CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

A literature review is essential to empirical research. It maps existing knowledge and identifies methods and approaches used to study similar phenomena. Against this purpose, this chapter lays the foundation for exploring the dynamics of BIM adoption in Ghana's construction industry while drawing comparisons with global developments. It synthesizes prior studies to describe the current state of adoption in Ghana and, at the same time, draws comparative lessons from both developed and developing contexts to clarify where Ghana aligns with, or diverges from broader trends.

The primary focus of this review is on BIM awareness and knowledge, as well as organizational and technological readiness for the adoption of BIM. It aims to highlight how these factors shape the construction industry's capacity to integrate BIM into its processes. Additionally, the factors driving BIM adoption and the barriers limiting its adoption are examined to identify the opportunities and challenges peculiar to Ghana's construction industry. The review further explored the impact of BIM adoption on project performance to provide insights into the potential benefits on the overall project outcomes. Additionally, previous studies related to strategies for effective BIM adoption are examined for insights into actionable pathways that can guide stakeholders in overcoming the adoption barriers and leveraging enabling factors. Finally, a theoretical framework is introduced, offering a structured approach for analysing the relationships between various variables.

By integrating global insights with Ghana-specific evidence, the review connects theory to practice and provides a clear basis for advancing BIM adoption. It establishes the conceptual and empirical platform for the study's subsequent methods, findings, and recommendations.

2.2 Study Area - Ghana

Ghana is a diverse and historically significant country situated along the coast of West Africa. With a land area of approximately 238,533 square kilometres, the country boasts a rich ecosystem ranging from green tropical rainforests to coastal savannas (Boateng et al., 2006). It shares its eastern border with Togo, western border with Côte d'Ivoire, and northern border with Burkina Faso (Figure 2.1). Politically, the country has gained recognition as one of the most stable democracies within the West African sub-region.

As of 2022, Ghana’s population was approximately 33.8 million, with about 56% being under 25 (Ghana Statistical Service, 2021). The capital city, Accra, stands out as the country’s most populous urban centre, complemented by other notable cities such as Kumasi, Tamale, and Sekondi-Takoradi, which significantly contribute to the country’s urban landscape. Cultural plurality is a defining feature of Ghana, evident in the numerous ethnic groups, each characterized by its unique customs, traditions, and language (Ghana Statistical Service, 2012). The religious composition of Ghana further highlights its diversity. The country features a predominantly Christian majority, a substantial Muslim minority and a smaller segment practising traditional faiths or identifying as non-religious. This diversity demonstrates the nation's dedication to coexistence and tolerance. English, the official language of Ghana, reflects the country's colonial past and continues to play an important role in education, governance, and international communication (Edu-Buandoh, 2016). Nonetheless, indigenous languages such as Twi, Ewe, and Ga remain widely spoken in daily life.

Economically, Ghana is classified by the World Bank as a lower-middle-income country (World Bank, 2024). It has a GDP of approximately USD 77.59 billion, which is structured around three primary sectors: agriculture, services, and industry. The government’s strategic initiative to digitize the economy outlines ambitious objectives aimed at accelerating national development. As such, Ghana envisions achieving industrialized status by 2039 (Ntim & Botchway, 2023).

A significant infrastructural drive to enhance urban development and economic growth is currently ongoing. Major projects such as road expansions, housing initiatives, modernization of the inner cities and digital infrastructure development underscore the country’s commitment to positioning itself as a vibrant hub for sustainable development and investment in West Africa (Zakaria et al., 2023).

Figure 2. 1 Locational map of Ghana
Source: Charles Sturt University Spatial Analysis Unit (2015) cited in Cobbinah and Erdiaw-Kwasie (2018)

2.2.1 Ghana's Construction Industry

The construction industry serves as a vital pillar of national economies, given its elaborate interconnections with other sectors. According to Anaman and Osei-Amponsah (2007), there is a strong correlation between the growth of the construction industry and the overall macroeconomic development of emerging economies. Over the past two decades, Ghana has experienced a notable increase in construction activities, mainly driven by the discovery of commercial oil reserves in 2007. This boom in construction activities is evident in the heightened investments directed towards grand-scale projects, including stadia, the airport city initiative, and a range of nationwide infrastructure and real estate developments (Evans & Antwi, 2019; Yeboah et al., 2023). It is expected that the ongoing increase in infrastructure development, coupled with government initiatives aimed at enhancing economic growth, will continue to propel the construction industry in the next several years.

According to data from the International Trade Administration (2023), the Ghanaian construction industry is valued at approximately USD 8 billion, accounting for 15% of the country's Gross Domestic Product (GDP) Despite the disruptive impacts of the COVID-19 pandemic, which led to a slowdown in construction activities in 2020 and 2021, the outlook remains positive (Boadu et al., 2020). Recent forecasts suggest that the industry is expected to experience an average annual growth rate of 4.3% from 2022 to 2026 (Economics, 2021). The industry presents considerable employment opportunities, particularly individuals who are unemployed or lack specialized skills (Darko & Löwe, 2016). According to the Labour Force Report published by the Ghana Statistical Service, the construction industry accounted for the employment of over 600,000 individuals, representing approximately 7% of Ghana's total workforce (Ghana Statistical, 2016). This underscores the sector's role as a critical driver of poverty alleviation and improved living standards through the generation of job opportunities within local communities. Beyond providing direct income for employees and local enterprises, the industry also contributes indirectly to community development by stimulating infrastructure growth.

A central force behind this expansion is the government's infrastructure development agenda which is designed to enhance Ghana's economic competitiveness and advance social progress. These initiatives have not only stimulated domestic activity but also attracted the participation of major international firms from China, Brazil, Turkey, and India (Evans & Antwi, 2019; Somiah et al., 2020). The presence of such global actors has introduced advanced technologies and technical expertise (Osabutey & Croucher, 2018), raising construction standards, especially on large-scale projects that are mainly commissioned by the state. Nevertheless, despite this remarkable potential, scholars argue that the Ghanaian construction industry has yet to achieve full realization of its capacity (Ofori-Kuragu, 2020). Persistent challenges continue to undermine growth and effectiveness. Chief among these is the absence of a centralized public regulatory body mandated to oversee the sector. Researchers such as Boadu et al. (2020), Owoo and Lambon-Quayefio (2018), and Ofori (2012) highlight that this gap has fostered fragmentation, where numerous professional associations operate independently, limiting collaboration within the industry. This deficiency has resulted in a fragmented landscape where numerous professional bodies tend to operate in silos, thereby impeding the industry's advancement and its capacity for collaboration. Ofori-Kuragu (2020) further emphasizes that the dispersal of responsibilities across multiple ministries has deepened this fragmentation, impeding the industry’s development and long-term sustainability.

Building on this structural challenge, Afolabi et al. (2018) highlight another pressing concern: the industry’s persistent dependence on paper-based methods for processing, storing, and transmitting information. This reliance on outdated practices, coupled with a heavy dependence on informal communication channels, creates a complex and unreliable trail of information that complicates decision-making processes. The outdated approach has adversely impacted industry performance, reflecting the absence of advanced mechanisms for effective information exchange. Addressing these weaknesses demands wide-ranging reforms and the adoption of technological systems that can streamline communication, enhance efficiency, and strengthen the industry’s institutional capacity.

2.2.2 Procurement of Construction Works

In Ghana, the construction procurement process has historically been dominated by the traditional approach, which is typically organized around three core participants: the client, the consultant, and the contractor (Boadu et al., 2020). This tripartite relationship clearly delineates the roles, responsibilities, and expectations of each party, thereby providing a structured framework that has endured largely due to its familiarity and established practices. Within this framework, the client initiates the procurement process by defining project requirements and securing funding, while also playing a decisive role in contractor selection, often prioritizing cost-effectiveness alongside considerations of quality and track record (Dadzie et al., 2012).

The consultant, usually an architect or engineer supported by a team of professionals, is tasked with preparing design drawings that reflect the client’s specifications and overseeing the construction phase to ensure adherence to standards and regulations (Ameyaw et al., 2021). Beyond their technical function, consultants also act as intermediaries, facilitating communication and alignment between the client and contractor throughout the project lifecycle (Kipo-Sunyehzi et al., 2024). Contractors, in turn, are responsible for the practical execution of works, including managing resources, schedules, and quality control (Asamoah et al., 2019). Their performance, however, depends heavily on the clarity of project documentation and the client's timely fulfilment of obligations such as approvals and payments. These relationships are generally formalized through standard contract forms, often adapted from the Joint Contract Tribunal (JCT), which detail roles, compliance requirements, and remedies for default (Opoku & Ibrahim-Adam, 2018; Rwelamila et al., 2015).

While this conventional model provides predictability and affords the client substantial control, Ofori and Fuseini (2019) caution that it is underpinned by regulatory frameworks that tend to entrench traditional practices and resist innovation. This reliance has created notable challenges, including project delays, cost overruns, rework, and safety concerns. The linear and often fragmented communication flow between parties is frequently cited as a key contributor to these inefficiencies. Nevertheless, the method continues to be favoured for its perceived reliability and the sense of accountability it provides to clients (Agyekum et al., 2023).

In response to the limitations of traditional procurement, alternative strategies are increasingly being explored. One such approach is the design-and-build (D&B) method, which consolidates responsibility for both design and construction under a single contracting entity. This integration, often involving in-house multidisciplinary teams, has been shown to reduce time and cost overruns while fostering more practical and adaptable designs (Guribie et al., 2022; Moore & Dainty, 1999; Owusu-Ansah et al., 2019). The attractiveness of D&B lies in its ability to transform fragmented project structures into integrated ones, thus enhancing efficiency and collaboration (Franz et al., 2017). However, critics highlight its potential drawbacks, particularly the diminished client control over design, which may compromise quality assurance and limit oversight on cost management.

Beyond D&B, there is a growing call for procurement frameworks that incorporate broader evaluation criteria, such as sustainability and social value, reflecting the evolving priorities of the industry (Gidigah et al., 2024). In this context, electronic procurement (e-procurement) has emerged as a promising innovation for enhancing transparency, accountability, and stakeholder participation. Despite its potential to streamline processes and improve governance, adoption remains limited, with many construction firms struggling to transition from entrenched practices to digital platforms (Gidigah et al., 2024).

2.2.3 Major Construction Professionals

The construction industry in Ghana operates through a network of professionals, each performing distinct roles vital for the successful execution of construction projects. From design conception to physical execution, these actors are accountable for the efficiency, safety, and quality of outcomes within their domains (Hussin & Omran, 2009). Key professionals include architects, engineers (civil and MEP), quantity surveyors, project managers, and contractors. While their functions are interdependent, they often operate under distinct regulatory bodies responsible for maintaining professional standards.

Architects play a pivotal role during the design stage, shaping both the functional and aesthetic dimensions of projects. Their input reduces inefficiencies and ensures that structures respond to user needs and contextual requirements. In Ghana, architects frequently assume leadership positions within consulting teams (Addy et al., 2024). With market demands evolving rapidly, adaptability has become a critical competency, enabling architects to align their services with changing client expectations (Chan et al., 2018; Kwofie et al., 2016). Professional practice is regulated by the Architect Registration Council, while the Ghana Institute of Architects (GIA) provides ethical and professional oversight.

Engineers, both civil and mechanical-electrical-plumbing (MEP), are indispensable to the technical dimension of construction. Civil engineers safeguard the structural integrity and safety of projects, while MEP engineers ensure the efficient integration of mechanical, electrical, and plumbing systems, elements vital for functionality and sustainability (Asiedu & Adaku, 2020; Buertey et al., 2015). As projects grow in complexity, multidisciplinary collaboration has become increasingly important, enabling engineers to enhance efficiency and deliver more effective outcomes (Guribie et al., 2022). The Engineering Council of Ghana regulates the profession, with practitioners required to register with the Ghana Institution of Engineers (GhIE) or the Institution of Engineering and Technology (IET).

Quantity surveyors (QS) provide critical financial expertise, specializing in cost estimation, budgeting, and resource management. Their role is particularly important in Ghana's construction sector, where escalating material prices create persistent cost pressures (Adinyira et al., 2022). However, challenges such as delayed payments frequently undermine their ability to maintain budgetary discipline and project timelines, highlighting the need for stronger financial governance within the industry. The Ghana Institution of Surveyors (GhIS) is responsible for regulating QS practice.

Project managers occupy a coordinating role, ensuring that projects are delivered within scope, budget, and time constraints. Their responsibilities span leadership, communication, and problem-solving, all of which are central to managing diverse professional teams and resources effectively (Ahadzie et al., 2014). The performance of project managers is closely tied to their competencies, which require regular assessment and development to sustain stakeholder satisfaction and project success (Guribie et al., 2022). In Ghana, licensing and regulation are overseen by the Institute of Project Management Professionals (IPMP).

Construction workers form the backbone of the industry, executing the physical tasks necessary to bring designs to fruition. Skilled trades such as carpentry, masonry, and electrical work are critical to achieving precision and quality. Yet, Ghana's construction workforce continues to grapple with inadequate training and limited access to professional development opportunities, often resulting in substandard workmanship (Amudjie et al., 2023). Strengthening vocational training and skills development is therefore essential to raising industry standards (Novieto & Kportufe, 2022).

Taken together, these professionals form an ecosystem where effective collaboration, adherence to regulatory standards, and investment in skills enhancement are indispensable. Continuous professional development (CPD), coupled with adaptability to emerging challenges, remains central to improving performance, ensuring sustainability, and advancing the industry's contribution to national development (Aigbavboa et al., 2024; Kissi et al., 2022).

2.2.4 Previous BIM Studies in Ghana

In Ghana's construction industry, the adoption of BIM remains at a relatively early stage, progressing more slowly than in many developed countries(Appiah, 2020a). This gradual uptake has been attributed in part to the fragmented nature of the sector, where a lack of collaborative culture undermines the integrated project delivery that BIM requires (Oteng et al., 2018). Nonetheless, scholars recognize BIM's potential to transform project communication and coordination, which is particularly critical in Ghana's construction environment given its dispersed stakeholder landscape. Existing research has begun to shed light on discipline-specific applications of BIM in Ghana, with studies exploring its use among architects, engineers, and other practitioners (Addy et al., 2018; Akwaah, 2015a; Bamfo-Agyei & Nani, 2015). Architects, in particular, appear to be at the forefront of adoption, increasingly championing BIM as a tool for enhancing the design process through 3D modelling and visualization (Acquah et al., 2018). Despite this growing recognition, Appiah (2020a) observes that while awareness of BIM is relatively high among professionals, its practical implementation remains limited.

The challenges impeding widespread adoption are multifaceted. A central barrier lies in the lack of education and training programs specifically designed to build BIM competencies, creating a skills gap that stifles innovation. (Oteng et al., 2018). Moreover, technical and institutional constraints, including issues of data interoperability, weak adherence to international standards, and high investment costs, further hinder its integration into construction workflows (Acquah et al., 2018). These limitations underscore the need for deliberate capacity-building initiatives, as well as policy and institutional reforms, to support a structured path toward BIM implementation

Despite the progress made by individual studies, there remains an absence of comprehensive, industry-wide research that could provide a holistic understanding of BIM adoption in Ghana. Without such a body of evidence, efforts to establish a contextually relevant BIM framework remain fragmented and poorly coordinated. Hamma-adama and Kouider (2020) caution that strategies imported from developed economies may not adequately address the unique needs of Ghana's construction sector, highlighting the importance of localized approaches In this regard Olugboyega (2024) advocates for a nationwide investigation into BIM adoption, an initiative that could inform tailored frameworks, guide capacity-building, and position BIM as a catalyst for improvement across the industry.

2.3 Technology Adoption in the Construction Industry

Technology adoption in the construction industry has emerged as a focal point of global research in recent times, driven by the need to productivity, safety and sustainability. As the industry continues to evolve amidst growing digitisation, researchers, policymakers, and industry practitioners seek to understand what shapes the acceptance and use of new tools. Studies consistently point to a blend of organizational, individual, and contextual determinants as critical to adoption outcomes (Gholami, 2023; Na et al., 2022). A recurring theme in the literature is the influence of organizational culture and social dynamics. Park et al. (2018) and Kahsay et al. (2023) suggest that peer influence, leadership commitment, and a shared vision for innovation can collectively build momentum for technological change. Perceived benefits also matter: when teams expect better communication and smoother coordination, their willingness to work with unfamiliar tools increases (Huang et al., 2022; Siddiqui et al., 2022).

Despite these incentives, persistent barriers slow uptake. Historical biases, entrenched practices, associated costs, training needs, and interoperability issues often fuel skepticism (Steinhardt & Manley, 2016). Overcoming such perceptions requires not only technical justifications but also targeted broader organisational change and stakeholder alignment (Park et al., 2019). Capacity gaps compound the problem. Limited digital literacy and insufficient training opportunities constrain adoption, especially in developing contexts where firms struggle to recruit and retain skilled personnel (Liu et al., 2017; Olugboyega et al., 2023). In response, many organizations adopt incremental strategies, beginning with basic visualization and moving toward advanced applications as capability grows (Abubakar et al., 2014; Arayici & Aouad, 2010). Programs that combine hands-on learning with continuous professional development are effective enablers. (Sampaio et al., 2021).

Emerging technologies such as artificial intelligence, digital twins, robotics and extended reality are increasingly being explored for their potential to revolutionise various aspects of the construction process. One notable area gaining traction is the use of BIM for project planning and execution. By creating data-rich digital models, BIM allows teams to simulate processes before site work begins, improving safety awareness, procedural clarity, and error reduction (Abubakar et al., 2014). The growing interest in BIM highlights the importance of aligning technological innovation with practicality.

Context also plays a decisive role. Cross-jurisdictional research shows that legal frameworks, market conditions, professional norms, and government policy influence adoption trajectories. According to Wu et al. (2021), the adoption of BIM was significantly impacted by government legislation and industry practices in China and the United States. Similar conclusions were highlighted in studies undertaken by Underwood et al. (2010) in the United Kingdom and Hallstedt and Pigosso (2017) in Sweden.

Similarly, by researching the phenomenon of technology adoption within the construction industry in Ghana, valuable insights can be gained on the country's potential and challenges in embracing new technologies. The use of advanced technology to enhance construction project outcomes, efficiency, and collaboration has seen a growing interest in Ghana, just as it has in the rest of the world. Limited awareness of modern technologies such as BIM has slowed diffusion (Appiah, 2020b; Osei-Tutu et al., 2023). According to studies conducted by Babatunde et al. (2020) and Zaineldeen et al. (2020), well-defined legislative frameworks and regulations are crucial in incentivizing and facilitating the use of technology within construction projects. This underscores the need to establish a favourable environment for using innovative technologies. Besides, Bamfo-Agyei and Nani (2015) emphasize the importance of training and capacity-building initiatives in disseminating novel technologies. The effectiveness of incorporating new technology in the construction industry is contingent upon acquiring suitable training and education by experts in the field.

In sum, successful technology adoption in construction depends on aligning organizational culture, skills development, supportive policy, and practical value, while adapting these elements to the local context.

2.4 Concepts of BIM

In recent years, BIM has gained much popularity as a transformative concept in the AEC industry. It transcends mere software functionality, as it embodies a transformative paradigm shift in the conception, planning, construction, and management of building projects. BIM is fundamentally a digital representation incorporating a building or system's physical and operational attributes (Eastman et al., 2011; Momeni Rad et al., 2024). This extensive portrayal considers several aspects, including geometric characteristics, spatial relationships, geographical information, numerical data, and other properties.

The fundamental principle of BIM is to foster collaboration and achieve the seamless integration of project information. BIM enables a collaborative work environment where stakeholders from many disciplines may collectively engage with a unified digital model. It stands in stark contrast to the traditional workflow that depends on distinct sets of drawings and documents. The occurrence of errors, conflicts, and the need for revisions is significantly reduced in this collaborative ecosystem due to enhanced communication, coordination, and the integration of diverse knowledge (Becerik-Gerber et al., 2011; Zhu et al., 2023).

The inherent wealth of information possessed by BIM is a central characteristic of the technology, which incorporates a wide range of data that extends beyond the mere representation of a building's physical elements (Biagini et al., 2016). This includes non-geometric information such as object attributes and specifications. The use of a technology abundant in data facilitates the execution of scenario simulations, impact analysis and data-driven decision-making. These practices together enhance the overall outcomes of a project (Eastman, 2011a; Succar, 2010).

The uses of BIM extend beyond the limitations of the construction process. The full scope of a project encompasses all phases of its lifecycle, spanning initial planning and design through construction to ongoing operation and maintenance. BIM enables the seamless integration of all data incorporated during the design and construction phases into facility management systems, enhancing the efficiency of continuing operations and maintenance activities (Azhar et al., 2012). The concept of "BIM for Facilities Management" or "BIM for Operations" underscores the enduring significance of the technology in enhancing the operational efficiency and sustainability of developed assets over an extended period (Al-Yami & Sanni-Anibire, 2021; Succar, 2010).

BIM dramatically enhances the potential for visualization and simulation. BIM offers project stakeholders a deeper understanding of project design and aesthetics through its advanced 3D visualization capabilities, facilitating improved communication and decision-making among stakeholders (Emmitt, 2016; Xu et al., 2022). BIM encompass several aspects, such as lighting, acoustics, energy use, and structural performance. This capability provides a basis for informed design choices.

2.4.1 Level of Development

A general level of refinement has been developed as an industry standard for measuring the level of BIM service essential for a project. This standard, known as "BIM Levels of Development (LOD)," signifies the degree of detailing and refinement in the 3D digital model at different stages during the project's lifespan. The LOD 100 level pertains to the conceptual design phase, whereas the LOD 500 level includes as-built and functioning information. According to the American Institute of Architects (2020), the potential for improved information integration and cooperation is heightened as one ascends the hierarchical structure. Figure 2.1 shows the various BIM levels of development.

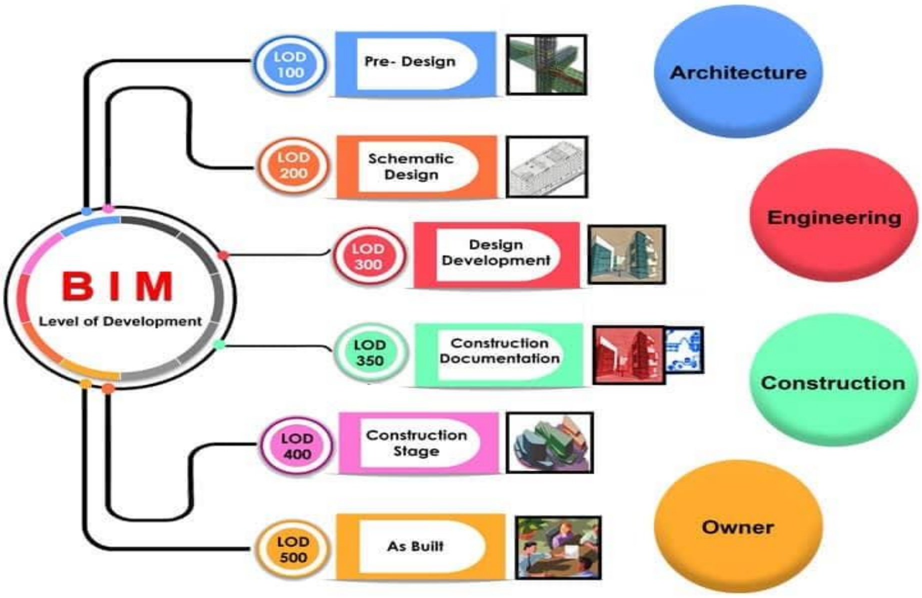

Figure 2. 2 BIM Level of Development (LOD) (TrueCADD, 2023)

According to Latiffi et al. (2015), LOD 100 is the first tier within this hierarchical framework, focusing on creating a conceptual model that encompasses fundamental requirements such as area, height, volume, location, and orientation. During this phase of the BIM process, stakeholders can develop a conceptual understanding of the project's core components. LOD 100 aids in enhancing the decision-making process for early planners by providing a fundamental understanding of the project’s spatial characteristics and arrangement (Weygant, 2011).

LOD 200 is a progression from LOD 100 since it integrates generic modelling and schematic design considerations. At this stage, components are represented using approximate numbers, sizes, shapes, locations, and orientations (Latiffi et al., 2015; Sanhudo et al., 2021). The incorporation of non-geometric data inside the model components at this level is crucial for enhancing the level of understanding. Using LOD 200 in project design helps stakeholders gain a more profound understanding, enhances communication, and fosters collaborative efforts across diverse disciplines (Reddy, 2011).

Once the BIM model reaches LOD 300, it becomes suitable for detailed modelling and shop drawings. The description of elements encompasses several aspects, such as assemblies, quantities, sizes, shapes, locations, and orientations

(Weygant, 2011). Like earlier iterations, the model components include non-geometric data, facilitating a more detailed understanding of the evolving project needs. LOD 300 enables thorough planning and enhanced stakeholder cooperation.

As one progresses through the levels of abstraction, LOD 350 introduces a new dimension of heightened complexity and detailing. The incorporation of components at this stage in the project's construction documentation becomes advantageous as it allows for the representation of intricate relationships among various building systems. To ensure that the model accurately represents the physical attributes and functional connections of various components, LOD 350 prioritizes the inclusion of precise visual representations and descriptive text (Sanhudo et al., 2021). At this level, a substantial level of reciprocal understanding and collaboration exists among all entities engaged in the project.

Once a model reaches Level of Detail 400, each component piece is precisely described as a separate assembly, accompanied by detailed documentation outlining its manufacturing and assembly processes. Sanhudo et al. (2021) proposed an extensive discussion on several aspects, including precise quantities, dimensions, configurations, positions, and alignments within the context of LOD 400. The model consistently stores non-geometric data inside its components, serving as a complete data repository for the project. The meticulousness shown by LOD 400 leads to enhanced efficiency in a project's manufacturing and assembly stages (Weygant, 2011).

LOD 500 broadly depicts a project's as-built condition, signifying the pinnacle of BIM maturity. The models of the components at this level accurately depict the physical attributes, including size, shape, location, number, and orientation (Abualdenien & Borrmann, 2019). The model serves as a comprehensive project data repository by incorporating non-geometric information within its components. The indispensability of LOD 500 models in the context of operations and maintenance lies in their facilitating the efficacy of facility management (Afzal, 2021; Banihashemi et al., 2022). The systematic use of BIM can be enhanced by the ordered progression of the LOD, which enables a comprehensive understanding of project intricacies across all phases.

2.4.2 BIM Maturity

Due to the absence of absolute clarity on the level of BIM application, BIM maturity becomes a factor. It refers to the quality, predictability, and variability within the use of BIM across an organization or project (Succar et al., 2012). Several BIM maturity models have been developed to determine an organization's progress in adopting BIM (Siebelink et al., 2021). These models typically assess BIM maturity based on various technological, organizational and process-related criteria. One of the most widely cited BIM maturity models is the BIM Maturity Levels proposed by Bew and Richards (Borrmann et al., 2018). This model identifies four maturity levels for assessing BIM, ranging from Level 0 to Level 3, which indicate the transformational milestones along the BIM implementation spectrum. Each level represents an increasing sophistication and integration of BIM within an organisation or workflow process.

2.4.2.1 Level 0:

This level represents the lowest level of BIM use (Borrmann et al., 2018). It is often described as unmanaged CAD. This BIM level includes the use of paper-based 2D CAD drawings and low-level CAD usage, with little to no collaboration or information sharing among project stakeholders. The focus is on individual, isolated workflows rather than a coordinated, integrated approach to project delivery (Hannele et al., 2012).

2.4.2.2 Level 1: Object-based modeling:

At this level, the use of BIM is characterized by 2D drawings with partial single-disciplinary 3D parametric modelling, also known as managed CAD. This phase often involves the use of 3D parametric software such as Revit to generate a 3D model for visualization and the automation of 2D drawings and documentation (Kassem & Succar, 2017b). A Common Data Environment (CDE) at this level simplifies the exchange of information in proprietary formats (Borrmann et al., 2018). The level represents a transition from the predominantly paper-based workflows and low-level CAD usage seen in Level 0 towards a more collaborative and integrated approach to project delivery.

2.4.2.3 Level 2: Model-based collaboration:

At this level, the focus of BIM operation shifts towards a more collaborative and integrated approach to project delivery. The cornerstone of this level is the use of federated BIM models, where different disciplines and stakeholders contribute to a shared, coordinated model using a CDE (Hannele et al., 2012). All stakeholders use BIM software capable of exporting information in IFC (Industry Foundation Classes) to ensure that no party is excluded from this integrated BIM process. Organizations become more aware of their position within the supply chain and their dependence on their partners. This increased collaborative focus on BIM leads to a shift from an internal to an inter-organizational perspective as organizational maturity increases (Siebelink et al., 2021). Collaborative BIM levels require interoperability, legal clarity, and workflow alignment.

2.4.2.4 Level 3: Network-based integration:

Level 3 is considered the most advanced stage of BIM use (Borrmann et al., 2018). The process focuses on a fully integrated, interoperable, cloud-based BIM environment. This level is characterized by the use of a single, shared model that is accessible to all project stakeholders, enabling true collaboration and information exchange throughout the entire project lifecycle (Hannele et al., 2012). All stakeholders have access to and can modify the same model in real-time, eliminating the risk of conflicting information. This level offers a broad overview of the whole project life cycle.

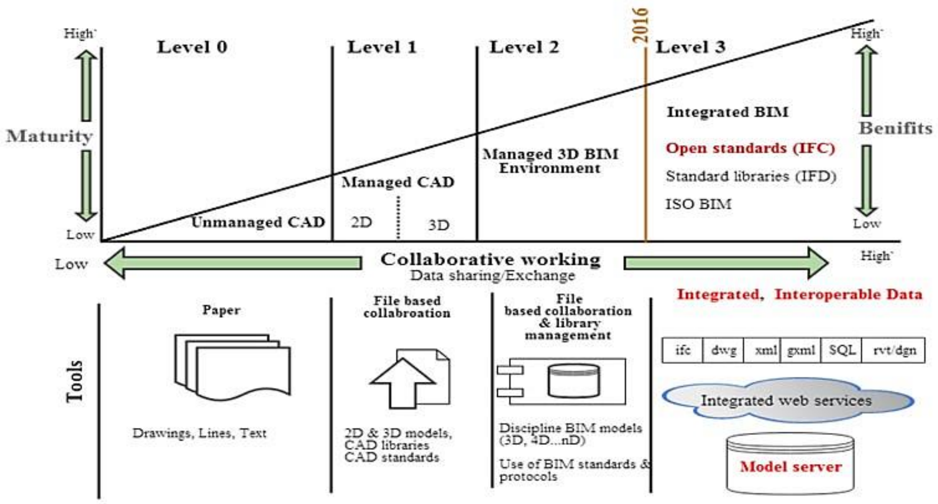

Figure 2. 3 BIM Maturity Level (Shafiq, 2021) (modified from the Bew-Richard BIM maturity model)

Chen et al. (2022) underscored the role of organizational culture in the effectiveness of BIM adoption. complementing this, Latiffi et al. (2017) note that BIM progression is often non-linear and highly dependent on institutional readiness. Their study revealed that organizations with a culture of collaboration, information sharing, and innovation were more likely to achieve higher levels of BIM maturity. The separation of BIM stages provides organizations with a roadmap for proceeding along the operation route, from object-based modelling through model-based collaboration to network-based integration.

2.4.3 BIM Adoption in the Construction Industry

The increasing popularity of BIM reflects both its demonstrated benefits and the industry's recognition of the limitations of traditional project delivery. BIM represents a substantive shift that disrupts conventional project management, altering how projects are conceived, planned, executed, and managed. Foundational studies (Doukari et al., 2023; Succar & Kassem, 2015) emphasize that its core value lies in better communication, streamlined collaboration, and more informed decision-making across the project life cycle.

BIM adoption, however, is not a single event but a staged process. Succar and Kassem (2015) describe a progression in organizational capability from object-based modeling, to model-based collaboration, and ultimately to network-based integration. Competence at the individual level, such as 3D modeling, collaborative workflows, and data integration, is equally important (Ullah et al., 2019). On the project side, implementation means applying BIM tools and methods in real settings: conducting detailed site planning, detecting and resolving design clashes, sequencing activities in 4D, and estimating costs in 5D (Noor et al., 2018). Establishing clear standards, protocols, and practices helps integrate these dimensions and align them with day-to-day project execution.

Global experience shows uneven rates of progress. Government policy and strategic initiatives have pushed many developed economies toward advanced stages of adoption. Surveying multiple regions, Jung and Lee (2015) find that North America, Europe and parts of Asia are approaching maturity, while South America, Africa, and the Middle East remain in early stages.

National strategies show these dynamics. In the United Kingdom, BIM is positioned as a driver for growth within the "Government Construction 2025" agenda, with policy direction for public projects accelerating uptake strategy (Arayici et al., 2011b; Langston & Zhang, 2021) In the United States, progress is reinforced by requirements for IFC submissions on public work and by institutional clients' demand for detailed 3D models (Kassem & Succar, 2017b).

Despite advances, challenges persist. High perceived costs and resistance to change remain common barriers (Howard et al., 2017). Encouragingly, cloud-based solutions and competition in the software market are lowering financial burdens and broadening access to BIM, creating more enabling conditions for a wider range of stakeholders.

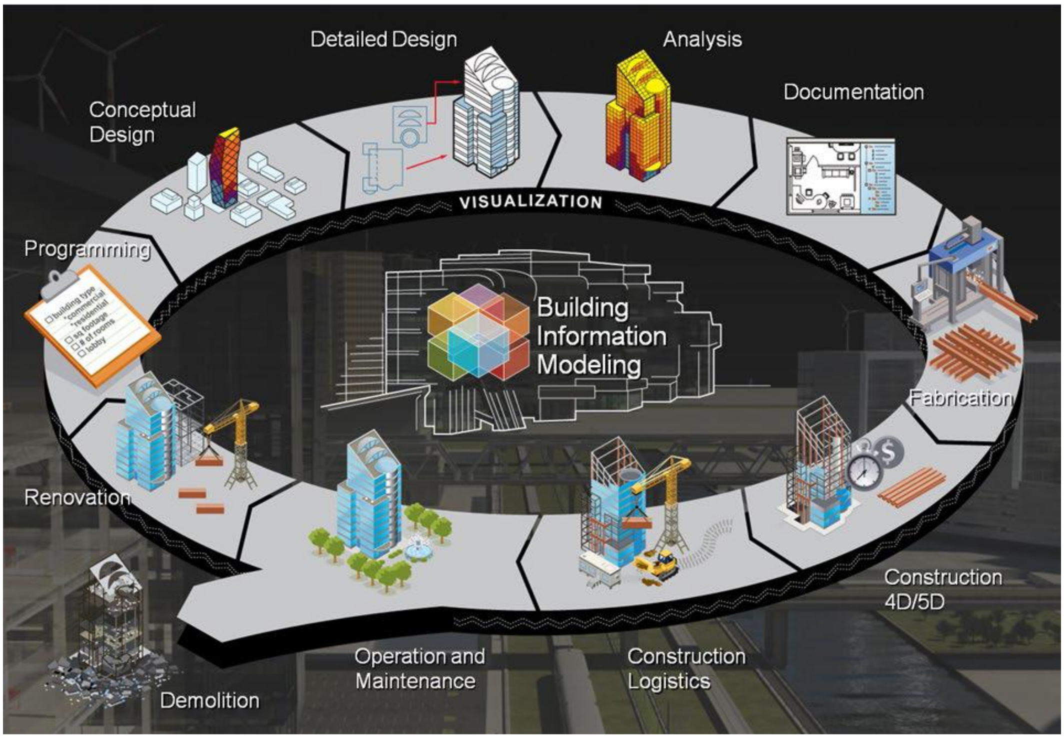

Figure 2. 4 BIM implementation process (Pan et al., 2023)

2.4.4 Global Trends and Advancement in BIM Technology in the Construction Industry

The advent of BIM technology and other current advancements has initiated a phase of rapid transformation within the construction industry. Once seen as a mere tool, BIM has evolved into a digital ecosystem that significantly transforms all phases of a construction project's lifecycle, including design, construction, and operation. The change in approach reflects a broader trend within the industry, characterized by a growing focus on technological innovation, multidisciplinary collaboration, and achieving better project outcomes (Eastman, 2011a; Succar, 2010). Integrating artificial intelligence (AI) and machine learning (ML) into BIM processes has become a significant global trend. Algorithms powered by artificial intelligence are facilitating the advent of a new age in data analysis, including anticipated insights that empower stakeholders to make informed decisions. The combination of AI with BIM has the potential to provide precise performance predictions and real-time simulations (Al-Yami & Sanni-Anibire, 2021; Zhang et al., 2020).

The Internet of Things (IoT) era has ushered in a phase of intelligent construction characterized by interconnected and sophisticated smart devices deployed across construction sites. The emergence of this phenomenon has given rise to the concept of "intelligent construction," wherein sensors supported by the IoT gather real-time data about diverse construction-related activities and equipment. The integration of these data streams into the BIM model enables complete monitoring of project progress, assessment of quality, and enhancement of safety, thereby fostering a culture of ongoing improvement (Bao et al., 2022; Teizer et al., 2017).

The breakthroughs in virtual and augmented reality technologies have undeniably transformed how BIM is visualized and conveyed. Stakeholders have the opportunity to gain a meaningful understanding of the project's tangible aspects through the use of immersive virtual environments that closely replicate reality. This kind of engagement leads to a more profound comprehension of concepts, enhances the level of support from relevant parties, and the early identification of issues. By effectively minimizing errors and reducing the need for costly revisions, augmented reality (AR) technology enriches the physical environment by integrating BIM data. This integration enables on-site construction personnel to access real-time information and guidance (Deng et al., 2021; Yilmaz et al., 2023).

The increasing emphasis on sustainability and environmental accountability within the construction sector is a significant catalyst for the global proliferation of BIM technology. BIM technology has been used to simulate energy consumption, examine the life cycles of buildings, and assess the environmental impacts as the construction industry increasingly adopts sustainable building practices. Architects can refine their plans to achieve maximum energy efficiency, minimize waste generation, and ensure long-term sustainability by adopting an inclusive perspective (Tian et al., 2023; Xia et al., 2021).

One of the fundamental features of BIM technology is its capacity to foster collaboration across diverse disciplines. Incorporating geographical data into the BIM framework enables the convergence of BIM and Geographic Information Systems (GIS), allowing for enhanced site analysis, urban planning, and overall infrastructure management. Collectively, these criteria ensure that the construction of BIM models accurately represents their corresponding geographical context, facilitating well-informed decision-making and promoting a higher rate of project success (Guo et al., 2021; Lin & Golparvar-Fard, 2020). The convergence of global trends and advancements in BIM technology is propelling the construction industry to unprecedented growth and development. The incorporation of artificial intelligence, the Internet of Things, virtual and augmented reality, sustainability, and multidisciplinary collaboration is revolutionizing the construction process of buildings. By leveraging the transformative capabilities of BIM, the major stakeholders in the construction industry will be able to address the complexities associated with construction project delivery in an unprecedented manner, characterized by enhanced precision, productivity, and proactive planning.

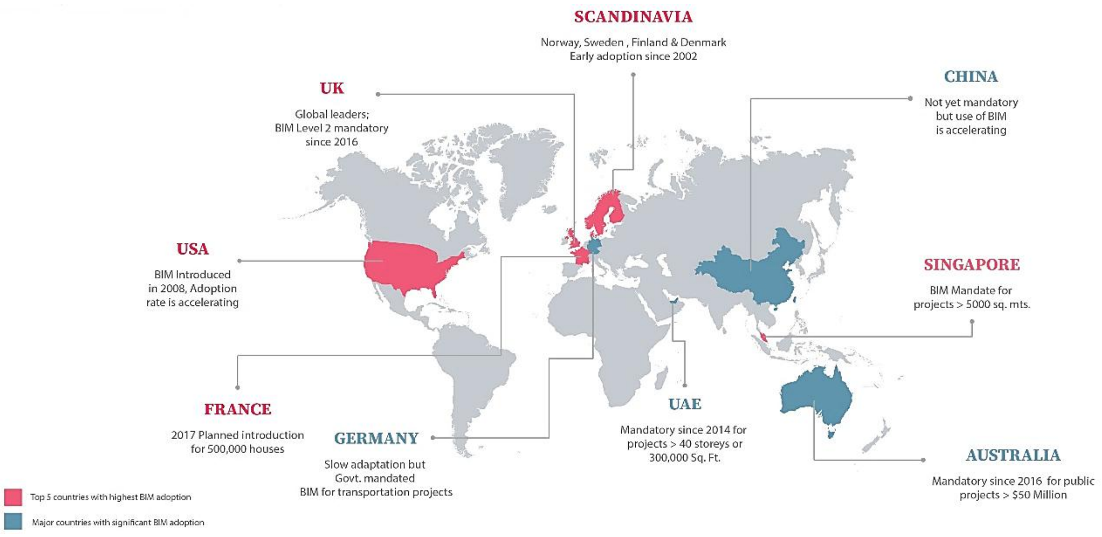

Figure 2. 5 The Global Rise in BIM (Heins et al., 2021)

2.4.5 Trends and Advancement of BIM Technology in Ghana's Construction Industry

Despite the notable transformations in recent years, mainly attributed to the growing trend of investment in large-scale infrastructural and real estate projects across various cities, Ghana's construction industry continues to grapple with challenges of delay, cost overrun, and poor project quality. Ofori-Kuragu (2020) attributes these challenges to ineffective collaboration among project stakeholders. But, in recent times, BIM has gained considerable traction as a potential solution within the construction industry in Ghana (Wu & Issa, 2014). This development is particularly significant due to the increasing global and local emphasis on sustainability. According to Osei-Kyei and Chan (2017), BIM offers simulation and analytical capabilities that foster the development of environmentally conscious and energy-efficient structures, aligning with current ecological objectives.

BIM represents a new paradigm for the AEC industry, emphasizing the integration of all stakeholders' responsibilities within a project with the potential to enhance productivity and foster collaboration among previously antagonistic project stakeholders. Addy et al. (2018) asserted that adopting and implementing BIM is essential for the construction industry in Ghana. Therefore, it is not surprising that there is an increasing inclination towards using BIM technology to support digital collaboration and information exchange within the industry. This movement aligns with the global inclination towards cloud-based collaboration, enabling project participants to engage in collaborative work irrespective of geographical proximity. Cloud-based BIM systems enhance collaboration efficiency by giving architects, engineers, contractors, and other stakeholders immediate access to project data. It reduces communication bottlenecks and enhances project coordination (Camngca et al., 2022).

However, in developing nations like Ghana, the adoption of BIM has been relatively slow despite its inherent capacity to address critical issues such as project delays and cost management. While some studies have explored the use of BIM in Ghana's construction industry, these inquiries have often focused on specific professional domains (Acquah et al., 2018; Akwaah, 2015b; Bamfo-Agyei & Nani, 2015). According to research conducted by Armah (2015) and Appiah (2020b), it has become evident that industry professionals in Ghana possess limited knowledge and awareness of BIM. This lack of awareness has hindered the adoption, particularly among architects and engineers who are at the forefront of championing BIM integration. Acquah et al. (2018) further noted that the private sector has embraced BIM in Ghana's construction industry. Nevertheless, its use has been limited to fundamental stages such as 3D rendering, perspective development, and idea generation. The industry has only begun to scratch the surface of BIM's immense potential.

Keeping pace with the fast breakthroughs in global technological innovation requires overcoming the perceived limitations to BIM adoption related to people, technology, and processes (Loh, 2014). Various entities such as higher education institutions, professional associations, and governmental organizations have initiated processes to enhance the proficiency of architects, engineers, contractors, and other professionals in effectively harnessing the advantages of BIM technologies and processes. Training programs and workshops have emerged as vital methods for achieving this objective (Boamah et al., 2022). The recent push to increase collaborative project delivery within Ghana’s construction industry is closely aligned with the global emergence of trends and advancements in BIM technology. But, the absence of national BIM implementation programs presents a significant challenge to industry stakeholders seeking to embrace BIM.

2.5 BIM Awareness and Knowledge

The importance of possessing BIM awareness and knowledge in contemporary construction is readily apparent, as it directly influences design, construction, and project management processes (Eadie et al., 2014; Succar, 2010). The adoption of BIM has significant consequences due to its potential to disrupt existing conventions through the integration of digital technology, fostering enhanced collaboration among team members, and ultimately enhancing the overall quality of the project outcome. According to Osei-Kyei and Chan (2017), there has been a notable increase in the construction industry's acknowledgement of the transformative capabilities of BIM in recent times. The advantages of transitioning from traditional workflow to BIM practices are increasingly evident to professionals, organizations, and stakeholders (Adam et al., 2021).

The phrase "BIM awareness" refers to a wide-ranging cognizance of the principles, applications, and benefits associated with BIM. The concept involves recognizing how BIM promotes enhanced communication, streamlined collaboration, reduced errors, improved visualization, and data-informed decision-making throughout the various stages of a project's lifecycle. On the other hand, BIM knowledge extends beyond a surface-level understanding to include a grasp of the technical workings of the technology (Chew et al., 2020). Aptitude in BIM packages, tools, and procedures is essential as it represents the starting point of effective adoption in practice (Keung et al., 2023). Understanding the interoperability of software packages is an essential factor in advancing BIM, as it aids effective communication and cooperation across many disciplines.

The convergence of several factors has contributed to advancing BIM knowledge and awareness (Yilmaz et al., 2023). Academic institutions, professional bodies, and government agencies have played significant roles in disseminating information about the potential and benefits of BIM. The availability of numerous training courses, workshops, seminars, and easily accessible online resources has significantly assisted professionals in acquiring of proficiency in navigating the complex landscape of BIM. These efforts have played a pivotal role in bridging the knowledge disparity and equipping individuals with the necessary resources to effectively use BIM within their respective environments.

The transferability of knowledge and understanding of BIM technology extends to many occupational positions within the construction industry (Owusu et al., 2022). An in-depth understanding of BIM protocols becomes advantageous for the stakeholders engaged in the building industry, encompassing architects, engineers, contractors, project managers, facility managers, and other relevant personnel. Enhanced cooperation is advanced when individuals from diverse disciplines possess a shared understanding of BIM-related concepts such as data formats, procedures, and terminologies. This collaboration helps to establish a cohesive work environment by ensuring the accurate transmission and use of data throughout various phases of the project execution.

In addition to possessing technical proficiency, the use of BIM technology has considerable significance (Bao et al., 2022). Nonetheless, Babatunde et al.

(2020) assert that a lack of familiarity with standardised BIM protocols often impedes practical adoption. By prioritizing education and training in BIM, firms can benefit from enhanced project efficiency, less rework, and increased customer satisfaction. Nevertheless, Adekunle et al. (2021) and Li et al. (2023) found that advanced BIM applications are frequently less understood in developing countries due to limited exposure to case studies of BIM-based projects. The need for continuous education and training becomes more apparent as the use of BIM technology progresses and becomes increasingly integrated into the construction industry (Succar, 2010). To maintain a competitive edge and make meaningful contributions to the continuous transformation of the construction industry, professionals in this industry must proactively remain updated and adaptable to the latest advancements in BIM packages, industry standards, and emerging trends (Silverio et al., 2023).

Although BIM awareness is gradually increasing among Ghanaian construction professionals, technical proficiency remains limited, with understanding often restricted to basic 3D modeling. Weaknesses in formal training, academic curricula, and practical exposure hinder the development of deeper expertise. This disparity between awareness and competence slows adoption, underscoring the need for structured training, capacity-building, and professional education to convert awareness into effective implementation. Globally, higher BIM awareness has been shown to correlate strongly with adoption readiness, but in Ghana, the disparity between conceptual awareness and practical competency reinforces slow adoption. A more deliberate focus on structured training, capacity-building initiatives, and professional education is essential to translate awareness into meaningful implementation.

2.6 Organizational and Technological Readiness for BIM Adoption

The adoption of BIM in the construction industry is significantly impacted by the level of readiness, both in terms of organizational and technological contexts, within the evolving industry environment. The successful setup of BIM, which represents a significant shift in project delivery workflow, requires aligning organizational policies and seamlessly integrating sufficient technological infrastructure. It is crucial to evaluate an organization's readiness to integrate BIM as a fundamental component of its everyday operations. To achieve a high level of preparedness, individuals must go beyond surface-level efforts and actively cultivate a cultural environment that places significant emphasis on the appreciation of innovation, collaboration, and the pursuit of knowledge (Tezel & Aziz, 2017). Enhancing the seamless integration of BIM processes requires organizations to cultivate an environment that encourages open communication and a proactive approach toward embracing change. It may be imperative to re-evaluate internal procedures, roles, and responsibilities to achieve readiness for BIM-driven project delivery (Azhar et al., 2012).

Conversely, technological readiness ensures an organization has the requisite hardware and software resources to adopt BIM effectively. This entails allocating financial resources towards acquiring technological assets such as computers and databases capable of effectively processing the elaborate data generated through BIM. Establishing interoperability across diverse software platforms is essential to technological readiness, as it enables seamless information exchange and collaboration among individuals from many disciplines engaged in a joint project (Eastman, 2011a). Another crucial aspect is the proper training of personnel in using BIM software packages to their maximum potential (Howard et al., 2017).

The successful adoption of BIM relies on the combined readiness of organizational and technological aspects. Organizations that understand the significance of efficiently coordinating these preparatory factors will experience efficiency in managing the complexities associated with implementing BIM. According to Tezel and Aziz (2017), an organization prepared to implement BIM has the essential technological infrastructure and a corporate culture that fosters innovation, collaboration, and a proactive approach to addressing change. When there is alignment across departments, organizations can effectively use BIM, resulting in improved project outcomes, reduced errors, and increased stakeholder satisfaction.

Difficulties may arise when the organizational and technological aspects of BIM adoption are not properly addressed. The absence of a well-defined adoption strategy exposes organizations to the potential challenges and difficulties associated with integrating BIM into their projects. This lack of planning may result in inefficiencies, time wastage, and conflicts (Azhar et al., 2012). The exacerbation of frustration among team members occurs when technical restrictions, such as inadequate hardware or software resources, hinder the effective adoption of BIM. The ability of professionals to effectively acquire and use BIM technology may be hindered by a lack of training and development initiatives (Howard et al., 2017).

The literature affirms that effective BIM adoption is contingent upon both organizational and technological readiness. In Ghana, organizational barriers, including fragmented structures, traditional procurement practices, and limited managerial commitment, combine with technological deficits such as inadequate infrastructure, outdated software, and insufficient training to constrain adoption. This dual weakness underscores that organizational reform without robust digital capacity, or technology acquisition without strategic alignment, is inadequate; rather, coordinated investment in infrastructure, capacity building, and leadership-driven change is required to advance BIM integration in the Ghanaian construction industry.

2.7 Drivers of BIM Adoption

The construction industry is undergoing tremendous growth due to several influencing driving factors that highlight the transformative potential of BIM technology (Bhattacharya & Momaya, 2021; Jamal et al., 2019). These drivers act as practical incentives for clients, consultants, and contractors to embed BIM in day-to-day delivery Taken together, they operate at three levels: the project (better coordination and control), the organization (productivity and capability), and the industry (policy, standards, and market expectations). Framing BIM’s benefits across these levels helps explain both its growing visibility and its gradual normalization in practice (Patel et al., 2021).

A first and persistent motivation is improved efficiency at lower cost. On-time and on-budget delivery remains a core priority, yet traditional information flows often create delays, rework, and disputes. BIM supports tighter planning and control by coordinating disciplines in a shared environment and by enabling data-driven decisions about scope, sequencing, and interfaces (Harris et al., 2021; Yuan et al., 2019). When teams work from consistent information, they can reduce variation, anticipate risks, and minimize waste across the project life cycle

Closely linked to efficiency is quality. Data-rich 3D models allow early identification of clashes, interferences, and design inconsistencies in advance, hence preventing their manifestation during the actual construction phase (Rajendran et al., 2014). This proactive approach improves constructability reviews, reduces change orders, and lowers the likelihood of errors during execution. Eastman (2011a) notes, shifting problem-solving to the preconstruction phase increases overall project reliability and frees resources for value-adding tasks rather than rework.

The prevailing movement towards sustainability and environmentally friendly construction has also reinforced the widespread use of BIM. The same information backbone that supports coordination can also power detailed energy analysis, Environmental Impact Assessments (EIAs), and Life Cycle Assessments (LCAs). These capabilities align project decisions with environmental objectives, encouraging efficient material use and better operational performance of built assets (Osei-Kyei & Chan, 2017). In this way, BIM links day-to-day design choices with broader policy goals on climate and resource stewardship.

Public policy often drives the global adoption of BIM technology in most cases. Governments increasingly require BIM on publicly funded projects, recognizing its role in transparency, productivity, and value for money. In the United Kingdom, BIM features prominently in the "Government Construction 2025" agenda, with clear expectations for public procurement encouraging uptake across the supply chain (Arayici et al., 2011b; Işık et al., 2021). Australia shows a similar pattern: governmental endorsement has expanded BIM use on public works and provided a consistent reference point for standards and deliverables (Pinti et al., 2022; Toklu & Mayuk, 2020). Such mandates reduce uncertainty for firms, align incentives, and encourage investment in skills and tools.

Collaboration is another practical driver. BIM functions as a shared digital platform that improves communication among architects, engineers, contractors, and clients, thereby reducing misunderstandings and information silos (Raja Mohd Noor et al., 2021). According to Succar (2010), a common data environment and standardized protocols help teams coordinate decisions and record changes transparently, supporting a more unified approach to delivery. Rapid advances in complementary technologies such as Internet of Things (IoT), virtual reality (VR), and augmented reality (AR), further enhance visualization, analysis, and site management, strengthening the business case for BIM-enabled workflows (Bao et al., 2022; T. A. Nguyen et al., 2022; Yilmaz et al., 2023).

In general, a myriad of incentivizing drivers contributes to the widespread adoption of BIM technology in the construction industry. These drivers (see Table 2.1) explain BIM's expanding role in contemporary practice. At the project level, improved visualization, better coordination, and tighter cost and time control are compelling benefits. At the organizational level, productivity gains, competitive positioning, and stronger team collaboration motivate investment. At the industry level, global digitalization, client demands for efficiency, and sustainability targets reinforce adoption. In Ghana, while awareness of these drivers exists, their potential is often undermined by systemic and contextual challenges such as limited infrastructure and regulatory support. Even so, many stakeholders view BIM as a practical means to reduce errors, prevent communication breakdowns, and improve outcomes across the project delivery chain.

While drivers illustrate the potential benefits and motivating factors for BIM adoption, it is equally important to recognize the barriers that constrain its implementation. Understanding these challenges provides a balanced perspective and highlights why adoption has been slower than anticipated in contexts such as Ghana.

Table 2. 1 Key Drivers of BIM Adoption

Driver	Author(s) & Year
Improved project visualization	Gerges et al. (2017); Abanda et al. (2015)
Enhanced collaboration	Gu & London (2010); Eadie et al. (2013)
Reduction of errors and rework	Arayici et al. (2011); Cao et al. (2015)
Cost efficiency and time savings	Darko et al. (2017); Ahuja et al. (2020)
Improved project coordination & quality	Bryde et al. (2013); Akinradewo et al. (2022)
Competitive advantage & innovation	Abubakar et al. (2014)
Quality improvement and error reduction	Rajendran et al. (2014); Eastman (2011a)

Driver	Author(s) & Year
Government mandates and public procurement policies	Arayici et al. (2011b); Işık et al. (2021); Pinti et al. (2022); Toklu & Mayuk (2020)
Market incentives to adopt	Jamal et al. (2019); Patel et al. (2021)
Better sustainability outcomes	Wong & Fan (2013); Olawumi et al. (2018)

2.8 Barriers to BIM Adoption

The integration of BIM technology can can transform construction practice, yet its diffusion is slowed by interrelated organizational, technological, financial, and regulatory barriers (Chan et al., 2019). Together, these constraints limit its widespread, routine use.

A persistent obstacle is resistance to change. Many stakeholders often demonstrate a reluctance to break away from existing operational norms and are firmly rooted in the industry's long-standing traditional approach (Yan & Demian, 2008). Due to potential disruptions to existing practices, individuals and organizations may be reluctant to allocate the necessary time, effort, and resources to acquire proficiency in successfully adopting BIM tools and workflow (El Hajj et al., 2023; Lee & Borrmann, 2020). Targeted change-management, clear communication, phased rollout, and visible leadership support, helps address misconceptions and reduce anxiety as BIM-enabled processes are introduced.

Skills and training gaps compound this challenge Without formal education and continuous upskilling, professionals remain uncertain about BIM’s applications and value (Girginkaya Akdag & Maqsood, 2020). Regional studies report lack of expertise and limited training opportunities, particularly among contractors in the Middle East and North Africa (Abdullah et al., 2024), and more broadly in developing contexts with weak state support for digital transformation (Hassan et al., 2024). Misconceptions about BIM’s complexity and suitability for certain project types further deter use. Education programs and knowledge-sharing platforms are therefore critical to build competence and confidence.

The practical application of BIM is hindered by technological capacity. Inadequate IT infrastructure, obsolete hardware, outdated software, and weak networks, undermine efficient model authoring and data exchange (Belay et al., 2021b). Because BIM is interdisciplinary and data-intensive, interoperability and platform compatibility are essential (Kassem & Succar, 2017b). Strategic investment in capable hardware, current software, and robust connectivity is required to support reliable collaboration and information management.

The insufficiency of financial resources is a recurring and substantial obstacle to the widespread adoption of BIM, particularly in developing countries (El Hajj et al., 2023). Upfront costs for licenses, upgrades, and training can appear prohibitive (Alam et al., 2023; Aziz & Zainon, 2022). Organizations may resist adopting BIM due to the perceived high initial costs despite the potential for significant long-term benefits. Phased adoption, use of cost-effective or open-source tools, and a clear focus on life-cycle returns can improve the business case.

Organizational culture plays a decisive role. Reluctance to take perceived risks with new technologies slows uptake (Aziz & Zainon, 2022), and weak leadership support correlates with lower adoption rates (Tezel & Aziz, 2017). Effective leadership, transparent communication, and an environment that rewards collaboration and learning can shift norms. Early pilot projects that demonstrate tangible benefits often help build internal momentum (Altohami et al., 2021; Saka & Chan, 2020).

A further barrier is the absence of consistent standards and protocols. Without agreed data formats, naming conventions, and collaboration procedures, information transfer and interoperability suffer, creating confusion and rework (Lee & Borrmann, 2020; Manzoor et al., 2021). Standardized workflows and industry best practices, preferably embedded in national or sectoral frameworks, can streamline implementation and reduce ambiguity (Paneru et al., 2023). In many developing countries, limited government initiatives and regulatory guidance magnify these issues.

The presence of legal and contractual difficulties further hinders the adoption of BIM. According to Azhar et al. (2012) and Abd Jamil and Fathi (2020), collaborative data-sharing and model authorship integrating may conflict with existing contractual agreements and liability considerations. It is imperative to advocate for contractual frameworks that clarify responsibilities, intellectual property, and risk allocation to support BIM-based delivery.

In summary, BIM adoption is constrained by capability, infrastructure, cost, culture, standards, and legal frameworks. These challenges are often sharper in developing contexts like Ghana, due to sector fragmentation and limited knowledge transfer. Recognizing this background helps explain slow uptake and underscores why the documented performance benefits of BIM justify continued efforts to eliminate these barriers. The demonstrated benefits provide further justification for continued investment in BIM adoption strategies.

Table 2. 2 Key Barriers to BIM Adoption

Barrier	Author(s) & Year
Lack of skilled professionals	Girginkaya Akdag & Maqsood (2020)
Inadequate IT infrastructure	Belay et al. (2021)
High cost of BIM software	Gerges et al. (2017); Liao & Teo (2019)
Resistance to change	El Hajj et al. (2023); Lee & Borrmann (2020)
BIM complexity	Klaschka (2019); Wee (2023)
Limited BIM education	Chen et al. (2022);
Interoperability issues	Lee & Borrmann (2020)
Lack of standardized protocols and data conventions	Manzoor et al. (2021); Paneru et al. (2023)
Limited awareness & knowledge	Abanda et al. (2015); Khosrowshahi & Arayici (2012)
Limited regulatory frameworks & policies	Sierra & Rodboonpha (2023); Adewola et al. (2023)
Legal and contractual uncertainties	Aziz & Zainon (2022)
Fragmentation of the construction industry	Kpamma et al. (2021); Arayici et al. (2011)
Lack of leadership & institutional support	Saka & Chan (2020); Altohami et al. (2021)

2.9 Impact of BIM on Construction Project Performance

The integration of BIM in construction projects is thought to improve various dimensions of construction project performance, including quality, cost, time, safety, and overall efficiency (Bryde et al., 2013; Samimpay & Saghatforoush, 2020). A common opinion among most researchers is that project delivery is greatly enhanced through BIM integration, as it improves collaboration, coordination, and decision-making. Barkokebas et al. (2021) assert that BIM serves as an effective tool for cost management, emphasising its role in facilitating decision-making that aligns with the project delivery schedule. Similarly, Kukah et al. (2023) contend that the integration of BIM impacts project performance by enhancing project outcomes related to cost, quality and time. Their findings support the argument that BIM is a collaborative approach essential for effective project management. The emphasis on collaboration in BIM-based projects is echoed by Zaker Hosein (2019), who asserts that integrating BIM into project management practices enables better insights and scheduling capabilities that lead to enhanced efficiency in execution.

Notable cost reductions and improved timelines are achieved through the operational efficiency that BIM brings to projects through enhanced simulation of construction workflows and equipment operation (Barkokebas et al., 2021). Likewise, Cao et al. (2017) reported an enhancement in overall project efficiency due to BIM adoption, which has led to a reported decrease in design errors and change orders. The ability to visualise and manipulate a project in a digital environment with BIM before actual construction begins ensures that design intents are accurately translated into buildable solutions.

There is an additional recognition of BIM's influence on materials management and resource allocation during the construction phase of projects. For instance, Shin et al. (2024) highlighted that the integration of BIM enables improved material selection and management. This improvement directly reduces waste and minimises material costs for projects.

According to McDermot et al. (2022), the success of a project is contingent upon factors beyond the mere attainment of financial and time-related objectives. BIM's influence on other dimensions is also notable. Baharuddin and Yusof (2018) and Dakhil et al. (2019) emphasize the significance of BIM in enhancing quality assurance, risk mitigation, safety practices and environmental sustainability within construction projects. This is achieved through enhanced visualization and simulation, which enable better error detection and amendments before actual construction. Besides the immediate performance metrics, the long-term sustainability of projects managed through BIM is increasingly recognised. Motalebi et al. (2022) assert that BIM plays a critical role in green construction by improving energy efficiency, reducing waste, and improving material usage. Zhang et al. (2023) echo this by stipulating that BIM affect project sustainability performance by integrating innovative green measures throughout the project lifecycle. The connection between BIM adoption and sustainable project delivery highlights BIM's contribution towards environmentally responsible design and execution in the construction industry. BIM's ability to aggregate and streamline project lifecycle data plays a critical role in fostering sustainable construction practices (Kukah et al., 2023)

Notably, Barajei, Kheni, et al. (2023) highlighted the need for effective stakeholder management to harness the benefits of BIM to elevate project quality and overall performance. The need for organisations to assess BIM maturity levels and ensure personnel are adequately prepared to adopt these technologies is highlighted by Olugboyega and Windapo (2019). Hence, maximising the potential impact of BIM on project performance requires investment in skills and training. Samimpay and Saghatforoush (2020) found that while BIM adoption improves project performance, the full benefits are only realised when firms invest in continuous training and infrastructure development.

The success of construction projects in Ghana is influenced by several factors, including the socio-economic environment, regulatory framework, and cultural dynamics (Barajei, Kheni, et al., 2023). An enhanced understanding of the interaction between these factors can lead to the development of tailored strategies to achieve improved outcomes (Barajei, Appiah-Kubi, et al., 2023). Investment in BIM and other emerging technologies is viewed as a key strategy that can fundamentally transform project management practices in Ghana's construction industry, which is currently characterized by inefficiency and time overrun (Ofori, 2012).

The synthesis of the literature consistently affirms that BIM adoption has a transformative impact on construction project performance. Studies show that BIM enhances project visualization, streamlines coordination among stakeholders, reduces errors and rework, and improves cost and time efficiency. At the quality level, BIM enables more accurate design, better clash detection, and improved change order management, leading to higher overall project delivery standards. Furthermore, BIM facilitates transparency and collaboration, which in turn fosters stronger stakeholder relationships and decision-making. In the Ghanaian context, while these benefits are acknowledged in principle, their realization remains limited due to low adoption readiness, poor digital infrastructure, and skill shortages. Nonetheless, the potential for BIM to significantly improve project outcomes particularly in addressing fragmentation, inefficiencies, and cost overruns makes it a vital tool for advancing the performance of Ghana's construction industry.

Given the positive impacts of BIM on project performance and the persistent barriers to its adoption, effective strategies are required to bridge the gap between potential and practice. The following section discusses practical approaches for promoting BIM adoption within the Ghanaian construction industry

2.10 Strategies for Effective BIM Adoption

Despite its acknowledged benefits, the path towards effective BIM adoption remains constrained by numerous challenges. However, these challenges can be navigated through strategic initiatives and interventions. A multifaceted approach is evident where policy frameworks, public procurement processes, educational initiatives, and integrated incentives intersect to address the challenges associated with BIM adoption (Koseoglu et al., 2019; Whitlock et al., 2021).

Government mandates and policy interventions in several countries have demonstrated the impact of top-down strategies in fostering BIM adoption (Lam et al., 2015; Zhou et al., 2019). For instance, Zhou et al. (2019) observed that since 2016, all public procurement projects in the UK have been mandated to use BIM, and similarly, in South Korea, BIM adoption is mandated for public buildings exceeding a cost threshold of approximately $27.6 million as of 2016. In Brazil, the government issued Decree 9.377, which established a national strategy for the dissemination and adoption of BIM in public procurement (Nardelli, 2019). This decree mandated the use of BIM across government projects and established the groundwork for capacity building, targeted training, and enhanced operational guidelines within public agencies. These highlight how top-down strategies through government mandates and policy interventions have been successfully used in several countries to promote BIM adoption.

Ahmed and Kassem (2018) indicate that national and regional strategies aimed at promoting BIM adoption, such as the issuance of standardised data exchange protocols and frameworks for industry-wide collaboration, are essential in bridging the gap between technological potential and practical market application. Their research highlights that the convergence of government initiatives and industry standards creates an enabling market environment in which increased productivity and competitive advantage are readily available.

The effectiveness of BIM in construction firms is predominantly influenced by internal organizational dynamics, including leadership, culture, process management, strategic alignment, and capacity building (Olanrewaju et al., 2021; Olugboyega et al., 2023). Visionary leadership is crucial for overcoming resistance to change and cultivating an organizational culture that is receptive to technological innovation (Omer et al., 2022). Olugboyega et al. (2023) contend that essential BIM approaches involve transformative leadership, which actively champions the digitalisation process, allocates appropriate resources, and encourages interdepartmental collaboration. An essential organisational approach involves the development of internal capabilities through education, training, and cross-functional collaboration. Investing in human capital is a crucial prerequisite for the effective operationalisation of BIM, as continuous learning and adaptation ensure that employees remain up-to-date with ever evolving BIM technologies (Hong et al., 2019).

The success of BIM adoption requires strong technology and infrastructure strategies that transcend traditional digitisation efforts (Koseoglu et al., 2019). It is essential for organizations to assess their existing technological capabilities and invest in advanced software systems that support effective BIM use (P. Li et al., 2019). Durdyev et al. (2021) assert that up-to-date technological infrastructure streamlines project processes and attracts a more skilled workforce eager to engage with modern technologies such as BIM. As these investments materialise, organisations can expect improved communication, higher quality of deliverables, and a reduction in project delays (Vitente et al., 2024).

Training, capacity building, and government support are pivotal strategies for mitigating the shortage of skilled practitioners and foster an effective digital transformation in the construction industry. Olugboyega et al. (2023) present that a successful BIM process within an organisation is not solely a function of mandating compliance but rather a dynamic process that includes customised in-house training, role creation, and iterative work process redesign. Their findings underscore that successful capacity building involves aligning new digital roles with clear job titles and responsibilities to emphasise the importance of BIM competencies within each project lifecycle. Additional evidence is provided by Adam et al. (2021), who assessed the BIM readiness of construction professionals in the Seychelles. Their research indicates that BIM competency is closely related to the level of engagement in targeted education and training programs, highlighting that awareness and hands-on skills with BIM software are critical for fostering technical readiness.

Khoshfetrat et al. (2022) and Chen et al. (2020) emphasise that creating open communication channels among stakeholders significantly mitigates risks associated with BIM adoption by promoting data sharing and collaborative decision-making. Effective collaborative practices are not merely supplementary but are at the heart of BIM's value propositions. Fostering a culture of collaboration is not only a technical challenge but also an organizational and managerial one, requiring clear communication protocols, shared governance and standardised data exchange mechanisms (Alreshidi et al., 2017).

The adoption of BIM is increasingly justified by its potential to reduce costs and deliver measurable financial benefits over the entire project lifecycle. Darko and Chan (2018) identify financial and market-based incentives as pivotal strategies for promoting the adoption of technology-based solutions within the construction industry. These strategies are critical for persuading stakeholders of BIM's economic benefits and for guiding financial planning and decision-making across projects.

As BIM transforms the very nature of project delivery by integrating design, construction, and operational data through digital models, it simultaneously introduces novel legal risks and uncertainties that must be managed through proactive contractual arrangements (Abd Jamil & Fathi, 2018; Almarri et al., 2019). These concerns can create significant barriers to BIM adoption if they are not addressed by updating existing contractual practices. Traditional contracts, which were designed for the exchange of static information, may not fully account for the dynamic and multifaceted nature of BIM data (Almarri et al., 2019). X. Liao et al. (2019) provide an additional perspective by examining contractual practices between consultants and employers in Chinese BIM-enabled projects. Their study demonstrates that effective BIM adoption requires contractual provisions that clearly define roles, responsibilities, risk-sharing mechanisms and dispute-resolution procedures. By integrating BIM-specific clauses into contracts, parties can better coordinate design and construction activities while managing the uncertainties that arise from digital model interoperability (Chong et al., 2017; Fan et al., 2018).

Overall, effective BIM adoption requires a combination of technological investment, organizational change, capacity-building, and regulatory support. At the organizational level, leadership commitment, clear strategic planning, and the integration of BIM into workflows are highlighted as critical success factors. Training and professional development emerge as equally important, as they build the technical competencies and collaborative skills needed for effective implementation. Technologically, firms must invest in reliable digital infrastructure and interoperable software to fully realize BIM's potential. At the industry level, supportive government policies, regulatory frameworks, and standardized guidelines are vital in driving consistent adoption across the sector. In Ghana, strategies such as embedding BIM in tertiary education curricula, promoting public-private partnerships, and raising awareness through industry workshops have been recommended to overcome contextual challenges.

2.11 BIM Implementation Initiatives of Three (3) Leading Countries

The implementation process for BIM differs across various countries and regions. Numerous studies have underscored the importance of understanding the macro-level adoption initiatives at the national and market levels (Georgiadou, 2019; Troiani et al., 2020). These "macro-level" initiatives, such as the development of BIM standards, guidelines, and mandates, play a vital role in facilitating the effective integration of BIM within the construction industry.

The United States of America (USA), the United Kingdom (UK), and Singapore stand out as global leaders in BIM adoption (Kassem & Succar, 2017b). These countries have achieved notable progress in advancing BIM by implementing a range of government-led initiatives, industry engagement, and establishing BIM frameworks (Borrmann et al., 2018). This section examines the existing literature to explore the BIM adoption journey across these three leading countries. It offers insights into the factors that have contributed to their success and the challenges they have faced along the way.

2.11.1 The United Kingdom

The UK has primarily positioned itself as a global leader in BIM adoption through a structured, government-driven approach. The UK has employed a multi-agency framework with specialized groups taking on distinct roles at different stages of the BIM adoption process. This collaborative approach has been pivotal in driving BIM innovation, setting the stage for mandatory use, and preparing the industry for future advancements. The UK's BIM revolution officially began in 2011 with the launch of the "Government Construction Strategy" (GCS 2011–2015). This strategy mandated the adoption of BIM Level 2 for all publicly procured projects by April 2016 (UK Cabinet Office, 2011). Several specialized groups were established at various times to achieve this, each contributing to different aspects of BIM adoption.

As an advisory group, the Construction Project Information Committee (CPIC) provided best practices for managing construction information. It developed fundamental standards, such as the classification system and assessment forms, to guide industry stakeholders in evaluating their readiness for BIM (Wu et al., 2017). These tools helped ensure that firms had the IT resources to adopt BIM effectively. The BIM Task Group (BTG), created in 2011, became the backbone of BIM Level 2 adoption. Acting as regulator and initiator, it released critical standards such as BS1192:2007 for naming conventions and BS1192-4:2014 for exchanging BIM data (Cabinet Office, 2016). The group also introduced the Plan of Work to define BIM deliverables at each project stage, integrate end-user feedback, and improve asset performance after completion.

Additionally, BTG launched "BIM4 Groups" to provide domain-specific support and "BIM Regions" as local hubs, ensuring communication and technical assistance across the UK. BIM Technologies Alliance, a non-product-specific group representing software vendors, focused on developing interoperability solutions, technical support, and industry-wide protocols. It also worked as an educator, helping firms integrate BIM technologies into their workflows.

Building on the success of its first roadmap, the UK launched the "Government Construction Strategy 2016–2020″ to transition from BIM Level 2 to Level 3. This phase emphasized closer collaboration through centralized data models and the integration of asset lifecycle management. The Public Sector BIM Working Group (PSBWG) was established to support government departments. It focused on assessing the benefits of BIM, publishing case studies, and ensuring the smooth adoption across the public sector. It acted as a demonstrator, showcasing BIM success stories and tools to encourage broader adoption.

Formed in 2016, the UK BIM Alliance took over key responsibilities from the BTG, including managing the BIM4 Groups and BIM Regions. It also launched initiatives such as the BIM Academic Forum to promote education and research, aiming to make BIM Level 2 the industry standard by 2020 (Hooper, 2015). However, in 2017, the Centre for Digital Built Britain (CDBB) was created to lead the transition to BIM Level 3. Expanding the scope of BIM from construction projects to smart cities and infrastructure, the CDBB emphasized the importance of information management and interoperability. It introduced tools like ISO 19650 standards, developed e-training modules, and funded research into emerging technologies such as digital twins and Design for Manufacturing and Assembly (DfMA) (Allmendinger & Sielker, 2018).

Subsequently, the Construction Innovation Hub (CIH) was launched in 2018 to focus on combining BIM with off-site manufacturing techniques. It worked to develop new technologies, improve organizational capacities, and establish security-minded frameworks for the built environment (Neely et al., 2019).

The UK's approach to BIM adoption stands out for its reliance on collaboration between government agencies, industry groups, and academic institutions. By leveraging a diverse network of specialized groups, the UK has created an all-inclusive ecosystem that supports BIM, fosters innovation, and prepares the industry for future advancements. As the UK moves toward BIM Level 3 and beyond, its journey offers valuable lessons for other nations seeking to integrate digital technologies into their construction industry.

2.11.2 Singapore

Singapore's BIM journey is often regarded as a global standard for structured and deliberate execution. This transformation began in 2010 with the Building and Construction Authority (BCA), a statutory board responsible for developing and regulating Singapore's building and construction industry (L. Liao et al., 2019). They launched the country's first BIM Roadmap (2010–2015) to achieve 80% BIM adoption in the construction industry by 2015 (Kaneta et al., 2016). The roadmap addressed the key challenges of BIM adoption with five focused strategies: public sector leadership, streamlined regulatory approvals, removal of barriers, capacity building, and financial incentives (Liu et al., 2022).

The BCA collaborated with government procurement entities to integrate BIM into public projects. Between 2010 and 2012, pilot projects were implemented to test the use of BIM, accompanied by the introduction of BIM e-submission guidelines for architecture, structural engineering, and mechanical, electrical, and plumbing (MEP) disciplines (Fatt, 2011). By 2012, BIM had been integrated into public procurement requirements, marking a significant turning point in the widespread adoption across the industry. Mandatory BIM requirements were introduced in 2013 for architectural submissions of new buildings with a gross floor area (GFA) over 20,000 m² (L. Liao et al., 2019). This mandate was subsequently expanded to include engineering submissions in the following year. By 2015, BIM was mandatory for architectural and engineering submissions for all new projects with a GFA exceeding 5,000 m², pushing the industry toward the 80% adoption target (Liu et al., 2022). The BCA introduced funding programs to encourage the adoption of BIM, helping to alleviate the set up costs (Authority, 2013). In addition to its role as a policy initiator and funding agency, the BCA also served as a demonstrator by showcasing successful BIM applications and encouraging active participation from the industry.

In response to the demand for clear guidance, the BCA developed a range of resources, including the "Singapore BIM Guide and the BIM Essential Guide series". These documents provided detailed instructions on various topics, such as BIM execution plans, roles and responsibilities, quality assurance protocols, and ownership of BIM models. To ensure practical relevance, an industry-led steering committee oversaw the development of these guidelines, organized forums, and promoted success stories to address potential barriers and build confidence across the industry (L. Liao et al., 2019). The establishment of the Centre for Construction IT in 2010 further bolstered BIM capabilities by offering training, certification, and outreach programs to enhance modelling skills (Fatt, 2011).

Following the success of its first roadmap, Singapore introduced a second BIM Roadmap (2016–2020) aimed at facility and asset management, process transformation, and research and development (Hadzaman et al., 2015). Five new strategies were introduced: integrating BIM into facility management and smart city initiatives, fostering collaboration through Virtual Design and Construction, advancing Design for Manufacturing and Assembly, enhancing training programs, and prioritizing R&D (Shen et al., 2016).

The government's role evolved, emphasising research and development to foster innovation. As an educator, the BCA has expanded its training initiatives to equip professionals at all levels with the skills needed to adopt advanced BIM applications. Throughout this phase, the BCA maintained its role as a regulator, ensuring that the framework for BIM usage remained resilient and adaptable. Through its roles as a leader, educator, and researcher, the BCA established an ecosystem that promoted BIM adoption, encouraged innovation and fostered collaboration across the construction industry.

Singapore's planned approach to BIM implementation highlights the importance of a clear vision, strong leadership, and sustained industry engagement. The country has emerged as a global leader in BIM adoption by directly addressing technical, financial, and organizational challenges (Abdalla et al., 2023). Its journey offers valuable lessons for other nations seeking harness BIM's transformative potential in their construction industries.

2.11.3 The United States of America

The development of BIM in the U.S. is primarily driven by an industry-led model, with local governments, private organizations, and educational institutions playing significant roles in the process (Al-Mohammad et al., 2022; Wong et al., 2011). These entities develop their strategies tailored to their needs and challenges. The absence of centralized coordination means that there is no overarching national agency unifies BIM efforts. Instead, BIM use varies considerably across states and sectors. The federal government's role has primarily been regulatory rather than direct intervention. While it supports BIM adoption through guidelines and standards, mandates are not typical and limited to specific regions or projects. This decentralization has hindered the widespread usage of BIM across the country, with efforts often confined to local jurisdictions.

In 2003, a pivotal moment in the U.S. BIM journey occurred with the launch of the National 3D-4D-BIM Program by the General Services Administration (GSA) (Babatunde et al., 2020; GSA, 2024). In a pioneering move, the GSA mandated the use of BIM for all federally funded projects starting in 2007. This mandate marked a shift toward encouraging the integration of 3D and 4D BIM technologies within public sector projects (Doukari et al., 2022). As of 2017, the GSA had published eight detailed BIM guidelines covering the entire project lifecycle, enforcing its role as an initiator and regulator (GSA, 2024).

In addition to the GSA, the National Institute of Building Sciences (NIBS) has played an instrumental role in shaping BIM adoption. The NIBS brings together government agencies, industry professionals, and researchers as a non-profit organisation (Liu et al., 2019). It developed the "National BIM Standard-United States" (Annex & Rules, 2015). This standard provides guidelines for information exchange, project best practices, and data management (NIBS, 2021).

Private organizations, universities, and the military have contributed to advancing BIM development in the US. Since 2007, the American Institute of Architects (AIA) has released various guidelines to assist architects in integrating BIM into their design and operational process (Olawumi et al., 2017). Leading universities have established their own BIM standards, frequently taking the lead in implementing these practices. Additionally, the United States Army Corps of Engineers (USACE) has integrated BIM into the lifecycle management of new construction projects, using platforms like Autodesk and Bentley (West & Liu, 2021). USACE also supports research and development to explore advanced BIM applications, particularly within the Department of Defence (Moreno et al., 2014; West & Liu, 2021).

In the absence of national mandates, several states have taken the initiative to implement BIM requirements. In 2010, Wisconsin became the first state to mandate BIM for public projects exceeding $5 million and for new constructions valued over $2.5 million (Moreno et al., 2014). The Los Angeles Community College District recently mandated BIM for its $9.5 billion construction and maintenance projects across nine campuses in 2018 (Liu et al., 2019). These instances highlight state-level leadership's capacity to promote BIM adoption, even without federal mandates.

Despite these efforts, BIM adoption in the USA continues to encounter various challenges. The absence of national mandates limits the uniformity and scope of adoption (Giel & Issa, 2014). The level of financial support provided by the government for setting up BIM is quite limited, resulting in a significant burden on private organizations and local governments (Yilmaz et al., 2019). Moreover, the decentralized nature of the system presents challenges in fostering nationwide collaboration and achieving standardization.

2.12 Theoretical Framework

The theoretical framework provides conceptual basis that directs the research by clarifying the fundamental concepts and viewpoints influencing the research methodology. This study synthesises four theoretical perspectives: the Technology Acceptance Model (TAM), Diffusion of Innovations Theory, Resource-Based View (RBV), and Institutional Theory.

2.12.1 Technology Acceptance Model

This study integrates the Technology Acceptance Model (TAM) as a theoretical framework to investigate the dynamics of technology adoption in the construction industry. Thus, providing a more contextualized theoretical understanding of BIM adoption within Ghana’s construction industry. TAM, developed by Davis (1989), is one of the most well-known and widely accepted theories for predicting the factors influencing individuals' and organizations' adoption of specific technologies. TAM asserts that two critical determinants impact one's inclination to use technology: “perceived usefulness (PU),” which refers to the extent to which individuals believe that using the technology will improve their job performance, and “perceived ease of use (PEU),” which pertains to the extent to which individuals believe that using the technology will require minimal effort (Peng et al., 2022). TAM is used in this study to address why personnel embrace or resist BIM technology within an organization. This study aims to explore construction professionals' perceptions and attitudes toward the benefits of using BIM technology (Hsia et al., 2014). TAM aids in understanding how professionals assess BIM's capacity to enhance job quality and daily operational efficiency. We examine the extent to which these benefits impact individuals' choices when adopting BIM.

Integrating TAM into the study will enable a deeper understanding of the trade-off between the user-friendliness of BIM and the resources required for its execution. It prompts an evaluation of the benefits of BIM and the ease of use in terms of the effort required for construction professionals to fully adopt this technology. This balance illustrates the interplay between PEU and the perceived difficulty of practical adoption of BIM (Devarakonda, 2021).

Ultimately, will be guided by TAM towards an in-depth understanding of the dynamics of BIM technology adoption within Ghana’s construction industry. The multifaceted account of BIM technology adoption may be understood by examining its focus on PU, PEU, and the interplay between other factors referred to as “external variables.”

2.12.2 Diffusion of Innovation Theory

This study incorporates the fundamental principles of the Diffusion of Innovations Theory (DOI), which was initially proposed by Rogers (2010). This theory provides a valuable framework for understanding how innovative ideas, technologies, and products are adopted and spread through a population over time.

The integration of innovations, such as the adoption of BIM, is a progressive endeavour influenced by a diverse range of factors, which aligns with the concept of the theory. Rogers identifies many key factors that influence the diffusion of innovation. These factors include the inherent characteristics of the innovation, the communication channels used for its dissemination, the characteristics of the social system in which it is introduced, and, notably, the level of individuals' engagement and exposure to the innovation (Sadeh et al., 2023).

This study aims to provide an understanding of the adoption of BIM within Ghana's construction industry by using the valuable insights offered by DOI. The foundation of this theory is predicated on the understanding that innovations undergo a sequential process, commencing with the first acceptance by early adopters, followed by the general public, and ultimately culminating in the integration of the innovation at a systemic level (Shirowzhan et al., 2020). This study uses the adoption curve, a fundamental construct in DOI, as a valuable framework to examine the dissemination of BIM technology across a diverse group of industry professionals.

The theory explains how BIM's compatibility with current practices, and comparative benefits influence stakeholders' views, attitudes, and intentions toward adopting it. This study which examines the dissemination of information about BIM within the constantly evolving construction industry aligns with the theory's strong focus on the vital role communication channels play (Morgan, 2017). This study will investigate how such channels facilitate the spread of knowledge, foster awareness, and develop a deeper understanding of BIM's potential and wide-ranging benefits.

Since the study delves into the social framework of the construction industry, which encompasses a diverse array of stakeholders with varying roles, duties, and perspectives, DOI emerges as a valuable analytical framework. It provides an insightful context for examining the interrelationships among project parties such as architects, engineers, project managers, contractors, and clients (Ramakrishna, 2023). This study employs this particular perspective to shed light on how the underlying social framework of the construction industry impacts the adoption of BIM. Through the integration of the theory's fundamental principles, this study aims to understand the issues surrounding the diffusion of transformative innovations such as BIM within the construction industry.

2.12.3 Resource-Based View Theory

The study employs the theoretical tenets of the Resource-Based View (RBV) theory as an applied theory to shed light on BIM adoption in Ghana's construction industry (Barney, 2001). RBV theory, which originated in the field of strategic management, provides a unique framework for assessing organizational strengths and weaknesses in terms of the resources required to integrate BIM into project workflows (Barney et al., 2021). RBV theory posits that an organisation's unique resources and competencies are the primary determinants of its success. From RBV's perspective, organisations own many intangible assets such as human expertise, technological dominance, knowledge repositories and collaborative networks. The integration of these resources enables an organization to generate value, foster innovation, and maintain a prominent market position in its sector for an extended duration (Varadarajan, 2020).

By integrating RBV theory into the study, the researcher aims to investigate the impact of internal elements, specifically an organisation's resources and capabilities, on its progression toward adopting BIM technology. Using the RBV framework enables the explanation of how an organisation's existing resources facilitate the adoption process. RBV theory serves as a guiding theory for understanding an organization's readiness for BIM (Chaurasia & Verma, 2020). It asserts that a firm's success in adopting BIM depends on the technology and the organization's ability to exploit its inherent capabilities and accessible resources.

RBV theory also necessitates the recognition of the dynamic nature of organizational strengths and shortcomings. This theory involves assessing how organisations allocate resources towards staff training, procuring new equipment, and exploring current practices to foster flexibility and adaptation within the rapidly evolving domain of technological innovation in construction. The RBV theory is integrated into the study to examine the interaction between an organization's available resources, its objectives for adopting BIM, and the evolving nature of the construction industry (Ajgaonkar et al., 2022).

The RBV theory effectively explains the readiness and competence of organisations to adopt BIM. It emphasises the need for self-reliance rather than dependence on external pressure to adapt to technological advancements and enhance their competitive edge. The study will utilise the RBV theory to examine the connection between organisational resources and effective technological integration.

2.12.4 Institutional Theory

Scholars have developed institutional theory as a valuable framework for understanding how organizations respond to external pressure and adhere to established norms, values, and practices within their particular context (Scott, 2005, 2017). Essential elements, such as normative, mimetic and coercive pressures in institutional theory, emerge as indicators for determining organizational change. As a consequence of normative pressures, organizations are motivated to adopt behaviours that are deemed socially or professionally permissible. Besides, they are constrained to comply with external norms and institutional demands due to coercive forces (DiMaggio & Powell, 1983).

The institutional theory emphasizes the value of legitimacy and isomorphism (Ashworth et al., 2009). Organizations pursue legitimacy by adhering to established institutional standards and procedures. This theory will help shed light on the factors that motivate the adoption of BIM within the Ghanaian construction industry in pursuit of legitimacy and the desire to conform to global industry standards (Acquah et al., 2021). It is essential to consider the interaction between global influences that promote the use of BIM and the particular institutional context in Ghana. The study hopes to shed light on the quest for digital transformation in the construction industry and the impact of institutional theory on these dynamics (Olanrewaju et al., 2022).

In the context of Ghana's innovation adoption progression, institutional theory can be employed to assess the drivers and barriers to the adoption of innovative technologies, such as BIM. This theory entails understanding how the institutional environment, rules, and industry standards influence the propensity and readiness of construction firms to adopt BIM (Meyer & Rowan, 1977).

2.12.5 Philosophical Foundations of Digital Technology and Construction Vocations

The adoption of digital technology in construction is not only a technical process but also a philosophical and vocational transformation. The concept of technological determinism argues that technology drives social change by reshaping human behaviour and institutional practices (Smith & Marx, 1994). Within the construction context, this perspective suggests that the diffusion of BIM inherently compels industry stakeholders to restructure workflows, skill requirements, and collaborative practices. Conversely, the *socio-technical systems theory* emphasizes that technology and human agency are mutually shaping; digital adoption outcomes depend on how professionals, institutions, and cultural values align with technological innovations (Baxter & Sommerville, 2011).

Furthermore, the vocational aspect highlights that, digital technologies are transforming the very nature of professional practice in construction. As BIM adoption grows, construction vocations are evolving from craft-based tasks toward digitally mediated, knowledge-intensive roles (Succar & Kassem, 2015). This philosophical lens underscores that BIM is not merely a tool but a driver of a paradigm shift in skills, identity, and professional competence. In Ghana, this implies that BIM adoption requires rethinking the philosophy of construction training and practice, integrating both digital literacy and critical adaptability into vocational development.

2.12.6 Digital Transformation in the Construction Industry

Digital transformation represents a broader paradigm within which BIM adoption is situated. It refers to the integration of digital technologies to fundamentally reshape business models, processes, and value creation (Vial, 2019). In construction, this transformation aligns with the global shift toward Construction 4.0, characterized by the convergence of BIM, Internet of Things (IoT), Artificial Intelligence (AI), cloud computing, and big data analytics (Oesterreich & Teuteberg, 2016). These technologies collectively enhance efficiency, transparency, and sustainability, positioning construction within the larger digital economy.

BIM serves as a central enabler of this transformation by providing a digital platform for collaboration, visualization, and data-driven decision-making (Azhar, 2011). However, the process of digital transformation extends beyond the technical implementation of BIM, encompassing organizational readiness, leadership vision, and cultural adaptation (Khosrow-Pour, 2020). For Ghana's construction industry, the significance of digital transformation lies in bridging productivity gaps, overcoming fragmentation, and fostering competitiveness in the global market. Framing BIM adoption within this broader lens highlights that it is not an isolated innovation but part of an industry-wide reconfiguration that redefines how construction projects are conceived, designed, and delivered.

2.13 Previous Studies

2.13.1 BIM Awareness and Knowledge among Construction Professionals

Empirical studies provide evidence of varying knowledge on BIM in developed and developing countries. Various geographical regions exhibit varying levels of awareness and knowledge, characterized by a spectrum ranging from a profound understanding to nascent awareness (Azhar & Behringer, 2013; Olatunji et al., 2021; Sun et al., 2017; Wong et al., 2020). Olugboyega et al. (2024) note that contexts with structured BIM training programs often report higher levels of knowledge and proficiency in advanced BIM applications, contrasting with environments lacking such structures. These global studies highlight the inherent challenge of effectively motivating AEC professionals to maximise the use of BIM across diverse contexts.

Per the findings of Sanchez et al. (2021) and Howard et al. (2017), it is evident that individuals who have received specialist training in BIM exhibit a greater level of understanding and expertise in the concepts and practical applications of BIM. This assertion aligns with the insights provided by Succar and Kassem (2015), who highlighted the significant impact of educational interventions, especially when professionals adhere to structured learning pathways specific to BIM. Digital tools, such as BIM, are less likely to be fully adopted in contexts lacking structured training (Girginkaya Akdag & Maqsood, 2020). Besides, the creation of BIM expertise is often achieved through industry-sponsored initiatives and collaborative platforms. These mechanisms for information sharing in the field of BIM foster a culture of knowledge exchange that transcends geographical boundaries (Olawumi et al., 2017; Wang et al., 2020).

Ofori (2018) and Agyekum et al. (2019) have investigated the level of knowledge and understanding regarding BIM within the professional community of the construction industry, specifically in certain professions. Their findings collectively indicate a significant disparity in awareness and knowledge of BIM in Ghana. Certain professionals exhibit a high level of awareness and a thorough understanding of BIM's potential benefits. These individuals often exhibit a propensity for being early adopters, showcasing an understanding of the need to stay up-to-date with technological advancements in the industry. A significant number of AEC professionals in Ghana may possess limited knowledge of BIM. Appiah (2020a) conducted a study to investigate the key attributes that influence the level of knowledge and awareness of BIM within the Ghanaian construction industry. Their findings showed a common trend among individuals with a formal educational background in BIM or related fields, as they tend to possess heightened awareness and competence, underscoring the imperative need for structured educational and training programs to equip individuals with the requisite expertise and competencies in BIM. Girginkaya Akdag and Maqsood (2020) emphasised that digital tools like BIM are less likely to be fully adopted in contexts lacking structured training. Moreover, Hamma-adama and Kouider (2019) found that significant adoption gains only occurred in developed economies following targeted educational efforts and policy support.

Moreover, the availability of BIM training programs and readily accessible resources significantly influences the level of awareness and knowledge regarding BIM. This is reinforced by the findings of Agyekum et al. (2019), which emphasize the importance of providing professionals with learning opportunities and avenues for skill development to augment their proficiency in BIM. Organizations that invest in developing BIM education for their employees and foster an environment that encourages innovation are likely to have personnel who demonstrate improved proficiency in BIM (Addy et al., 2023). Enhanced training develops technical competence and aids the overall adoption process by familiarising personnel with BIM's advantages and practical applications (Ghosh et al., 2015; Huang, 2018).

Conversely, Kassem and Succar (2017a) suggest that even the most effective training programs will have limited influence on adoption if the broader ecosystem is not supportive. It is imperative that establishing a favourable organizational climate can foster continuous learning and skill development in BIM.

The extent of professionals' knowledge and understanding of BIM is substantially shaped by government actions and regulations, as highlighted in the work of Asare et al. (2020). According to Takyi-Annan and Zhang (2023a), the incorporation of government-driven BIM adoption initiatives could have a substantial impact on the construction industry’s level of knowledge and competence in BIM. Often, these initiatives comprise a variety of strategies, including incentives, regulations, and policies designed to promote the adoption of BIM. Ma et al. (2020) highlighted the pivotal role of institutional governance mandates in driving BIM literacy and uptake, asserting that those who actively participated in initiatives to use BIM applications are more likely to know BIM's functions and benefits. Gaining experience with practical situations that require the use of BIM enhances one's understanding of the practical implications that accompany its application.

In summary, the active involvement of industry associations and networks is vital for facilitating the exchange of knowledge and advancing awareness of BIM. Ofori (2018) emphasized that industrial networks play a crucial role as facilitators of collaboration and information sharing, thus nurturing a more informed and enlightened professional community. Awareness and knowledge of BIM are subject to ongoing evolution and are impacted by numerous factors, such as institutional practices, education, experience, and government policies. Recognizing the significance of these key factors is paramount in developing approaches to enhance the proficiency of construction professionals in BIM and to streamline the integration of BIM practices across the industry.

2.13.2 Organizational and Technological Readiness for BIM Adoption

An organization's preparedness to use BIM requires aligning the organizational culture, management attitude, and technological infrastructure, all of which impact the rate and effectiveness of BIM adoption (Liu et al., 2020; Shojaei et al., 2023). The concept of readiness encompasses several factors at the organizational level, including but not limited to leadership endorsement and change management, as well as the alignment of BIM objectives and other related aspects (Nguyen et al., 2022). The presence of leadership support plays a pivotal role in facilitating the integration of BIM into an organization's strategic plan. The commitment shown by individuals, combined with effective change management strategies, fosters an organizational environment in which employees are motivated to adopt and harness the transformative capabilities of BIM. Also, this commitment encourages the acquisition of the necessary competencies required for successfully integrating BIM into various projects (Al-Yami & Sanni-Anibire, 2021; Barlish & Sullivan, 2012). BIM adoption stalls if leadership does not perceive it as strategically beneficial, particularly when organizations are driven by short-term profits rather than a long-term vision (Ametepey et al., 2020).

Li et al. (2023) assert that organisations' readiness necessitates a cultural shift towards collaboration and the exchange of knowledge. The establishment of a conducive environment that promotes transparent communication and encourages collaboration across several disciplines is of utmost importance in ensuring the successful application of BIM (López et al., 2018), notwithstanding the inherent fragmentation within the construction industry. The change in mindset improves communication, reduces opposition to change, and creates a conducive environment for the collaborative benefits of BIM to flourish (Rahman & Ayer, 2017; Vigneshwar et al., 2022). Concurrently, the technical readiness examines the digital infrastructure and technologies that will serve as the foundation for the effective adoption of BIM. The evaluation encompasses hardware performance, software compatibility, and network design (Sanchez et al., 2021). The use of obsolete equipment and software may impede the exchange of data among project stakeholders (Ma et al., 2022). The full potential of BIM cannot be achieved without a strong foundation of technical support (Khudhair et al., 2021).

The examination of the technological readiness for integrating BIM with other emerging technologies, such as the IoT, virtual reality (VR), and augmented reality (AR), is now underway. The integration of these technologies with BIM leads to enhanced visualization, analysis, and decision-making capabilities (Mannino et al., 2021). Evaluating an organization's capacity to adopt and effectively use BIM and its associated technologies is crucial to achieving broad acceptance within a technologically advanced context (Dowsett & Harty, 2019). When assessing an organization's readiness to adopt BIM, it is important to consider numerous factors (Ismail et al., 2019; J. Li et al., 2019), encompassing organizational structure, corporate culture, and technological depth of the organization (Ibrahim et al., 2019). Phung and Tong (2021) suggest that successful organisational readiness for BIM necessitates managerial, cultural and technological adjustments as well as other factors that address seamless information exchange and digital workflow integration. Workflow integration, human resource capability and organisational collaboration were also acknowledged as essential factors facilitating successful BIM adoption (Alazmeh et al., 2018; Papadonikolaki et al., 2019; Yusuf et al., 2024). The study will provide a foundation for informed strategic planning, targeted interventions, and a roadmap for the seamless integration of BIM (Omar & Dulaimi, 2023).

2.13.3 Key Drivers and Barriers Influencing BIM Adoption

BIM has emerged as a technology with transformative potential, serving as a key driver of innovation in construction project delivery processes (Jamal et al., 2019). Various studies have emphasised its profound impact on the efficiency of construction projects, including those by Saka et al. (2022) and Doumbouya et al. (2016). The growing recognition of BIM’s value has led to its increased adoption across various segments of the construction industry. This substantial growth in adoption can be attributed to various influential drivers that underscore its strategic importance in advancing digital integration within the industry (Patel et al., 2021).

One of the key drivers of BIM adoption is its capacity to improve collaboration and communication among project stakeholders. Azhar and Behringer (2013) noted that the incorporation of BIM enhances workflow by providing a centralized platform for all stakeholders. This is emphasised by Forgues et al. (2016) and Raja Mohd Noor et al. (2021), who observed that BIM’s unified system strengthens coordination throughout a project lifecycle. By providing an integrated digital space for sharing and updating information in real time, BIM significantly reduces the likelihood of errors, rework, and disputes stemming from miscommunication. Moreover, the incorporation of 4D BIM allows for the electronic representation of the sequential construction process on a visual interface to aid on-site workers in understanding how tasks must be executed on the site (Doukari et al., 2022) suggested. posit that this visual representation empowers site personnel to provide solutions to buildability challenges.

Another significant driver is BIM's role as a centralized data repository. This function enables information management across project phases, allowing stakeholders to conveniently access up-to-date information that supports timely and informed decision-making (Egwim et al., 2023). This centralization process improves transparency, accuracy, and consistency in decision-making. Additionally, BIM's 3D visualisation capabilities represent a critical driver of adoption, enabling the virtual modelling and simulation of the construction project (Egwim et al., 2023). These features empower project stakeholders to anticipate potential design and construction issues, making well-informed decisions that mitigate design errors and costly revisions. Datta et al. (2023) affirm that simulation and visualization tools contribute to better planning, coordination and execution of projects.

The clash detection capability of BIM also stands out as a strong driver for adoption. Automated clash detection, a core feature of BIM processes, enables the early identification of clashes between building components, which could potentially lead to major delays and cost overruns (Kozlovska et al., 2023). Automating this process results in enhanced project efficiency and reduced construction rework. It provides a compelling rationale for organisations to invest in BIM.

An additional incentive for implementing BIM is its cost management capability. The demand for accurate cost estimations and control is a major concern in construction project management (Gurgun et al., 2022). Implementing BIM solutions enables real-time cost monitoring and budget tracking, facilitating more effective management of resources. Studies have consistently highlighted the criticality of precise cost allocation and oversight in construction projects (Gurgun et al., 2022; Kepher[1] et al., 2021; Towey, 2013). Beyond financial considerations, BIM is pivotal in promoting adherence to regulatory standards and advancing the pursuit of sustainability. This further consolidates BIM’s position as a multifaceted driver for digital transformation in the construction industry.

Despite numerous motivating factors, widespread BIM adoption remains hindered by several barriers that impede the full realization of its benefits. A common thread in this challenge is that organizations, regardless of size and financial capability, often encounter similar universal obstacles in their quest to adopt BIM (Teo & Loosemore, 2017). A critical issue lies in the multidisciplinary nature of construction project teams, where professionals exhibit varying degrees of familiarity and proficiency with BIM tools and processes. This disparity creates a barrier to uniform adoption imposed by pre-defined traditional roles and workflows (Mahamadu et al., 2017; Watts et al., 2023). Moreover, a lack of knowledge and limited understanding of BIM's potential benefits are cited as barriers preventing organisations from committing to its adoption (Howard et al., 2017).

Kassem and Succar (2017b) identified interoperability issues as a key barrier to BIM integration. The absence of standardized data exchange protocols and incompatibility between various software systems contribute to fragmented workflows. Fundamentally, these issues limit the ability of BIM systems to communicate seamlessly, discouraging collaborative project effort and data exchange. Insufficient interoperability results in the fragmentation of project information, which hampers the full realization of BIM’s potential. Addressing this challenge requires an industry-wide commitment to establish standardized protocols and procedures that streamline the integration of BIM software.

The lack of organizational culture that fosters a more collaborative and innovative attitude is equally an obstacle. Tezel and Aziz (2017) argue that when organisations operate within rigid silos and fail to foster cross-disciplinary communication, the collaborative essence of BIM remains untapped. Emmanuel et al. (2024) reinforce this concern, noting that a concerted effort is needed to break down silos and encourage interdisciplinary communication. Otherwise, BIM usage that is focused on collaboration and information sharing will remain limited.

Cultural resistance to change is recognized as a barrier to BIM adoption. Zhou et al. (2019) identified industry resistance to changing established thinking as a key impediment to BIM adoption. This reflects a preference for familiar workflows and practices, such as reliance on 2D drafting, which is compounded by insufficient external incentives and a lack of supportive framework for transitioning (Babatunde et al., 2021; Durdyev et al., 2021). Organizations must cultivate a work environment that values cooperation, innovation, and creativity to overcome this challenge and circumvent cultural barriers. This approach may encompass educational and training programs designed to help employees adapt to new methodologies and technologies, as proposed by Tezel and Aziz (2017). To secure buy-in at all organizational levels, effectively demonstrating the benefits of implementing BIM, such as enhanced project quality and efficiency, is critical. This cultural shift is crucial for successfully incorporating BIM functionalities in the construction industry (Tezel & Aziz, 2017).

2.13.4 Impact of BIM Adoption on Construction Project Performance

Several studies have been conducted on the impact of BIM adoption on construction project performance. An analysis of these studies highlights the transformative potential associated with the broad use of BIM. Studies conducted by Smith and Tardif (2009), Arayici et al. (2011b), and Ahankoob et al. (2020) in the United States, the United Kingdom, and Singapore, respectively, have made significant contributions to the understanding of the positive impact of BIM on enhancing construction project performance. The findings of these studies highlight a diverse range of benefits, including improved accuracy in project scheduling, enhanced collaboration among several stakeholders, less need for rework, and overall increased efficiency. Smith and Tardif (2009), Arayici et al. (2011a), and Ahankoob et al. (2020) collectively agree that the use of BIM enhances the construction processes. Which ultimately results in the execution of projects with enhanced accuracy and efficiency, irrespective of the specific geographical location. Oraee et al. (2019) and Yu et al. (2023) highlight the efficacy of BIM in streamlining workflows, reducing conflicts and proactively identifying and addressing potential quality issues during the early project phase.

Azhar et al. (2012) underscore the significant benefit of implementing BIM in enhancing project productivity and efficiency. The use of BIM is crucial for enhancing collaboration and communication among diverse stakeholders engaged in a project, resulting in streamlined workflows and reduced occurrences of rework. Using a 3D digital environment for project visualization can identify potential issues promptly, thereby reducing design errors and change orders. Thus, this could lead to decreased expenditures and accelerated project timelines. Significant effects of BIM use on project performance are evident, particularly in terms of cost management. Barlish and Sullivan (2012) conducted a study demonstrating that BIM practices can deliver accurate real-time cost estimations and monitoring. Improved communication and tighter coordination enabled by BIM contributed to cost savings by mitigating rework and waste during construction (Yu et al., 2023). This specific capability enables the effective management of project budgets, diminishing the likelihood of cost overruns and enhancing overall financial performance.

The integration of BIM into cost management is highly relevant in an industry where strict adherence to financial limitations is critical for the effective delivery of projects. The positive effects of incorporating BIM into project execution are evident in quality and accuracy (Eastman, 2011b). BIM serves as a centralized repository for project data, promoting greater transparency and ensuring a uniform decision-making process. Reduced errors and an enhancement in the overall standard of excellence distinguish the result. By incorporating dispute detection and coordination functionalities, BIM improves the quality of construction projects. BIM streamlines the process of resolving conflicts and interferences, reducing the necessity for revisions and mitigating the risk of potential project completion delays.

Moreover, the adoption of BIM has a significant impact on risk management. da Silva et al. (2022) underscored the importance of BIM in detecting and evaluating potential risks. BIM empowers project teams to efficiently simulate diverse scenarios, assess their potential ramifications, and make informed decisions to minimize risks. It is critical to have risk mitigation capabilities in place to ensure project success, particularly when dealing with complex endeavours that may face unanticipated challenges. Previous research has demonstrated that BIM plays a substantial role in enhancing stakeholders' satisfaction.

Becerik-Gerber et al. (2011) suggest that BIM improves stakeholder engagement and communication on a project. By providing stakeholders with a transparent, three-dimensional depiction of the project, a more thorough understanding and alignment of project objectives can be achieved, leading to increased satisfaction among clients and other project participants. Papadonikolaki et al. (2019) argue that BIM's strength lies in facilitating collaboration, enhancing clarity of communication, and improving project management. Hitherto, it is critical to acknowledge the challenges associated with the impact of implementing BIM on the efficiency of construction projects. Numerous studies, including the one conducted by Succar et al. (2016), have noted that the learning curve associated with implementing BIM could cause early interruptions in project performance. In addition, the pursuit of standardized protocols and interoperability, as underscored by Kassem and Succar (2017b), could impede the seamless incorporation of BIM.

In Ghana, Asare et al. (2020) and Lamptey et al. (2021) have provided valuable insights into BIM has been adopted in Ghana's context. The collective results of these studies provide a compelling narrative. This narrative underscores the gradual integration of BIM in Ghana, aligning with the global debate on the subject. It demonstrates the potential for BIM to transform the efficiency and effectiveness of construction projects within Ghana's distinctive construction landscape. The understanding of the potential impact of BIM is enhanced by integrating worldwide perspectives with the distinct insights derived from Ghana (Asare et al., 2020; Lamptey et al., 2021). Also, Appiah (2020a) and Agyekum et al. (2019) examined the correlation between the use of BIM and discernible improvements in project performance. The researchers have contributed to enriching the narrative and expanding our comprehension regarding the potential influence of BIM on the performance of construction projects in Ghana. Their works have revealed the distinctive opportunities and challenges shaping the trajectory of BIM adoption in Ghana.

2.13.5 Frameworks for Effective BIM Adoption and Utilization

This literature study synthesizes numerous ideas, providing a roadmap for directing BIM adoption efforts toward actual operational use. The success of many frameworks can be attributed to their unique characteristics. Critical tenets of the adoption frameworks include process standards, implementation approaches, and the coordination of stakeholder engagement. Liu et al. (2018) present a model that encompass several aspects, illustrating the path from the initial BIM planning through its subsequent operationalization. Similarly, Olugboyega and Windapo (2022) emphasize a systematic approach that combines technology, processes, and people to align BIM objectives with organizational goals. These frameworks emphasise the significance of thorough and systematic planning that integrates various factors into a unified approach.

A comprehensive framework for BIM adoption generally includes several essential components. Initially, it highlights the need for an inclusive training regimen to enhance the expertise of professionals in the industry, as advocated by Mustapa and Jamaluddin (2022). Their research underscores that knowledge gaps, particularly among quantity surveyors in developing nations, can hinder the effective deployment of BIM. Bamgbose et al. (2024) propose an approach that integrates government incentives and industry collaborations to promote the use of BIM technology, thereby mitigating the financial and resource obstacles identified by numerous industry stakeholders. These findings underscore a need for a paradigm shift in BIM implementation strategies across different national contexts.

By comparing and contrasting different frameworks, one can observe the effectiveness of their performance in different circumstances and their adaptability to different environments. The study by Olatunji et al. (2021) examines various frameworks and highlights their varying effectiveness in different organizational situations. The authors advocate for adopting a tailored strategy to address specific needs. Frameworks thrive in contexts that are coherent with commonly shared values and norms, as demonstrated by the study of Zhang et al. (2020), which emphasizes the importance of cultural factors in determining the deployment of frameworks. This study highlights the limitations of a generic approach to BIM adoption, showing how frameworks must be tailored to the unique requirements of each context.

Whilst nations such as the USA and the UK have achieved considerable advancements in BIM integration, developing countries are noted to be falling behind (Al Shanto et al., 2024). This mismatch necessitates tailored frameworks that account for local economic and socio-cultural considerations to facilitate the effective implementation of BIM technology.

Although these existing frameworks are helpful, they do have some limitations in their applicability, especially when employed in the construction industry beyond their designated region. The unique characteristics of Ghana's economy, regulatory environment, and skill dynamics necessitate a broader perspective when evaluating the effectiveness of existing institutions. There are potential avenues for enhancing frameworks to accommodate the unique characteristics of the Ghanaian context.

This suggests that successful BIM adoption requires comprehensive frameworks that include stakeholder involvement, skill enhancement, and infrastructure support. By tackling the constraints and capitalising on the indicated opportunities, stakeholders can enable a more seamless transition to extensive BIM adoption in the construction sector. Considering Ghana's distinct socioeconomic conditions, opportunities exist to refine frameworks to account for the peculiarities of the construction industry in Ghana.

2.13.6 Gaps in the Literature

The examination of existing literature about the adoption of BIM in various contexts has provided valuable insights. In spite of the growing global focus on BIM as a transformative tool in the AEC industry, considerable shortcomings, inconsistencies, and unresolved issues persist, especially within the context of developing countries like Ghana. Existing studies in Ghana tend to examine BIM within narrow disciplinary confines, often focusing on architects or engineers without offering a holistic, cross-professional view of the industry (Acquah et al., 2018; Addy et al., 2018; Appiah, 2020a). The absence of industry-wide insight limits the understanding of how BIM is generally perceived, adopted, and implemented across the construction industry.

Studies examining the readiness of construction firms to adopt BIM have not sufficiently addressed both the organizational and technological dimensions of preparedness. Where studies do exist, they tend to emphasize infrastructural deficiencies while neglecting cultural, managerial, and policy factors that influence adoption (Appiah, 2020a; Howard et al., 2017; Tezel & Aziz, 2017). A dual-lens approach is therefore necessary to understand how Ghanaian firms assess internal capacity and prepare for digital transformation.

Furthermore, although global literature identifies a wide range of factors influencing BIM adoption such as policy mandates, stakeholder collaboration, and technological infrastructure, there is a notable lack of research contextualizing these factors within Ghana's unique socio-economic, institutional, and cultural landscape (Bamfo-Agyei & Nani, 2015; Ofori-Kuragu, 2020; Oteng et al., 2018). Without localized evidence, it remains difficult to determine which factors serve as the most critical enablers or barriers in Ghana.

The impact of BIM on project performance has also received minimal attention in the Ghanaian setting. While international research has linked BIM to improved project outcomes, such as cost efficiency, schedule adherence, and enhanced collaboration (Bryde et al., 2013; Cao et al., 2017), these benefits have not been empirically validated in Ghana. Most references to BIM benefits in Ghanaian studies remain hearsay or speculative.

Another critical gap lies in the absence of a nationally recognized or empirically validated BIM implementation framework tailored to the Ghanaian construction industry. Global BIM strategies, such as those in the United Kingdom, Singapore, or the United States, have been shaped by advanced infrastructure, regulatory enforcement, and sustained government involvement, factors not yet prevalent in Ghana (Arayici et al., 2011b; Georgiadou, 2019; Jung & Lee, 2015). Attempting to directly replicate such models in Ghana may be ineffective due to contextual mismatches.

From a methodological standpoint, previous studies have tended to rely on either purely qualitative approaches, which lack generalizability, or quantitative methods, which fail to capture depth and nuance (Olanrewaju et al., 2021; Zhou et al., 2019). There are limited use of integrated mixed method designs capable of triangulating multiple perspectives. Such an approach provides methodological robustness and enhances the credibility, transferability, and depth of the findings (Bazeley, 2018; Creswell & Clark, 2017).

2.14 Research Framework and Hypotheses

2.14.1 Research Framework

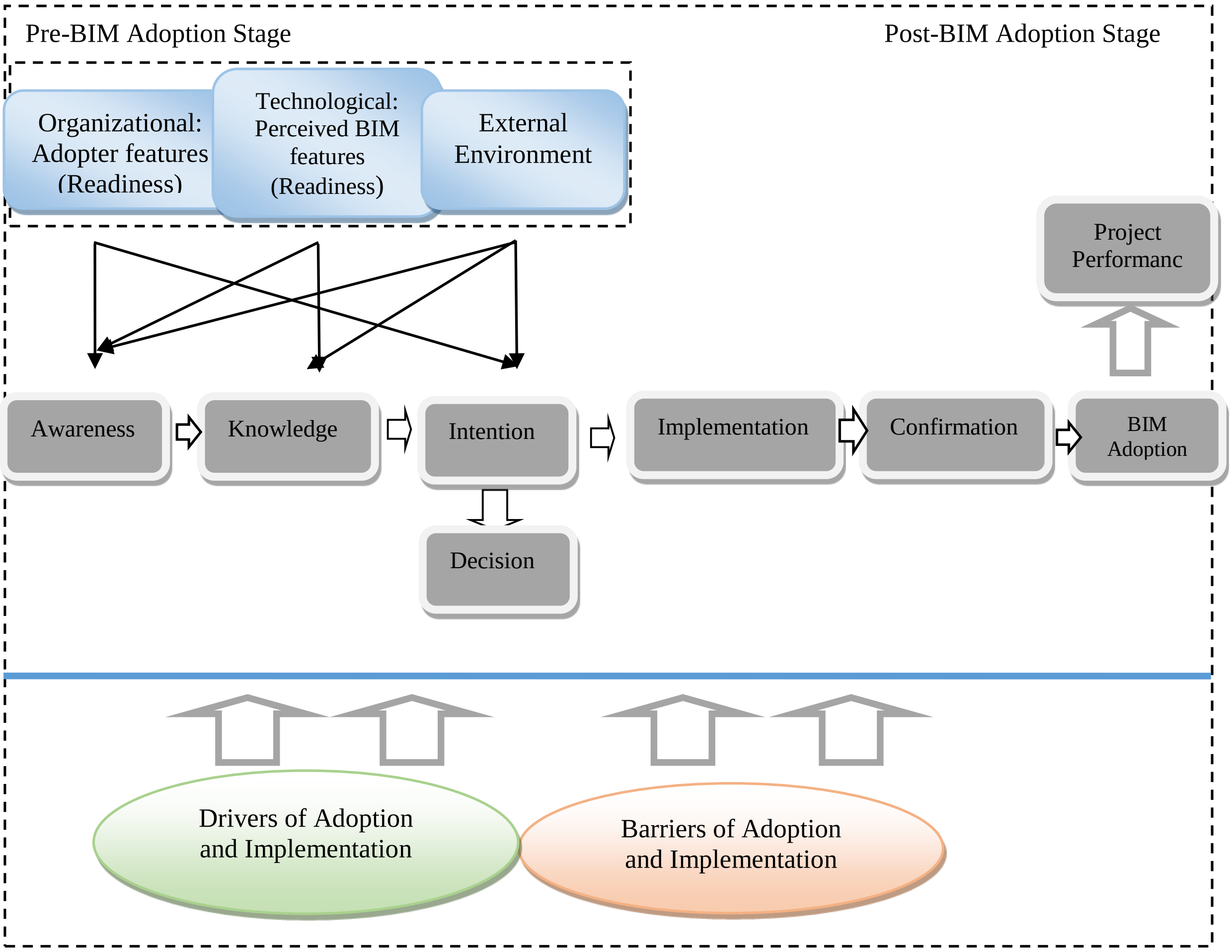

Figure 2. 6 Research Framework

Source: Author's Construct (2024), (adapted from Ahmed and Kassem (2018)

The primary focus of this research is to investigate the level of understanding of BIM within Ghana's construction industry, specifically among industry professionals. This examination encompasses several aspects, including awareness, knowledge, intention, and decision-making processes. The current phase of pre-BIM adoption aligns well with assessing the industry's existing level of familiarity with BIM. In this phase, the study assesses the level of knowledge in BIM among professionals by reviewing relevant scholarly literature and conducting independent investigations. This section examines the dissemination of BIM awareness and knowledge among various stakeholders, using insights from the Diffusion of Innovations Theory.

Furthermore, the study assesses the readiness of Ghana's construction industry towards adopting BIM. This assessment encompasses both the organizational and technological aspects of preparation, including the features of potential adopters and the perceived qualities of BIM. Investigating the factors that influence an organization's readiness to adopt BIM is linked to this phase. It is grounded on the Resource-Based View Theory. It examines the impact of elements, such as organizational skills, leadership commitment, and technical infrastructure, on a firm's preparedness for integrating BIM. To adequately analyse the factors influencing the adoption of BIM, it is necessary to investigate the dynamics between cultural shifts, collaborative practice, and technological capabilities. These elements together shape the extent to which BIM is embraced or hindered on a broader scale.

The step that follows the adoption of BIM is the implementation and validation. This stage is then followed by examining the impact of BIM adoption on the performance of construction projects in Ghana. The objective of this phase is to gain knowledge of the potential benefits and drawbacks associated with the integration of BIM. This study uses the TAM to investigate the impact of BIM adoption on project outcomes, including schedule accuracy, stakeholder involvement, rework reduction, and overall project efficiency. The objective is to analyse how BIM enhances conventional construction approaches.

The research methodology establishes a clear link between the key elements that drive or hinder the adoption of BIM in Ghana's construction industry, spanning several stages from pre-BIM adoption to post-BIM adoption. This broad approach encompasses the intricacies and complexities of the BIM adoption process, starting with the first phases of awareness and knowledge and extending to the eventual impact on project performance.

2.14.2 Hypotheses

Based on the discussions, the following hypotheses were formulated:

H_1: There is a significant positive relationship between BIM awareness and the adoption of BIM.

H_2: There is a significant positive relationship between BIM knowledge and the adoption of BIM.

H$_3$: There is a significant positive relationship between the organizational and technological readiness of Ghana's construction industry and the adoption of BIM.
H$_4$: The adoption of BIM technology in Ghana's construction industry is significantly enabled by a combination of key drivers.
H$_5$: Identified barriers to BIM adoption in Ghana's construction industry have a significant negative effect on the extent of BIM adoption.
H$_6$: The adoption of BIM has a significant positive effect on the performance of construction projects in Ghana.
H$_7$: There is a significant difference in BIM awareness and knowledge levels among various construction professionals.

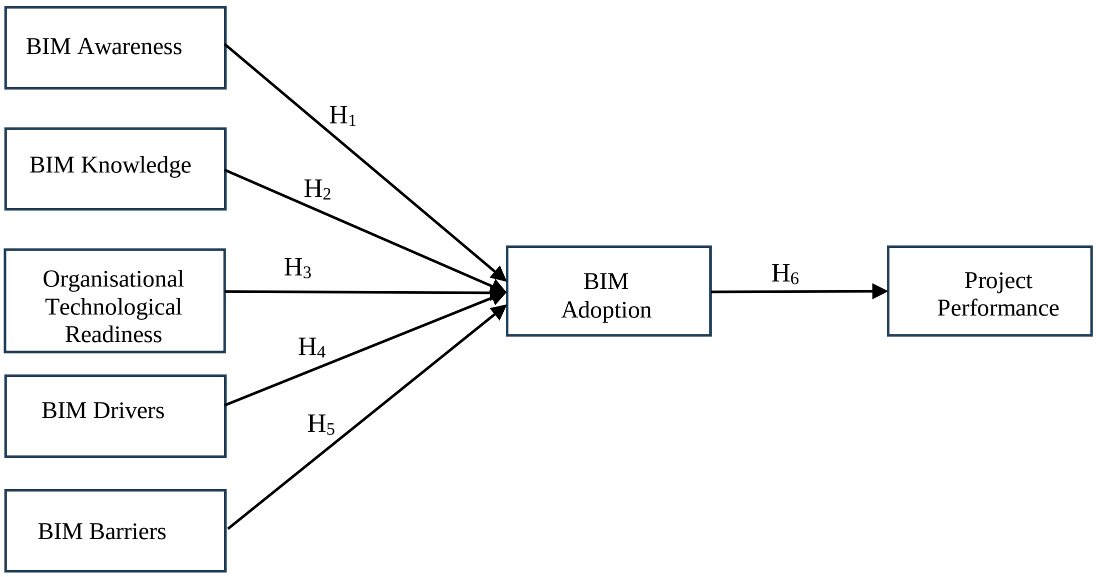

Figure 2. 7 Hypothesized model

Source: Author's construct (2024)

Table 2. 3 Summary of Theoretical Linkages to Hypotheses

Theory	Linked Hypotheses	Explanation of Linkage
Technology Acceptance Model (TAM)	H1, H2, H6	TAM explains how perceptions of usefulness, ease of use, and technological readiness influence BIM adoption. These correspond to hypotheses on awareness, perceived benefits, and readiness.

Resource-Based View (RBV)	H3	RBV highlights how internal organizational resources (e.g., skills, infrastructure, leadership capacity) drive BIM adoption. This is reflected in the hypothesis on organizational readiness.
Diffusion of Innovation (DOI)	H4, H5	DOI emphasizes innovation characteristics (relative advantage, compatibility, and complexity). These align with hypotheses on drivers and performance impacts of BIM adoption.
Institutional Theory	H7	Institutional Theory stresses external pressures (regulatory, normative, and competitive). This underpins the hypothesis on external influences shaping BIM adoption in Ghana’s construction industry.