CHAPTER 3

RESEARCH METHOD

3.1 Introduction

This chapter describes the procedure used to assess the adoption dynamics of BIM technology within the Ghanaian construction industry and provides a framework for its successful adoption. It offers an overview of the methods, including research design, participant selection, population and sample, research instruments, data analysis techniques, and ethical considerations. It is essential to use appropriate methods that provide meaningful insights (Vanderstoep & Johnson, 2008). The selected research methods are crucial to achieving the study’s objectives. This chapter, therefore, highlights the careful and systematic planning and rigorous methodology employed to ensure the study's validity, reliability, and ethical integrity.

3.2 Research Philosophy

A research philosophy is fundamental to all research, as it explores the nature and development of Knowledge (Creswell, 2012). It encompasses the underlying assumptions that guide the selection of methodologies employed in a study (Kreuger Neuman, 2006). These assumptions influence the justification and validation of research findings (Flick, 2015). Saunders et al. (2012) introduce multiple research philosophies in their "research onion" model, including positivism, realism, interpretivism, objectivism, subjectivism, and pragmatism. Some scholars categorise research philosophy into three broad domains: ontology, epistemology, and pragmatism (Kreuger & Neuman, 2006).

Ontology concerns the nature of reality and includes realism and subjectivism, while epistemology relates to the nature of Knowledge and is often linked to positivism and interpretivism (Creswell, 2012). On the other hand, pragmatism serves as the foundation for mixed-methods research, as it accommodates both quantitative and qualitative approaches in the pursuit of Knowledge (Ivankova & Creswell, 2009).

Given the objective of this study, which is to assess the adoption dynamics of BIM in Ghana's construction industry, this research adopts a pragmatist philosophy.

Pragmatism is particularly suitable for this study because it prioritizes practical solutions over rigid philosophical stances, allowing for a combination of qualitative and quantitative methods to derive critical insights. Since the study employs an exploratory sequential mixed-methods approach, pragmatism ensures that both objective statistical data and subjective experiential insights are considered, thereby enhancing the depth and applicability of findings.

The choice of pragmatism aligns with the research objectives by allowing the flexibility to explore perceptions, challenges, and factors influencing BIM adoption through qualitative interviews while also quantifying these insights through structured surveys. This philosophical stance ensures that both theoretical exploration and empirical validation contribute to the study, ultimately providing well-rounded conclusions that are both contextually relevant and statistically sound.

Pragmatism allows the study to flexibly use qualitative findings to inform the design of the survey while also permitting the quantitative results to validate, refine, or even challenge the qualitative insights. In cases where discrepancies arise between qualitative and quantitative results, pragmatism provides a bridging lens: rather than prioritizing one over the other, it acknowledges that each offers partial insights into the complex phenomenon of BIM adoption. Through triangulation and integration, both forms of evidence are combined to construct a more comprehensive and practically relevant understanding.

3.3 Research Design

A research design refers to a systematic approach used to collect and analyse data to logically accomplish a study's objectives and increase the general understanding of the phenomenon (Sileyew, 2019). The selection of an appropriate research design is of utmost importance for the successful execution of this study. The study employs a mixed-methods, non-experimental interpretive research approach that integrates both qualitative and quantitative research techniques. Using a mixed-methods approach in this research ensures the inclusion of diverse and in-depth perspectives and opinions of the target population, thereby facilitating a broad understanding of the research phenomenon (Creswell, 2014).

The decision to use a mixed-methods research strategy is driven by the study's objectives and the need to get an in-depth understanding of the dynamics surrounding the adoption of BIM. By leveraging the advantages of both qualitative and quantitative approaches, a mixed research design enhances the depth of the study findings, making it particularly suitable for investigations seeking to analyse the phenomena from several viewpoints. Specifically, the exploratory sequential mixed method (Figure 3. 1) was used for this research. The research draws on the concept of sequential developmental methods as outlined by Bazeley (2018). This approach involved an initial phase of designing the qualitative data collection tool. The findings from this phase then guided the design of a second phase for quantitative data collection and analysis.

The initial phase of collecting and analysing qualitative data entailed conducting in-depth interviews to gain a deep understanding of the research subject and employing the underlying themes to guide the development of a quantitative instrument. Research methodology experts concur that the qualitative approach is most appropriate for the deep exploration of a problem that necessitates an extensive understanding of a central phenomenon, such as the adoption of BIM in Ghana's construction industry for which the variables are varied, subjective, and multifaceted (Creswell, 2014; Creswell & Clark, 2017; Seale, 2017). Additionally, the qualitative methods allowed a deeper analysis of the language representing thoughts, perspectives, and behaviours (Leech & Onwuegbuzie, 2009). Subsequently, the quantitative phase focused on collecting and analysing quantitative data through administering survey questionnaires with Likert-type bounded descriptor question items that limited expression and choice. The study collected data to examine frequency distribution, central tendency, variability, and significance tests, as well as to verify the reliability of the survey instrument. A quantitative method was employed to explore the frequency and magnitude of different elements and potential connections.

The research integrated findings from these two approaches. This integration involved condensing key findings from each method, examining patterns, establishing connections between variables through statistical analysis, and ultimately interpreting the overall outcomes (Creswell, 2015). The convergence of several sources of evidence enhances the study's reliability and the accuracy of the findings (Creswell & Clark, 2017).

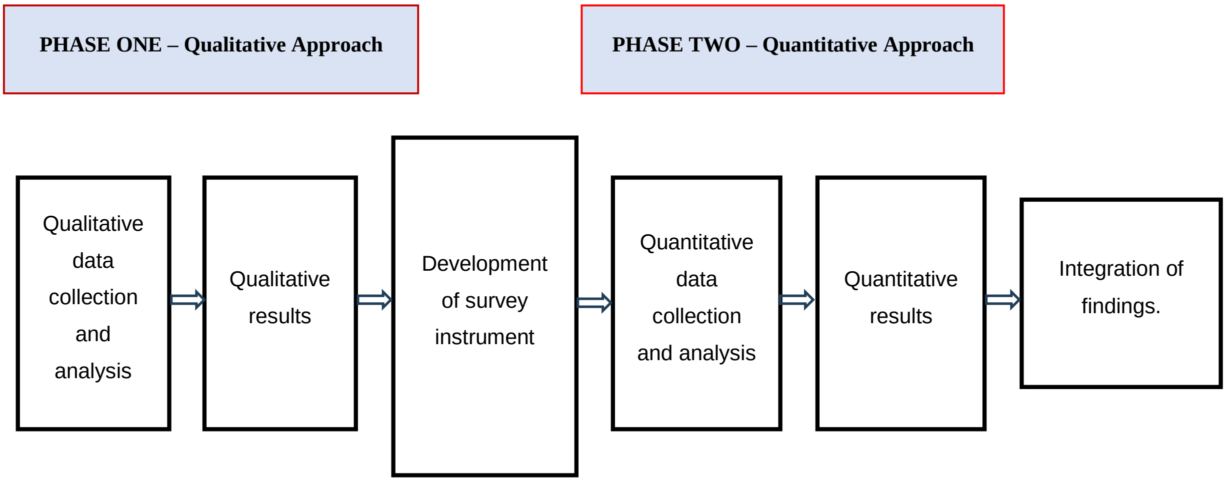

Figure 3. 1 Exploratory sequential mixed methods research design

3.4 Participants

The study participants, both for the quantitative and qualitative research phases, represented a diverse range of Ghana's construction industry stakeholders. The careful selection of these participants aimed to include diverse perspectives and insights to attain the study's stated objectives. The participants in the study belong to diverse categories, and each brings a distinct perspective to the study. They include professionals in the construction industry, such as architects, engineers, quantity surveyors, project managers, and contractors, who offer a wealth of first-hand experience and specialised knowledge about various aspects of construction project delivery. Their viewpoints were of the utmost significance in addressing the study's objectives of investigating BIM awareness, Knowledge, and integration. Moreover, their responses were highly relevant to the study of the effects of BIM on project performance. To access a wider network of professionals with BIM experience, bodies such as the Ghana Institute of Architects (GIA), Ghana Institution of Engineers (GhIE), Ghana Institution of Surveyors (GhIS), Institution of Engineering and Technology Ghana (IET) and the Association of Building and Civil Engineering Contractors of Ghana (ABCECG) were contacted for a list of members with valuable perspectives.

Government officials and Policymakers in the Ministry of Works and Housing in Ghana, who represent influential statutory regulatory agencies, provided indispensable insights into regulatory environment instituted to promote widespread BIM adoption in construction. Finally, clients and project owners, a mix of public and private sector stakeholders, constituted an additional component of the participants. Their role in shaping the trajectory of BIM adoption in construction projects is crucial. The perspective of this group is essential to understanding the demand for BIM integration and its ensuing impact on project outcomes.

3.5 Qualitative Research Phase

3.5.1 Participants

The qualitative phase of this study involved a total of twenty-one (21) interviewees selected from key stakeholder groups within Ghana's construction industry. These participants were categorized into three main groups: government officials, clients, and industry experts/consultants. Each group played a significant role in providing insights on BIM adoption, industry challenges, and strategic implementation efforts.

The first category comprised four (4) government officials (GO), who were selected based on their positional authority and involvement in policy formulation related to the construction industry. These officials provided valuable insights into government regulations, policy frameworks, and national strategies influencing BIM adoption. Their insights were crucial in understanding the level of government support, regulatory challenges, and potential policy interventions aimed at fostering BIM adoption.

The second category consisted of six (6) clients (C) drawn from both the public and private sectors. These participants were actively involved in construction projects that incorporated BIM workflow. Their perspectives were essential in assessing demand for BIM, investment considerations, project outcomes, and the practical challenges faced. Since clients drive technology adoption by setting project requirements, their contributions helped evaluate how BIM influences decision-making.

The largest group of participants included eleven (11) industry experts and consultants (IE). This group comprised representatives from recognized professional bodies such as the Ghana Institute of Architects (GIA), Ghana Institution of Engineers (GhIE), Ghana Institution of Surveyors (GhIS), Institution of Engineering and Technology Ghana (IET), and the Association of Building and

Civil Engineering Contractors of Ghana (ABCECG). These experts were selected for their specialized knowledge, extensive experience, and active involvement in BIM use. Their insights were instrumental in examining industry readiness, technological barriers, professional expertise, and best practices related to BIM adoption.

The categorization of interviewees ensured a diverse range of perspectives, allowing the study to capture multi-stakeholder viewpoints on BIM adoption. Additionally, they provided an in-depth understanding of the factors influencing BIM adoption in Ghana's construction sector, highlighting the associated opportunities and challenges.

3.5.2 Research Procedure

This phase was motivated by the need to explore diverse experiences of industry practitioners, uncover challenges and identify factors influencing the adoption process.

Semi-structured interviews were used to gain insights into BIM adoption and inform the development of quantitative survey instruments for this research. By employing semi-structured interviews as the primary data collection method, the study capitalises on their strength in uncovering deeper insights into participants' experiences and perceptions (Silverman, 2017). The choice aligns with the interpretive approach, which emphasises understanding the subjective realities of individuals within their specific contexts (Brinkmann & Kvale, 2015). This approach was suitable for obtaining insights into stakeholders' awareness, knowledge, and readiness for BIM adoption. It enables the exploration of challenges and opportunities in integrating BIM into project delivery processes (Merriam & Tisdell, 2015).

These interviews were recorded with the participant’s consent to capture the complete depth of the discourse. Subsequently, a textual record was derived from the recording through verbatim transcription.

3.5.2.1 Research Instruments

A carefully crafted interview guide based on existing literature on BIM was used to investigate the participants' perspectives on various aspects of BIM adoption. The interview guide developed for industry experts and consultants featured essential components that encompass various aspects of the study, including assessing participants' awareness and knowledge of BIM and organisational and technological readiness within their respective fields. Key factors influencing the adoption of BIM, both in terms of driving forces and challenges, and the potential effects of BIM on project performance were also explored. The interview guide was structured to ensure insightful responses. The questions were formulated to elicit thoughtful and relevant responses, guided by the research objectives to guarantee the thorough inclusion of perspectives.

The interview guide for clients comprised a set of well-crafted questions designed to explore the clients' perspectives on the factors that influence the integration of BIM in projects which they are involved. They were specifically formulated to gain a broad understanding of the perspectives and experiences of the clientele.

Similarly, the guide includes interview questions formulated to explore policy-related facets, aiming to gather perspectives on the Government's role and influence in facilitating the adoption of BIM within the construction industry. These questions were tailored to solicit the views of government officials working with agencies of the Ministry of Works and Housing.

3.5.2.2 Interview Guide Validation

The interview guidelines used in this study were evaluated and validated by experts with extensive knowledge and experience in the use of BIM in the construction industry. The comments from the evaluators served as valuable feedback to improve and ensure that the interview questions are effectively designed to align with the research objectives. The careful steps taken to ensure the accuracy and consistency of the interview guide enhanced this study's strength. The rigorous procedures applied to the research instruments, including content validation, expert review, and reliability assessments, were employed to improve the precision in capturing the intended insights and ensure consistent measurement of participants' views. Incorporating these procedures enhanced the reliability and integrity of the study's outcomes, thereby strengthening the overall methodological strength of the research.

3.5.2.3 Qualitative Data Collection

Clear communication of the study's objectives and interview procedures was made to promote informed participation. The interviews were conducted according to the participants' preferences, allowing them to choose between in-person and online formats. The online interviews were conducted remotely via Zoom, a practical and effective method necessitated by the geographical dispersion of the researcher and participants. This ensured accessibility and flexibility while preserving the depth and richness of face-to-face interactions. On average, each session lasted approximately 25 minutes, allowing participants to articulate their experiences and insights.

Generally, data collection was conducted with a solid commitment to maintaining ethical standards. Each participant was presented with a request for informed consent, ensuring they thoroughly understood the scope and purpose of the research. The maintenance of participant anonymity was emphasised, fostering greater trust between the researcher and participants. All collected data were administered and stored with utmost care. Subsequently, it was meticulously transcribed and coded to enable a broad thematic analysis.

3.5.3 Qualitative Data Analysis

The data from the interviews were subjected to thematic analysis using NVivo, a qualitative data analysis software. NVivo was specifically used for verbatim transcription, systematic coding, and organizing data into categories and themes. This allowed for efficient retrieval, comparison, and refinement of coded data, enhancing the transparency and rigor of the analysis. The procedure is known for its effectiveness in identifying patterns, trends, and overarching themes within textual materials. The identified themes provided the foundation for subsequent interpretation and conclusion (Clarke & Braun, 2013).

The process commenced with a phase of data familiarisation, where the transcribed narratives were thoroughly examined to allow for a deep understanding of their fundamental nature and the identification of initial ideas. Subsequently, a systematic categorisation process was carried out in which recurring ideas and concepts from the interviews were identified and coded in NVivo. These codes were then grouped into potential patterns and sub-themes based on their relationships and aligned with the research's focal area. The identified sub-themes were iteratively reviewed and refined to ensure coherence and clarity.

Through this rigorous process, five predominant themes were identified regarding industry stakeholders' perception of BIM adoption in Ghana's construction industry. The initial findings were further analysed using existing BIM adoption literature to explore themes related to BIM awareness and knowledge among industry stakeholders, industry readiness for BIM, drivers and challenges of adoption, impact of BIM adoption on project outcomes, and strategies for effective BIM adoption in Ghana’s construction industry.

3.6 Quantitative Research Phase

3.6.1 Population and Sample

The population for this quantitative research comprised approximately 2,734 AEC firms in Ghana, with 16,589 industry professionals (Table 3. 1) who were in good standing with their respective professional associations and actively engaged in the Industry (GSS, 2021). These professionals, including architects, engineers, quantity surveyors, and construction managers, were directly involved in construction projects, making their insights essential for understanding the factors influencing BIM adoption in Ghana's construction industry. Their inclusion ensured a broad assessment of industry perspectives on the subject.

Table 3. 1 Population of construction professionals in Ghana

SN	AEC Professional Body	No. of Firms	Members
1	Ghana Institute of Architects	73	1275
2	Ghana Institution of Engineers	71	1657
3	Institution of Engineering and Technology, Ghana	NA	1460
4	Ghana Institution of Surveyors	90	1693
5	Association of Building and Civil Engineering Contractors of Ghana	2500	NA

Source: *Author's compilation from membership directories of professional bodies (2025)*

3.6.1.1 Sample Size Determination

It was necessary to select a sample from the broader population to ensure the practicality and ease of management of the research process. According to Creswell (2014), sampling is the method used to select units from a population for participation in the data collection stage of a research study. Strategic sampling techniques in this study ensured that the obtained insights closely aligned with the research objectives, enhancing validity and applicability (Quinlan et al., 2019). The study employed a careful sampling procedure to guarantee the inclusion of participants who accurately reflect the characteristics and represent the population. The sample size formula devised for a finite population is stated as follows (Kadam & Bhalerao, 2010):

$$n = \frac{c^2 N p(1-p)}{(A^2(N-1) + (c^2 p[1-p])}$$

Where **n** is the sample size, **N** is the target population in question, **p** denotes the average percentage of AEC professionals who fulfil the inclusion requirements, (1-p) represents the average percentage of AEC professionals who are not anticipated to satisfy the requirements, and **A** denotes the allowable margin of error (calculated as a proportion). The confidence intervals selected determine the mathematical constant **C.** The targeted population (**N**) = AEC professionals (16,589).

Expected incidence (p) = 50%

Accuracy (A) = 0.05

Confidence interval (c) = 1.96

$$n = \frac{(1.96)^2(16{,}589\ )(0.5)(1-0.5)}{(0.05)^2(16{,}589\ ) + (1.96)^2(0.50)[1-0.50]}$$

$$n = 376$$

Therefore, the sample size (n) for AEC professionals is 376. The study's sample size is assumed to be sufficient. Norouzian (2020) opined that a sample size of 30 or more is appropriate for quantitative research.

Table 3.2: Stratified Population and Sample Distribution (Profession)

Stratum	Population (N)	Population Share (%)	Sample (n)	Sample Share (%)
Architects (GIA)	1275	7.7	142	37.4
Structural/Civil Engineers (GhIE)	1657	10.0	106	27.9
MEP Engineers (IET)	1460	8.8	63	16.6
Quantity Surveyors (GhIS)	1693	10.2	23	6.1
Contractors & Allied Roles	10504	63.3	46	12.1
Total	16589	100	380	100

The stratified distribution highlights the proportional representation of Ghana's construction professionals in the study. Architects (7.7% of the total population) formed 37.4% of the sample, ensuring their perspectives were strongly captured due to their central role in BIM design adoption. Structural/Civil Engineers and MEP Engineers were also adequately represented, contributing 27.9% and 16.6% of the responses, respectively, which reflects their critical involvement in project execution and technical integration. Quantity Surveyors, though forming a smaller share of the sample (6.1%), provided insights into cost and contract dimensions of BIM adoption. The largest stratum by population accounted for 12.1% of the responses, indicating some underrepresentation compared to their numerical dominance in the industry.

3.6.1.2 Sampling Technique

The study employed a stratified random sampling technique to ensure a representative selection of construction professionals in Ghana. Given the diverse nature of the Industry, this method was selected to enhance the reliability and generalizability of the findings (McLean, 2022). Stratified random sampling was particularly suitable as it allowed for proportional representation of various professional disciplines. By dividing the population into strata and randomly selecting participants from each group, the study minimised sampling bias and ensured an equal opportunity for all relevant professionals to participate.

The application of the sampling technique followed a structured process. First, the population was divided into strata based on professional categories, including architects, engineers, surveyors, contractors, and project managers. To recruit participants, the study engaged professional associations such as the GIA, GhIE, IET, GhIS, and ABCECG.

In this study, a stratified random sampling technique was employed to ensure that professionals from different groups within Ghana's construction industry were proportionately represented. The strata were based on professional categories, including architects, engineers, quantity surveyors, and contractors, reflecting the structure of the construction sector. Each stratum's share of the total population was calculated, and samples were then proportionally allocated to align with the population distribution while considering feasibility for data collection.

Table 3.2 presents the population and sample distribution. For example, architects constituted 3.3% of the total population, but to ensure adequate representation of this relatively small group, they were oversampled to form 37.4% of the total sample. Similarly, structural/civil engineers and MEP engineers, who make up 10% and 8.8% of the population respectively, were allocated 27.9% and 16.6% of the sample, to strengthen the reliability of their responses. Conversely, contractors and allied roles, although representing the largest group at 63.3% of the population, were intentionally under sampled at 12.1% of the sample, as their large numbers made proportional representation impractical within the study's sample size. This deliberate adjustment ensured that the study could capture balanced insights from all professional categories, rather than being skewed towards contractors who dominate the industry numerically. The approach enhanced the validity and richness of the data, while maintaining transparency in the sampling framework. To make this clearer, a target distribution table was provided (Table 3.2), showing both the actual population shares and the adjusted sample shares for each stratum. This enables transparency and justifies the differences between population proportions and sample allocation across professions.

3.6.2 Research Procedure

The quantitative phase of the study followed a structured procedure to ensure the systematic collection and analysis of data.

3.6.2.1 Research Instrument

The questionnaire served as the primary instrument for gathering quantitative data from stakeholders in the construction industry. The questionnaire was organised into five discrete parts to guarantee a thorough examination of the study objectives. The first segment collected demographic information from participants, including their gender, academic qualification, role, years of experience in the construction industry, organisation type and location. The subsequent section assessed participants' adoption stage, awareness and Knowledge of BIM through a series of statements designed to assess their familiarity with BIM principles and practices. This approach aligned with the methodology used by Succar and Kassem (2015) and Sanchez et al. (2021) in evaluating BIM awareness and knowledge.

The third section of the questionnaire focused on assessing the organisational and technological readiness for BIM adoption within Ghana's construction industry. The structure of this section was informed by Nguyen et al. (2022), who incorporated similar constructs and measurement items in their study. The fourth section examined the key factors that drive or hinder the adoption of BIM. A set of items was designed to identify the motivating factors for BIM adoption, while another set explored the barriers that impede its smooth adoption. This examination of drivers and barriers was consistent with previous research, such as the study conducted by Kassem and Succar (2017b).

The next section focused on the effect of BIM adoption on the performance of construction projects, with specific items developed to measure its influence on various aspects of project outcomes. The statements in this section were adapted from similar studies, including the work of Sidani et al. (2021). The final section of the questionnaire focused on identifying strategies for effective BIM adoption within Ghana's construction industry. A set of items was developed for various strategic interventions, including policy and regulatory frameworks, investment in technological infrastructure, capacity-building initiatives and academia-industry collaboration. Previous studies, such as those by Won et al. (2013) and Kassem and Succar (2017b), informed these strategies, which examined structured approaches to BIM adoption. This section provided insights into the most critical interventions needed to allow BIM adoption across the industry.

The measurement items were derived from prior research and the qualitative study results to ensure the instrument's relevance, validity, and credibility within the context of this study. A seven-point Likert scale ranging from "strongly disagree" (1) to "strongly agree" (7) was used for most items to allow structured responses.

To enhance the reliability and validity of the instrument, the questionnaire underwent expert review and pilot testing with a small group of construction professionals. Feedback from the pilot study was used to refine the wording, clarity, and relevance of the survey items.

3.6.2.2 Validity

Ensuring the validity of the questionnaire was a crucial step in maintaining the accuracy and credibility of the study results. Validity refers to the extent to which the research instrument accurately measures what it is intended to measure. To achieve this, the questionnaire underwent a rigorous validation process to confirm its relevance, clarity, and alignment with the study's objectives.

Content validity was ensured by thoroughly reviewing relevant literature and previous research on BIM adoption. This process helped in designing questions that comprehensively covered key aspects of the study. The questionnaire was structured to include a diverse range of items that effectively captured the various dimensions of BIM adoption within Ghana's construction industry.

Expert validation was conducted by seeking feedback from professionals with expertise in BIM, construction management, and research methodology. These experts assessed the questionnaire for clarity, relevance, and completeness, ensuring that each item aligned with the study's objectives. Their recommendations were incorporated to refine the questionnaire, improving the precision and appropriateness of the measurement items.

Face validity was established through a pilot study with a small sample of construction professionals who represented the intended target population. Participants in the pilot study provided feedback on the clarity, wording, and structure of the questionnaire. Their insights were used to refine ambiguous or unclear questions, ensuring that respondents could easily understand and accurately answer each item. This process also helped identify any redundancies or gaps within the questionnaire and ensured that the final version of the questionnaire was clear, precise, and capable of consistently capturing relevant information.

3.6.2.3 Reliability

Reliability is a crucial aspect of research instrument design, ensuring that the questionnaire produces consistent and dependable results when administered under similar conditions (Cohen et al., 2013). In this study, multiple strategies were employed to assess and enhance the reliability of the questionnaire, guaranteeing that the data collected accurately reflects the perceptions and experiences of construction professionals regarding BIM adoption in Ghana.

To establish internal consistency reliability, Cronbach's alpha coefficient was used to measure the degree to which items within each section of the questionnaire were correlated. A Cronbach's alpha value of 0.70 or higher was considered acceptable, indicating that the questionnaire items were measuring the same underlying construct in a reliable manner. This analysis was performed for key sections of the questionnaire, including BIM awareness, Knowledge, organisational and technological readiness, adoption drivers, barriers, and project performance. High Cronbach's alpha values across these sections confirmed the instrument’s internal consistency.

Test-retest reliability was also assessed by administering the questionnaire to a small sample of respondents on two separate occasions within a specified time frame. The responses were compared to evaluate the stability and consistency of the results over time. A high correlation between the two sets of responses indicated that the questionnaire provided stable and repeatable results, reinforcing its reliability.

To further ensure construct reliability, Exploratory Factor Analysis (EFA) and Confirmatory Factor Analysis (CFA) were conducted. These statistical methods helped to determine whether the questionnaire items accurately represented the theoretical constructs they were intended to measure. The factor loadings of individual items were examined, and items with low loadings were refined or removed to enhance the reliability of the questionnaire.

In line with standard CFA/SEM practices, an outer loading threshold of ≥0.7 was adopted as the criterion for indicator reliability, although values between 0.6 and 0.7 were considered acceptable in exploratory research contexts (Hair et al., 2019). This ensures that the retained indicators adequately represent their latent constructs. The structural and measurement models were analyzed using SPSS AMOS, which provided confirmatory factor analysis (CFA) and structural equation modeling (SEM) outputs consistent with best practices in model validation and hypothesis testing.

3.7 Measurement and Operationalisation of Variables

Table 3. 2 Operationalisation of variables

Variable	Operational definition	No. of Items	Indicators	Source	Measurement scale	Sample Question Item(s)
BIM adoption	The extent to which BIM technologies and practices are integrated into an organisation's project processes.	6	Integration of BIM technologies into routine project processes. Use of BIM as a key project management tool. BIM maturity levels (Level 0 to Level 3).	Succar and Kassem (2016), Ahuja et al. (2016), Borrmann et al. (2018)	Interval	Our organization has seamlessly integrated BIM technologies into our routine project practices
BIM Awareness	The extent of familiarity and understanding of BIM concepts, benefits and implementation standards among industry stakeholders.	21	Awareness of basic BIM concepts and their impact on project lifecycle and workflows. Awareness of BIM benefits, including error reduction, stakeholder coordination, improved visualisation, cost savings, and clash detection. Awareness of BIM standards, roadmaps and applications across project phases.	Gamil and Rahman (2019), Appiah (2020b)	Interval	I am aware of the concept of BIM.
BIM Knowledge	The extent of proficiency and understanding of BIM tools, processes and advanced applications.	14	Proficiency in using BIM software, Ability to manipulate 3D models using BIM software, Capability to run clash detection, Ability to generate automatic schedules and quantities, Knowledge of exporting and	Chew et al. (2020); Gamil and Rahman (2019), Ryal-Net and Kaduma (2015)	Interval	I am proficient in using BIM software I can manipulate 3D models using BIM software

Variable	Operational definition	No. of Items	Indicators	Source	Measurement scale	Sample Question Item(s)
			importing BIM data using various file formats, Understanding of steps required to implement BIM on a project, Familiarity with developing a BIM execution plan, Knowledge of how to collaborate with other disciplines using BIM models, Formal training in BIM software and processes, Opportunities for continuous BIM training and development. Understanding of how 4D and 5D BIM are applied in projects, Familiarity with integrating BIM with emerging technologies, Knowledge of digital twins and its relationship with BIM for data management and simulation.			
Organisational and Technological Readiness Towards BIM Adoption	The extent to which an organisation is prepared in terms of organisational structure and technological capacity to adopt and implement BIM.	28	Senior management's commitment to adopting BIM, Management's belief in long-term BIM benefits, Innovative culture supporting BIM adoption, Presence of documented BIM implementation strategy, Monitoring and evaluation system for BIM adoption progress, Adaptation of project management	Howard et al. (2017), Tezel and Aziz (2017), Saf'a et al. (2023), Yii et al. (2019)	Interval	BIM training in our organization is mostly self-led by employees. The implementation of BIM aligns with our organization's long-term goals. Our management believes that BIM will lead to long-term benefits despite the initial challenges of implementation.

Variable	Operational definition	No. of Items	Indicators	Source	Measurement scale	Sample Question Item(s)
			processes to accommodate BIM, Encouragement of cross-disciplinary collaboration for BIM, Workforce capacity for interdisciplinary collaboration in BIM projects, Workforce understanding of coordination benefits, Workforce skills in using BIM for communication and data sharing, Availability of staff with required BIMM skills, Employment of professionals with specialised BIM expertise, Workforce participation in formal training or certification, Regular in-inhouse training, Support for professional BIM certification, Measurement of BIM training effectiveness, Investment in BIM software, Regular upgrading of technological infrastructure to support BIM software, Systems for secure and efficient data sharing and collaboration, Dedicated IT or technical support team for BIM implementation.			

Variable	Operational definition	No. of Items	Indicators	Source	Measurement scale	Sample Question Item(s)
Key Drivers influencing the adoption of BIM	Factors or conditions that encourage or incentivise organisations to adopt and implement BIM.	16	Regulatory policies encouraging BIM adoption, Government incentives encouraging BIM adoption, BIM's potential to reduce project cost, Efficiency gains from BIM, Potential for long-term ROI, Client demand for BIM-based projects, Competitive advantage in securing new projects, growing digital transformation trends, BIM's ability to streamline workflows and enhance collaboration. Improved collaboration between project stakeholders, Efficient data management, BIM's capability to reduce project risks, Enhanced project quality due to BIM, Availability of BIM training and certification programs, Error reduction capabilities of BIM, Improved decision-making capabilities.	Raja Mohd Noor et al. (2021), Pinti et al. (2022), Arayici et al. (2011a), Ariono et al. (2022)	Interval	BIM adoption provides a competitive edge in winning new construction projects.
Barriers to BIM adoption	Factors that hinder or impede the adoption of BIM	24	Limited awareness among organisational leadership about BIM benefits, Lack of senior buy-in, Lack of awareness of BIM by industry stakeholders, Lack of demand and interest from	El Hajj et al. (2021), Klaschka (2019), Ahmed (2018), Babatunde and Ekunda	Interval	Lack of government regulations to support the implementation of BIM High cost of Data to operate cloud-based BIM

Variable	Operational definition	No. of Items	Indicators	Source	Measurement scale	Sample Question Item(s)
			clients, Absence of government mandate for BIM use, Lack of government regulations to support BIM adoption, Lack of IT infrastructure, High cost of data to operate cloud-based BIM, High initial cost of technology, Industry's cultural resistance to change, Lack of training course for industry professionals, High cost of BIM training, Lack of professionals with BIM expertise, Lack of case studies showing positive ROI from BIM, Lack of project funding to support BIM, Reluctance of project parties to share information, Non-adoption by other professionals, Data interoperability challenges between various BIM software, Unavailability of risk insurance, Lack of Industry BIM standards, Data security issues, Absence of BIM-based standard contract, Steep learning curve to develop BIM expertise, Low computer skills among construction professionals. Reduced rework. Streamlined work process,	yo (2019)		

Variable	Operational definition	No. of Items	Indicators	Source	Measurement scale	Sample Question Item(s)
			Improved budget adherence. Timely project completion Improved construction sequencing and planning. Enhanced tracking of change orders. Reduction in errors. Improved quality control. Real-time monitoring of safety conditions. Improved energy efficiency. Improved material selection.			
Strategies for Effective BIM Adoption	Approaches, actions and policies aimed at enhancing the adoption of BIM	24	Government support and incentives, Enforceable regulations on BIM usage, Availability of National BIM standards and guidelines, Government mandated BIM for public projects, Senior management's commitment to BIM, Establishment of a strategic roadmap for BIM, Innovative culture within organisations, Cross-departmental collaboration to support BIM, Investment in advanced technology infrastructure, Secure and efficient data-sharing platforms, Interoperability	Almuntaser et al. (2018), Mostafaio and Dulaimi (2022), Zhang et al. (2023),	Interval	Our organization has observed improved budget adherence across our projects with the integration of BIM The integration of BIM technologies has contributed to the timely completion of projects by our organization BIM has played a crucial role in optimizing construction sequencing and planning within our organization

Variable	Operational definition	No. of Items	Indicators	Source	Measurement scale	Sample Question Item(s)
			between BIM software Industry-academia collaboration for BIM education and training, Upskilling workforce through hands-on BIM training, Open collaboration and data sharing practices, Collaborative procurement models, BIM-based Contractual agreements, Demonstration of long-term financial benefits of BIM, Financial assistance for organisations to adopt BIM, Developing standardised BIM contract terms, Legal frameworks addressing data ownership, Organization of industry-wide BIM forums and seminars, Establishment of benchmarks and performance metrics, Conducting regular BIM project reviews.			

3.7.1.1 Quantitative Data Collection

This phase of the research involved collecting information from various stakeholders in the construction industry. The data collection process began with soliciting the consent of industry stakeholders to participate in the survey. A formal letter detailing the study's objectives and ethical considerations was directed to the targeted respondents within the industry, requesting their support and voluntary participation in the study. This measure, rooted in transparency and voluntary participation, underscored the research's ethical commitment.

Once finalised, the questionnaire was administered both online and in person. Online distribution used email invitations and professional networks, including membership directories of key industry associations. Additionally, physical copies of the questionnaire were distributed during site visits, industry conferences, and workshops to maximise participation. To encourage higher response rates, reminder emails and follow-up calls were made to participants who had not completed the survey within the stipulated timeframe. Participants received an explanation of the aim of the study and assurances that their responses would be kept strictly confidential and anonymous. The quantitative data collected were entered into a secure database for further analysis.

3.7.2 Quantitative Data Analysis

To ensure the study's objectives were systematically achieved, various statistical tests and analyses were conducted. These tests helped validate relationships between variables and provided empirical evidence to support the findings. The study employed descriptive statistics, reliability and validity tests, Exploratory Factor Analysis (EFA), Confirmatory Factor Analysis (CFA), regression analysis, and Structural Equation Modelling (SEM) to analyse the collected data. Each test was selected based on its suitability for addressing the specific research objectives.

To assess the current level of awareness and knowledge of BIM among construction professionals in Ghana, descriptive statistics, including mean and standard deviation, were used to summarise the extent of BIM awareness. This provided insights into the level of familiarity professionals had with BIM concepts, tools, and applications. Additionally, EFA was conducted to identify key dimensions of BIM awareness by grouping related questionnaire items into factors. To ensure internal consistency, Cronbach's alpha was computed, confirming the reliability of awareness-related items, with a value above 0.70 indicating acceptable consistency.

To examine the level of organisational and technological readiness of Ghana's construction industry towards BIM adoption, descriptive statistics were first used to measure the extent to which organisations were prepared for BIM adoption. This highlighted areas where firms had invested in digital infrastructure, training, and leadership commitment. EFA was conducted to identify key factors related to readiness, such as technology availability, financial investment, and skill development. CFA) was then used to validate these factors and ensure they accurately represented organisational and technological readiness for BIM adoption.

To identify the key drivers and barriers influencing the adoption of BIM in Ghana's construction industry, descriptive statistics, including mean and standard deviation, were used to summarise the findings. This allowed for a structured understanding of the leading enablers and obstacles. EFA was conducted to categorise related drivers and barriers into broader themes, ensuring a clear distinction between factors facilitating and hindering adoption. Regression analysis was then performed to determine the extent to which each driver and barrier influenced BIM adoption, with significant predictors identified based on standardised coefficients and p-values.

To examine the impact of BIM adoption on construction project performance in Ghana, mean scores and standard deviations were computed to assess professionals' perceptions of how BIM affected project outcomes such as cost efficiency, time savings, and error reduction. SEM was used to test the relationships between BIM adoption and project performance indicators. This technique enabled a thorough evaluation of how BIM use influenced construction efficiency. Additionally, hypothesis testing was conducted using p-values and model fit indices, such as the Comparative Fit Index (CFI), Root Mean Square Error of Approximation (RMSEA), and Chi-square/degree of freedom ratio (χ^2/df), ensuring that the tested model was statistically robust.

To develop a framework for promoting the effective adoption of BIM in the Ghanaian construction industry, the study integrated findings from both qualitative and quantitative analyses. Thematic insights from qualitative interviews were synthesised with statistical validation from the quantitative phase. Regression analysis was employed to determine which factors had the most significant influence on BIM adoption, ensuring that the framework was evidence-based.

Additionally, SEM was applied to validate the hypothesized model by testing the interrelationships between key variables. This ensured that the recommendations for BIM adoption were not only theoretically sound but also supported by empirical data.

3.8 Triangulation of Qualitative and Quantitative Data

Guided by a pragmatic stance and an exploratory sequential mixed-methods design, this study integrates interview and survey evidence to strengthen validity and deepen interpretation. Consistent with the study's emphasis on external validity and decision relevance, the quantitative survey is accorded analytic importance because it enables broader generalization to the study population. The qualitative strand plays a complementary, explanatory role, supplying contextual depth and help interpret quantitative patterns (Tashakkori & Teddlie, 2010; Creswell & Plano Clark, 2018).

Connecting themes from the interview phase informed the construction and refinement of survey measures, ensuring conceptual continuity across strands (Creswell & Plano Clark, 2018). Subsequently, qualitative themes and quantitative results were brought together in joint interpretation, classifying patterns as convergent, complementary, or discordant (Fetters, Curry, & Creswell, 2013). Where discordance appeared, we (a) re-examined qualitative coding for conditional nuance, and (b) conducted sensitivity analyses on survey data, documenting theoretically reasonable explanations. Throughout integration, the survey estimates remain the principal evidence base for inferential claims and general conclusions, while qualitative insights specify boundary conditions and contextual likelihoods.

While triangulation strengthens the credibility of the study, it is important to clarify how divergent findings treated. In this study, quantitative results take precedence for generalizable inferences, and qualitative findings are used to interpret, not override, the observed quantitative patterns. This deliberate weighting toward the quantitative strand, coupled with qualitative explanation, yields meta-inferences that are both externally valid and contextually meaningful, consistent with mixed-methods integration standards. Where discrepancies arise, the qualitative findings help explain the contextual reasons behind patterns observed in the quantitative data, while the survey results provide broader generalizability. This balanced approach ensures that neither source of data is disregarded but rather integrated to build a comprehensive understanding.

3.9 Ethical Consideration

The research was conducted with a firm commitment to ethical principles, ensuring that the rights, safety, and privacy of all participants were upheld. Ethical integrity was also paramount in safeguarding the validity and credibility of the findings, thereby fostering trust between the researcher and participants.

Prior to participation, each participant received a thorough briefing outlining the study's objectives, potential benefits, and the voluntary nature of participation. Participants were required to provide written informed consent in the case of survey respondents and verbal consent in the case of interviews, ensuring flexibility and accessibility. This process guaranteed that participants fully understood their rights, the scope of their involvement, and their ability to withdraw at any stage without any consequences. This approach upheld the principles of autonomy and respect for individual decision-making.

To safeguard participants' privacy and personal information, strict confidentiality measures were implemented throughout the research process. All collected data was stored in password-protected files on a secure local drive, with backup copies on an encrypted external device. Access was restricted to the researcher alone, and any identifiable information was either removed or anonymised to ensure that responses could not be traced back to specific participants. Data will be retained only for the duration required by institutional guidelines, after which it will be permanently deleted.

The study further emphasised voluntary participation, ensuring that participants were not subjected to any form of pressure or coercion. Interview and survey protocols were designed to be non-intrusive, with optional questions for potentially sensitive topics. Before data collection commenced, the study protocol including research design, data collection instruments, and ethical considerations was reviewed and approved by the relevant institutional ethics committee. This ensured full compliance with academic research standards and reinforced the study’s commitment to upholding the highest ethical standards in academic inquiry.