIM in the same way. Therefore, these findings provide a foundation for future research, where longitudinal studies, detailed case studies, and cross-country comparisons should be conducted. Such studies can explore how BIM maturity, skills, and practices evolve across different groups and regions over time. In addition, targeted strategies should be studied in enhancing BIM collaboration and communication, especially for groups which currently participate less.

Also, the findings provide strong evidence for policymakers to develop more effective BIM adoption strategies at the national and industry levels. It suggests that policymakers should formulate national BIM execution plans that establish national BIM standards that particularly cover communication and cooperation guidelines, ensuring that all stakeholders operate from common digital frameworks. The research further recommends introducing policies such as tax benefits or subsidies to encourage firms, particularly small and medium enterprises (SMEs), to adopt BIM technologies. Moreover, the findings highlight the need for mandatory BIM training certifications that require practitioners to demonstrate competence not only in technical proficiency but also in collaborative and communicative aspects of BIM application.

5.4 Research Limitations and Recommendations

Throughout the study, several limitations were encountered. First of all, the constrained timeframe restricted the opportunity to collect more extensive data, which could have uncovered deeper insights. Besides, it is believed that the sample size remains insufficient, as the survey should have covered more respondents. Additionally, the targeted respondents were found to be limited, covering mainly four professions (i.e., architect, engineer, quantity surveyor, and chartered builder). Furthermore, the research did not examine BIM practices across different company sizes and project types, which could provide a better understanding of how BIM adoption and usage vary depending on organisational scale and project complexity.

By reflecting on the limitations mentioned above, several recommendations are proposed for future studies. Firstly, it is recommended to seek more respondents to enhance the generalisability of the findings. Besides, the survey should cover a wider range of construction practitioners from different backgrounds, such as suppliers, subcontractors, and government agencies, to gain more diverse perspectives on BIM-related applications. Moreover, comparative studies should be extended to other countries or regions to examine how cultural, regulatory, and technological differences influence practices, collaboration, and communication in BIM execution.

5.5 Future Research

To further build upon this study, several directions are recommended. A critical area for exploration is the adoption of BIM among SMEs, which make up a large part of the construction sector, by examining the challenges they face, such as limited financial resources, lack of technical expertise, and insufficient regulatory support, and by identifying strategies to encourage wider BIM implementation among these firms. As most research focuses on building projects, it is also suggested to investigate BIM applications in infrastructure projects, where collaboration and communication among disciplines such as civil, structural, and geotechnical engineering are critical. While technical aspects of BIM have been widely explored, future research should also address human factors, including resistance to change, leadership, team dynamics, and organisational culture, which significantly influence the success of BIM implementation.

5.6 Summary

In summary, this chapter has concluded the key findings of the study by ensuring the accomplishments of the research objectives, outlining the broader implications of the study, and identifying the study’s limitations. Recommendations have been discussed to improve the study’s outcome, and potential areas for future research were suggested to build upon the current findings. Overall, the study contributes to a deeper understanding of how construction practitioners practise BIM in their work, particularly in collaboration and communication aspects, providing valuable insight that can guide the industry practices for more integrated project delivery environment.

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APPENDICES

Appendix A: Questionnaire

BIM-ENABLED COLLABORATION AND COMMUNICATION IN THE CONSTRUCTION INDUSTRY: A COMPARATIVE STUDY OF THE PRACTICES AMONG CONSTRUCTION PRACTITIONERS

Dear Sir/Madam,

I am Ong Jun Yuan, final year student from Universiti Tunku Abdul Rahman (UTAR) Sungai Long Campus undertaking the course of Bachelor of Science (Honours) Quantity Surveying. Currently, I am working on my Final Year Project entitled "BIM-enabled collaboration and communication in the construction industry: A comparative study of the practices among construction practitioners". The objective of this research is to compare the practices of different construction practitioners in BIM execution, to examine how practices of different construction practitioners engage the collaboration in BIM execution and to study how practices of different construction practitioners engage the communication in BIM execution.

The questionnaire consists of six (6) sections:
Section A: Practices of Different Construction Practitioners
Section B: How Different Construction Practitioners Engage Collaboration
Section C: How Different Construction Practitioners Engage Communication
Section D: Importance of Collaboration and Communication
Section E: Practitioners' Perspectives on Collaboration and Communication
Section F: Demographic Information

This survey will take approximately 5 to 10 minutes to complete. Please be assured that there will be no attempts to disclose your identity throughout this study. All the data will be used purely for academic purpose and will be strictly anonymous.
I believe that your relevant experience and expertise in construction industry are

useful for this research. Your contribution in this survey will be significant for the project and will simulate the development of construction industry. Please do not feel hesitate to contact me at ojy1313@1utar.my if you have any queries about this survey.

Thank you for your participation and time.

Faithfully,
Ong Jun Yuan

Introduction to BIM

Building Information Modelling (BIM) is a digital process that combines 3D modelling with comprehensive information management to create and manage data about a building or infrastructure project throughout its lifecycle. It enhances collaboration and communication among architects, engineers, and contractors, improving decision-making, accuracy, and efficiency in construction projects.

Section A - Practices of Different Construction Practitioners

How frequently do you use Autodesk Revit, Navisworks, BIM 360, IBM Maximo or other BIM-enabled software to perform the following tasks?

	Never	Rarely	Sometimes	Often	Always
To detect potential issues of the project.					
To enable scheduling for the project.					
To enable detailing for the project.					
To perform quantity takeoff.					
To prepare the construction documentations.					
To perform tendering.					
To track the project variation.					
To track the construction progress.					
To monitor the project cost.					
To perform quality checking.					

Section B - How Different Construction Practitioners Engage Collaboration

To what extent does your project team rely on Autodesk Revit, Navisworks, BIM 360, IBM Maximo or other BIM-enabled software in collaboration?

	Never	Rarely	Sometimes	Often	Always
To identify potential design conflicts by clash detection tools.					
To align client requirements across multiple disciplines.					
To enable simultaneous updates from different team members on a shared model.					
To facilitate off-site prefabrication.					
To facilitate remote access to the project model between on-site and off-site.					
To improve site coordination by providing real-time access to construction models.					
To enable shared access to up-to-date construction schedules.					
To visualise the impact of design modifications on construction tasks before implementation.					
To reduce response time in addressing defects and maintenance issues.					
To enable real-time monitoring of building systems for predictive maintenance and operational efficiency.					

Section C - How Different Construction Practitioners Engage Communication

To what extent does your project team rely on Autodesk Revit, Navisworks, BIM 360, IBM Maximo or other BIM-enabled software in communication?

	Never	Rarely	Sometimes	Often	Always
To share design models, drawings, and specifications efficiently among stakeholders.					
To enhance stakeholder understanding of the design concept via 3D visualization.					
To enable instant notifications of design changes to on-site team members.					
To communicate construction issues to relevant stakeholders for timely resolution.					
To keep all stakeholders informed about project progress, variations, and milestones.					
To convey safety protocols and risks visually to the site workers.					
To generate automated reports, including progress updates and task lists, for project tracking.					

To manage Requests for Information (RFIs) and responses efficiently through a centralised system.					
To maintain organised project documents, logs, and communication records.					
To facilitate repair works by sharing accurate building data from the BIM model.					

Section D - Importance of Collaboration and Communication

Please rate each item based on its importance to your business organisation.

	Never	Rarely	Sometimes	Often	Always
Reduces costly errors and rework.					
Enhances site safety.					
Improves resource management and allocation.					
Enhances decision-making.					
Reduces project delays.					
Engages non-technical stakeholders (e.g., clients) effectively.					
Enhances commitment to sustainability.					
Improves quality control.					

Section E - Practitioners' Perspectives on Collaboration and Communication

Please share your perspective/ experience in the following questions.

1. Do you agree that the collaboration is important? Why?
2. What are your usual activities you engage in collaboration?
3. Do you agree that the communication is important? Why?
4. What are your usual activities you engage in communication?

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

1) Profession.

activities?

○ Architect

○ Engineer

○ Quantity Surveyor

○ Chartered Builder

○ Other (Please specify): _______________

2) Position Level.

○ Non-executive

○ Executive

○ Manager

○ Upper Management

○ Other (Please specify): _______________

3) Years of Experience in Construction.

○ Less than 2 years

○ 2 years but not more than 5 years

○ 5 years but not more than 10 years

○ 10 years and above

4) Organisation's Main Business Activities.

○ Construction Businesses

○ Consultancy

○ Property Development

○ Other (Please specify): _______________

5) Current Level of Proficiency in Using BIM Tools.

○ Do not know

○ Poor

○ Fair

○ Good

○ Very Good

<u>Consent of Participation</u>

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

1) You understand that if you have any additional questions, you can contact ojy1313@1utar.my.

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 azwani@utar.edu.my.

4) You agree to participate in this survey voluntarily.