"THE ADOPTION OF BUILDING INFORMATION MODELING (BIM) IN PROJECT MANAGEMENT IN GHANA"

BY

SOLOMON ANIM–WIREDU

(BSc. CIVIL ENGINEERING)

A THESIS SUBMITTED TO THE DEPARTMENT OF CONSTRUCTION TECHNOLOGY AND MANAGEMENT, KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY KUMASI IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF A MASTER OF SCIENCE DEGREE IN PROJECT MANAGEMENT

NOVEMBER, 2019

DECLARATION

I hereby declare that this submission is my own work towards the award of MSc. Project Management and that, to the best of my knowledge, it contains no material previously published by another person, nor material which has been accepted for the award of any other degree of the University, except where due acknowledgment has been made the text.

Solomon Anim-Wiredu (PG5038018)	………………….......	…....…….………
(Student Name & PG ID)	Signature	Date

Certified by:

Dr. Gabriel Nani	…….………….......	…....…….………
(Supervisor)	Signature	Date

Certified by:

Prof. Bernard K. Baiden	…….………….......	…....…….………
(Head of Department)	Signature	Date

ABSTRACT

Building Information Modeling (BIM) was developed in an effort to improve the coordination between disciplines in the construction sector. The Ghanaian Architecture, Engineering and Construction (AEC) industry has started adopting BIM in projects but at a low level. Considering the role project management practitioners play in the success of projects, this study sought to investigate the adoption of BIM in project management in the AEC sector mainly in the Ashanti region in Ghana. Specifically, the study sought to determine the level of knowledge and expertise of project management practitioners in BIM, identify the project management knowledge areas for which BIM is employed and determine the barriers that affect the adoption of BIM in project management activities. Using a questionnaire as the survey instrument, relevant data was obtained from twentythree project management practitioners through purposive sampling and statistically analyzed. The results of the study showed that level of knowledge and expertise of project management practitioners in BIM were averagely low even though most of the experts were aware of BIM. Also, although current BIM usage was relatively low, it was realized that overall, BIM application in project management activities was perceived to be useful in project management knowledge areas especially in Project Integration Management (PIM), Project Scope Management (PScM), Project Cost Management (PCoM), Project Schedule Management (PShM) and Project Quality Management (PQM). Moreover, the study further determined that the reluctance of project management practitioners to change their old working practices, the lack of trained professionals and the cost of procuring BIM technology were the top three barriers that affected the adoption of BIM in project management in the AEC industry. In the recommendation, project management practitioners were therefore encouraged to embrace new technology, find cost-effective and innovative ways of procuring BIM

technology and finally engage in formal training in order to improve the adoption of BIM in the Ghanaian AEC sector.

ACKNOWLEDGMENT

I would like to express my deepest gratitude to the Almighty God for the strength and courage to successfully complete this work. I am indeed grateful to my project supervisor, Dr. Gabriel Nani for his guidance and direction throughout this project. My heartfelt gratitude also goes out to all project management practitioners in the Architecture, Engineering and Construction sector in Ghana whose contributions and support helped in the completion of the project work.

DEDICATION

I dedicate this work to my parents.

TABLE OF CONTENTS

KNUST

LIST OF FIGURES

LIST OF TABLES

CHAPTER ONE

INTRODUCTION

1.1 Background to the Study

In an effort to improve the coordination between disciplines in the construction industry to ensure the effectiveness and efficiency of project delivery, Building Information Modeling (BIM) was developed and touted as the solution to this problem. BIM is basically an intelligent 3D model-based process that gives Architecture, Engineering and Construction (AEC) professionals the insight and tools to efficiently plan, design, construct and manage buildings and infrastructure (Autodesk, 2019). Additionally, BIM is expounded to 4D, 5D and even 6D. This is when time, cost implications and project lifecycle information is added to the 3D model (McPartland, 2018). The BIM model, according to (Philp et al., 2015), of a building or infrastructure serves as a repository of all relevant data throughout the project's life cycle.

Project management is the practice of initiating, planning, executing, controlling and closing a project to achieve specific goals under some constraints. BIM technology is a tool that has been proven to aid in better management of projects in the developed world. As a result, a country like the United Kingdom has made it a requirement on all government infrastructure projects (UK Government, 2011)

Ghana, however, seems to be stuck in the era of 2D management of project information. This paper seeks to explore the assumption of BIM technology in Ghana by project management practitioners. This will determine the level of familiarity/expertise in BIM of AEC professionals with an emphasis on project management practitioners in Ghana and how that knowledge is being implemented. It will also attempt to determine the various barriers hindering the nationwide adoption of BIM throughout the industry with a focus on project management practitioners as well as suggest solutions to them.

1.2 Problem Statement

The Ghanaian Architecture, Engineering and Construction (AEC) industry has started adopting Building Information Modelling (BIM) technology in projects but at a low level (Akwaah, 2015; Nani & Akwaah, 2015). With its enormous potential and challenges alike, BIM provides powerful tools to assist in construction project management. However, the AEC industry faces a wide range of challenges for which the Project Management profession provides a pool of solutions (Sawhney, 2017) which have to be assisted with the use of BIM technology to complement the project management tools and techniques. A few of these challenges include lack of coordination between engineering drawings, inaccurate generation of bills of quantities for construction works, inaccurate quantification of claims, unrealistic construction sequencing and difficulty in managing change orders (Telaga, 2017).

Developing countries such as Ghana are lagging behind in the implementation of BIM which has been acclaimed to be the panacea to the mounting problems of the construction industry notably delayed delivery of projects, cost management inter alia (Akwaah, 2015). Project management practitioners in Ghana, therefore, have to be equipped with workable knowledge in BIM in order to utilize its tools in efficient project delivery.

1.3 Aim and Objectives of the Study

The main aim of this study is to:

- Investigate the adoption of Building Information Modelling (BIM) in project management in Architecture, Engineering and Construction (AEC) industry in Ghana.

The specific objectives of the study are:

a) To determine the current level of knowledge and expertise of project management practitioners in BIM in the AEC industry;
b) To identify project management knowledge areas in the AEC industry for which BIM can be employed;
c) To determine the barriers project management practitioners encounter in the adoption of BIM in the AEC industry.

1.4 Research Questions

a) What is the current level of knowledge and expertise of project management practitioners in BIM in the AEC industry in Ghana?
b) What are the project management knowledge areas in the AEC industry in Ghana for which BIM can be employed?
c) What are the barriers project management practitioners encounter in the adoption of BIM in the AEC industry in Ghana?

1.5 Significance of the Study

A project is of better quality, lower costs and shorter durations when managed with BIM (Flórez et al., 2014). This is done by improvements made in terms of knowledge and cost management. In achieving the above-mentioned benefits, studies like this would prove to be an important piece in the overall goal. This study will help define the path and/or with subsequent studies help create a path to the full adoption of this tool for project delivery in Ghana. In addition, with the benefits of BIM identified in studies worldwide, the following study would outline the utilization of BIM in the Project Management processes thus identifying its applications and strategies that need to be in place for BIM to have a maximum effect in Ghana.

1.6 Brief Methodology of the Study

This research is exploratory in nature and uses the mixed-method research approach that involves both quantitative and qualitative strategies. Data from respondents and data from literature including academic journals, published articles and books on BIM and project management serve as the primary and secondary data respectively. The population identified for the study is project management practitioners in the Architecture, Engineering, and Construction (AEC) industry in Ghana mainly in the Ashanti region. A purposive sampling technique is used to draw a sample of project management practitioners in the population. A survey questionnaire and interviews are used as data collection tools to gather data from respondents in an attempt to determine the adoption of BIM in project management in the AEC industry in Ghana. The data is statistically analyzed using Microsoft Excel and Statistical Package for Social Sciences software programs and presented in the form of tables, charts, and narrative analysis.

1.7 Organization of the Study

The study is divided into the following sections:

Chapter 1: It consists of the background of the study, problem statement, research questions, aims and objectives, brief methodology, the significance of the study and the research organization.

Chapter 2:

This entails the literature review where previous studies in Building Information Modelling (BIM) and project management and BIM adoption levels and strategies in the AEC and other industries in Ghana and other jurisdictions are examined.

Chapter 3: This covers the research methodology. It explains the justification for the selected research design. It looks at the choice of sampling technique, population, data collection instruments, data processing and analysis tools and the need reliability, validity and ethical issues.

Chapter 4: It presents the results of the data processing and analysis stage, the findings, and further discussions.

Chapter 5: This chapter sums up the study with a summary of the results and findings, the conclusions drawn and the recommendations.

CHAPTER TWO

LITERATURE REVIEW

2.1 Project Definition

A project is basically "a unique process, consisting of a set of coordinated and controlled activities with start and finish dates, undertaken to achieve objectives conforming to specific requirements, including constraints of time, cost and resources". This is a definition as provided in the Seventh Edition of Project Management, Planning and Control by Lester (2017).

Another definition offered by the Guide to Project Management Body of Knowledge (PMBOK) 6th Edition states that a project is "a temporary endeavor undertaken to create a unique product, service, or result (Project Management Institute, PMI, 2017).

Lester (2017) further indicates that the size of an activity or operation does not necessarily influence the capacity of that operation to be described as a project. Therefore, an activity or operation to build a garden shack, a detached house, a hospital, a cathedral, or a government department office complex, can all be described as projects.

Projects are temporary in nature and in the end, produce results or products that exceed the time limit of the project activity periods as well as produce deliverables with characteristics that tend to drive change socially, economically, materially and environmentally (PMI-PMBOK, 2017). A project can be undertaken by one person or a group of persons, one unit of an organization or multiple units from various organizations. In all situations, these project activities must be completed on time, completed within the estimated cost and must satisfy the quality requirements, and these form the basic fundamental criteria that must be met by all projects (Lester, 2017; PMI, 2017).

2.2 Project Manager

According to Benator et al. (2003), "the project manager's responsibility is to manage the financial, technical and schedule requirements of the project in such a manner as to bring the project in on-time, within budget and with a technical quality that meets or exceeds the contractual performance specifications".

Sears et al. (2008) stress that the project manager is the central point of all the different parts of the project is responsible for the organization, planning, scheduling and control of work and must see to it that the project is successfully completed within the cost and time frame established.

Moreover, in Lester (2017), a project manager is defined as "the individual or body with authority, accountability, and responsibility for managing a project to achieve specific objectives".

Sawhney et al. (2017), also described the project manager as the "person, practice or employee appointed by an employer to lead and manage the project and be accountable to the project sponsor or project board for its successful completion".

Drawing from the definitions above, a project manager or project management practitioner can be described as the person with the responsibility to organize and coordinate all the different elements involved in a particular project towards a common effort to ensure that the project is completed successfully within the budgeted cost and time frame.

It is important to note, however, that several professionals within the architecture, engineering and construction industry actively practice project management activities and can, therefore, be described as project management practitioners.

2.3 Project Management

Projects involve many different parts or key components that are needed for the project to be completed and an effective and efficient way to successfully carry out projects is through project management.

According to the British Standards Institute (2010), project management refers to the "the planning, monitoring and control of all aspects of a project and the motivation of all those involved in it to achieve the project objectives on time and to the specified cost, quality, and performance". They emphasize that it includes the integration of all the phases of a project.

A definition of project management offered by Lester (2017) states that project management is "the planning, monitoring, and control of all aspects of a project and the motivation of all those involved in it, in order to achieve the project objectives within agreed criteria of time, cost, and performance".

According to the Guide to the Project Management Body of Knowledge (PMBOK) 6th Edition, project management is defined as "the application of knowledge, skills, tools, and techniques to project activities to meet the project requirements" (PMI, 2017). In other words, one is said to be practicing project management if one appropriately applies and integrates all the processes that have been identified for that particular project.

Project management requires interrelations between the key components of the project and through effective and efficient project management, project managers or project management practitioners can always successfully complete projects and meet business objectives, satisfy stakeholders among many other benefits (PMI, 2017).

Table 2.1 shows an outline of the key components of a project and their descriptions (PMI, 2017).

Table 2.1: Key Components of Projects

PROJECT KEY COMPONENT	DESCRIPTION
Project Life Cycle	- Series of phases a project passes through from its start to its completion
Project Phase	- Collection of logically related project activities that culminates in the completion of one or more deliverables
Phase Gate	- Review at end of a phase in which a decision is made to continue to the next phase, to continue with modification, or to end a program or project
Project Management Processes	- Systematic series of activities directed toward causing an end result where one or more inputs will be acted upon to create one or more outputs
Project Management Process Group	- Logical grouping of project management inputs, tools and techniques, and outputs. The Project Management Process Groups include Initiating, Planning, Executing, Monitoring and Controlling, and Closing. Project Management Process Groups are not project phases
Project Management Knowledge Area	- An identified area of project management defined by its knowledge requirements and described in terms of its component processes, practices, inputs, outputs, tools, and techniques

(Source: PMBOK-PMI, 2017)

Figure 2.1 also shows the interrelationships between the various key components during the management of the projects as illustrated in the 6th Edition of the Project Management Book of Knowledge Guide (PMI, 2017).

According to Sawhney et al. (2017, citing Montague, 2015), Building Information Modelling can be employed in all aspects of the project life cycle, however, the nature and level of BIM may vary as the project travels through the various stages in the cycle. The employment of BIM in projects are grouped in the following categories – Information

Model or Model Authoring (*Information Production*), Information Modelling or Model Management (*Information Management*) and Model Information Extraction and Usage, and the project manager must have adequate knowledge of all the stages.

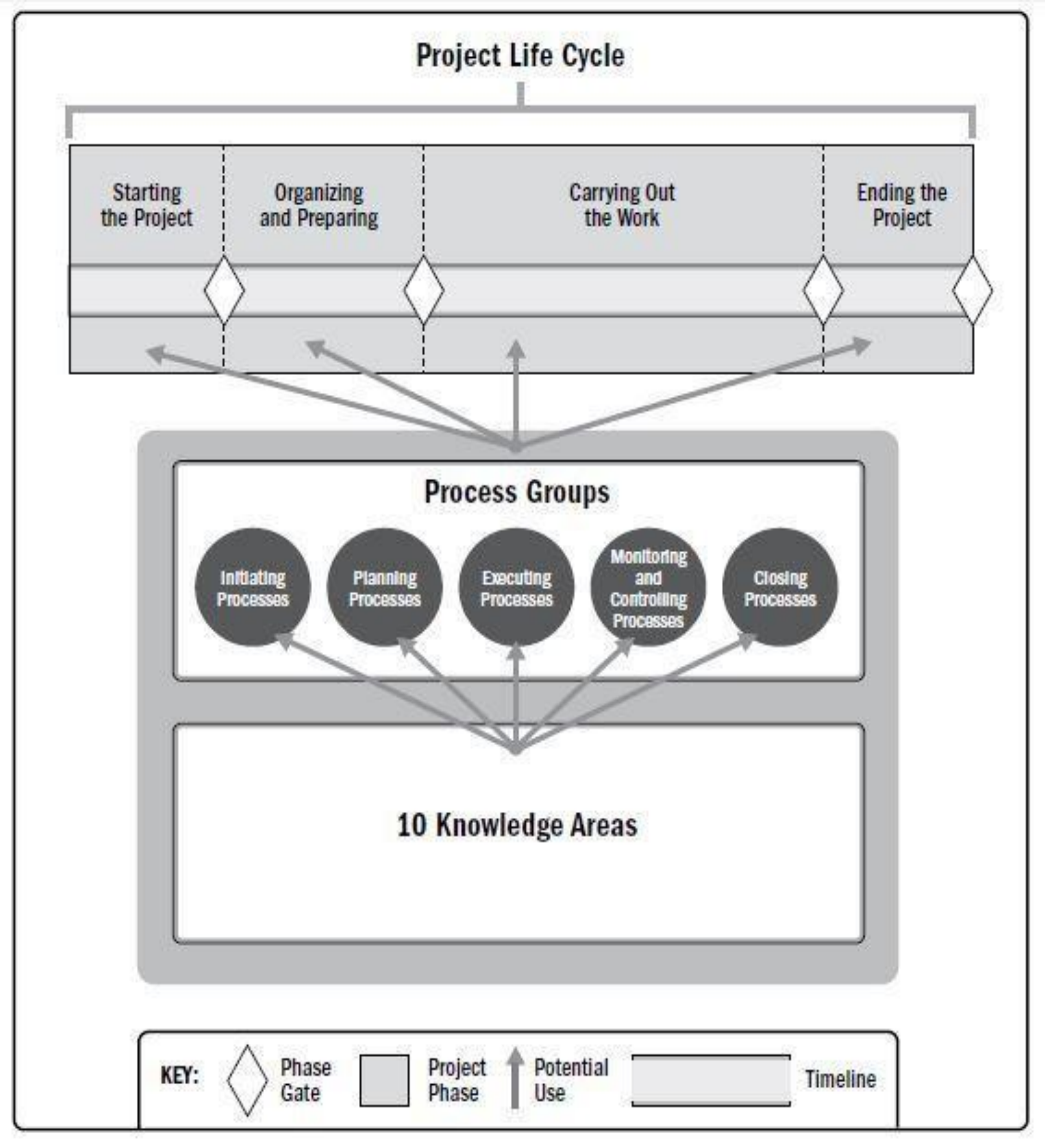

Figure 2.1: Interrelationship between project key components

(Source: PMBOK - Project Management Institute, 2017)

2.4 Project Management Knowledge Areas

A Project Management Knowledge Areas is basically an area within project management that is "defined by its knowledge requirements and described in terms of their component processes, practices, inputs, outputs, tools and techniques" (PMBOK-PMI, 2017). Javed at al. (2015, citing the PMBOK 5th edition) defined a knowledge area as representing "a complete set of concepts, terms, and activities that make up a professional field, project management field, or area of specialization". The PMBOK Guide describes ten knowledge areas that are often used in projects. These knowledge areas are described in the subsequent sub-sections based on the 6th edition of the PMBOK Guide.

2.4.1 Project Integration Management (PIM)

Project Integration Management includes the processes and activities to identify, define, combine, unify, and coordinate the various processes and project management activities within the Project Management Process Groups. In Project Integration Management, this knowledge area allows the project management practitioner to look at issues of allocating resources, balancing competing demands, examine alternative approaches, manage interdependencies among knowledge areas, etc.

It is made up of the following processes (PMBOK - Project Management Institute, 2017):

- Development of Project Charter
- Development of Project Management Plan
- Direction and Management of Project Work
- Management of Project Knowledge
- Monitoring and Control of Project Work
- Performing Integrated Change Control
- Closing of Project or Phase

2.4.2 Project Scope Management (PScM)

Project Scope Management includes the processes required to ensure the project includes all the work required, and only the work required, to complete the project successfully. This basically involves the definition and control of which things or matters are included in a project. It is made up of the following processes:

- Planning of Scope Management
- Collection of Requirements
- Definition of Scope
- Creation of Work Breakdown Schedule (WBS)
- Validation of Scope
- Control of Scope

2.4.3 Project Schedule Management (PShM)

Project Schedule Management includes the processes required to manage the timely completion of the project. It includes the following processes:

- Planning of Schedule Management
- Definition of Activities
- Sequencing of Activities
- Estimation of Activity Durations
- Development of Schedule
- Control of Schedule

2.4.4 Project Cost Management (PCoM)

Project Cost Management includes the processes involved in planning, estimating, budgeting, financing, funding, managing, and controlling costs so the project can be completed within the approved budget. It includes the following processes:

- Planning of Cost Management
- Estimation of Costs
- Determination of Budget
- Control of Costs

2.4.5 Project Quality Management (PQM)

Project Quality Management includes the processes for incorporating the organization's quality policy regarding planning, managing, and controlling project and product quality requirements, in order to meet stakeholders' expectations.

It includes the following processes:

- Planning of Quality Management
- Management of Quality
- Control of Quality

2.4.6 Project Resources Management (PReM)

Project Resources Management includes the processes to identify, acquire, and manage the resources needed for the successful completion of the project.

It includes the following processes:

- Planning of Resource Management
- Estimation of Activity Resources
- Acquisition of Resources

- Development of Team
- Management of Team
- Control of Resources

2.4.7 Project Communications Management (PCmM)

Project Communications Management includes the processes required to ensure timely and appropriate planning, collection, creation, distribution, storage, retrieval, management, control, monitoring, and ultimate disposition of project information.

It includes the following processes:

- Planning of Communications Management
- Management of Communications
- Monitoring of Communications

2.4.8 Project Risk Management (PRiM)

Project Risk Management includes the processes of conducting risk management planning, identification, analysis, response planning, response implementation, and monitoring risk on a project. It includes the following processes:

- Planning of Risk Management
- Identification of Risks
- Performing Qualitative Risk Analysis
- Performing Quantitative Risk Analysis
- Planning of Risk Responses
- Implementation of Risk Responses
- Monitoring of Risks

2.4.9 Project Procurement Management (PPM)

Project Procurement Management includes the processes necessary to purchase or acquire products, services, or results needed from outside the project team.

It includes the following processes:

- Planning of Procurement Management
- Conducting Procurements
- Control of Procurements

2.4.10 Project Stakeholder Management (PStM)

Project Stakeholder Management includes the processes required to identify the people, groups, or organizations that could impact or be impacted by the project, to analyze stakeholder expectations and their impact on the project, and to develop appropriate management strategies for effectively engaging stakeholders in project decisions and execution. It includes the following processes:

- Identification of Stakeholders
- Planning of Stakeholder Engagement
- Management of Stakeholder Engagement
- Monitoring of Stakeholder Engagement

An interesting trend or observation reported in the PMBOK Guide is the use of technological tools such as visual management tools in the various project management knowledge areas. This has come about as a result of the growing complexity and size of the data and information that project management practitioners have to constantly deal with. By using these technological tools, project management practitioners are able to collect, process, analyze and integrate different kinds of information to achieve the objectives and benefits of the project. For example, project management practitioners in the architecture, engineering and construction sectors have recorded significant gains in cost minimization, time schedule and many other benefits in projects through the application of technological tools like Building Information Modelling (BIM) in managing projects. It is therefore not surprising that international organizations, governments, and private organizations are gradually making the use of technological tools like BIM a mandatory feature in projects (PMI, 2017).

2.5 Building Information Modelling (BIM) in the Architectural, Engineering and Construction Industry

The modern Architectural, Engineering, and Construction (AEC) industry is often characterized by its fragmented, complex and multidisciplinary nature. Hence, project success is heavily pivoted on its effective collaboration among the stakeholders during various project phases (Kiprotich, 2014).

Philp et al. (2015) emphasize the fact that the construction industry has been doing things the same way for thousands of years. Concrete is poured and set, blocks are stacked on top of blocks, and systems for heating and water are designed around corners and over multiple floors. For way too long, the construction industry has done a lot of these processes in isolation.

Building Information Modeling (BIM) is a tool, which addresses these issues in the design, construction and facility management phases of construction projects. BIM is defined in different ways and tends to mean different things to different people. According to Dastbaz, et al. (2017), BIM is purely a technical enabler in the form of sophisticated software. They also give an alternative definition as a philosophical framework that offers a paradigm shift within the construction sector.

The BIM Industry Working Group (2011) also defined BIM by incorporating the concept of management and explained the BIM as "a digital representation of physical and functional characteristics of a facility creating a shared knowledge resource for information about it forming a reliable basis for during its life cycle, from earliest conception to definition.

According to Eastman et al. (2011), BIM is a "modeling technology and associated set of procedures to produce, communicate and analyze building models". Succar (2009) also defined BIM as an "approach that fully integrates people, systems, business structures, and practices into a collaborative and highly automated process."

However, Philp et al., (2016) puts it best in my view, as a "process for combining information and technology to create a digital representation of a project that integrates data from many sources and evolves in parallel with the real project across its entire timeline, including design, construction, and in-use operational information".

BIM is an intelligent 3D model-based process that gives architecture, engineering and construction professionals the insight and tools to more efficiently plan, design, construct and manage buildings and infrastructure (Autodesk, 2019). Although BIM is 3D based, it is not 3D CAD (Computer Aided Drafting). BIM uses its 3D model as a basis to add information to the model. BIM is not just a 3D visualization of a model but includes vital information such as material properties, coordination with other construction disciplines and so on (Philp et al., 2015). Additionally, BIM is expounded to 4D, 5D and even 6D. This is when time, cost implications and project lifecycle information is added to the 3D model respectively (McPartland, 2018).

BIM processes aim to make the construction industry more efficient, and to allow project teams to make savings in terms of cost, time, and removing waste across the timeline The real value in BIM is the ability to interrogate the model and find the data you need, when you need it. The building information modeling process covers geometry, space, light, geographic information, quantities, and properties of building components. BIM can be used to demonstrate the entire building life cycle, including the processes of construction and facility operation. It is, however, important to note that BIM is not limited to buildings but covers other infrastructure like roads, bridges, railways, and tunnels. Building Information Modeling is also applied in other sectors of the built environment. For example, BIM can be applied in mining and land survey. Aerial images from photogrammetry can be used to generate 3D models upon which further information would be embedded.

2.6 Features of Building Information Modelling (BIM)

According to Azhar et al. (2012), Building Information Modelling (BIM) can be used in visualizing (generating 3D renderings), fabricating (generating shop drawings), code reviewing, cost estimation, construction sequencing (coordinating material ordering, fabrication, and delivery schedules), detecting conflict interference and collisions, forensic analysis, facilities management (renovations, space planning, maintenance activities).

Velasco (2013) provides a summary of the major features of the BIM technology cited in Eastman et al. (2011). According to Velasco, BIM technology comes with seven major features that enable users in the AEC industry to efficiently and effectively carry out activities in the sector. The seven BIM features are provided below:

- **Parametric Design** – This feature allows users to closely design and create models that contain automated functions and smart objects that tend to behave like the real objects of construction. It helps to quickly spot discrepancies and achieve effective design processes.

- **3D Graphics** – With 3D graphics, BIM helps users and other stakeholders (nonconstruction industry workers) to have a better understanding of the designs and also easily identify any mistakes in the design.
- **Information at the Element Level** – BIM enables users to have greater control over designs and individual elements because each element or object has a lot of valuable information stored within it.
- **Coordination** – By using BIM technology, different industry players can seamlessly make different changes within designs and models that will easily be reflected in all the different views of the design process.
- **Communication Platform –** BIM has considerably reduced the problem of communication that plagued the AEC industry. With BIM, users can now retrieve needed information from the model or design with little difficulty and operate in a more transparent manner.
- **Visualization** – An interesting feature offered by BIM is the change from model representation to visualization. Users can alter, filter and generate part views in order to visualize a particular part of the structure.
- **Entire Life Cycle of Building –** BIM can be applied in all aspects of the life cycle of the structure (i.e. from design to demolition). With its ability to store relevant information of all elements of the model, all participants are able to use BIM at different phases of the project.

The following diagram (Figure 2.2) shows examples of the BIM design platforms and the application software they offer (Eastman et al., 2011).

COMPANY	BIM PLATFORM	LOGO
Autodesk	Revit (Architecture, Structures, MEP) *Last Version: Revit 2014*	AUTODESK REVIT
Graphisoft	ArchiCAD *Last Version: ArchiCAD17*	GRAPHISOFT ARCHICAD
Bentley	Bentley Architecture *Last Version: Bentley Architecture V8i*	Bentley
Nemetschek	Allplan Architecture *Last Version: Allplan Architecture 2013*	NEMETSCHEK Allplan
Gehry Technologies	Digital Project *Last Version: Digital Project V1, R5*	Gehry Technologies
Tekla	Tekla Structures* *Last Version: Tekla Structures 19*	TEKLA Structures

*Only for the creation of structural BIM models

Figure 2.2: BIM design platforms (Source: Eastman et al., 2011)

2.7 Adoption of Building Information Modelling (BIM)

Adoption and implementation of Building Information Modelling (BIM) is an activity that is very crucial and involves an array of differing factors.

According to Gu and London (2010), there are different levels of Building Information Modelling (BIM) across the globe. BIM implementation in different countries is at different levels mainly because the awareness levels, knowledge levels and interest levels of the various industry sectors and individuals vary across these countries.

A study by the McGraw-Hill Construction in the AEC sector in 2008 cited in Azhar et al. (2012) showed that architects were the heaviest users of BIM in the industry.

In the United States of America and Canada construction industry, for instance, the BIM adoption rates rose from 28% to 71% from 2007 to 2012. It was also revealed that the rise in adoption of BIM was almost two times greater among larger firms when compared to smaller firms (SmartMarket Report, 2012). Seed (2015) also found that 62% of respondents sampled from the UK construction sector had adopted BIM.

Some of the key drivers for the adoption of BIM in the UK construction industry are flow and management of information, technological benefits, the focus of effort high impact areas and governmental standards (Seed, 2015). Seed (2015) established in his study that government mandates and the benefits derived from BIM were the major factors driving the adoption of BIM among larger construction companies in the UK construction industry.

Acquah et al. (2018) investigated the acceptance of Building Information Modelling (BIM) in the Ghanaian construction industry. They came to the conclusion that in order to improve the adoption of BIM in the sector, the BIM awareness of sector players should be improved through workshops and seminars. Also, they suggested that including BIM education in related academic programs of study and encouraging clients to demand BIM application in their projects will help improve the adoption of BIM in the Ghanaian construction sector.

2.8 Benefits of Building Information Modelling (BIM) Adoption

The adoption of Building Information Modelling (BIM) in the AEC sector comes with a lot of benefits. Ford et al. (1995) reported that BIM contributes to greater efficiencies in the construction sector by improving the level of collaboration among the various project stakeholders and reducing the instances of corrections and adjustments on projects.

According to the CRC Construction Innovation (2007), some benefits of using BIM include faster and more effective processes, better designs, controlled whole-life costs and environmental data, better production quality, automated assembly, better customer service, and lifecycle data.

A report by Autodesk in 2009 indicated that higher quality of work, greater speed and lower costs of projects were the three top benefits of BIM adoption. Riese (2009) observed a substantial reduction in construction costs and timely completion of project when BIM was applied in the Swire Properties project.

A study by Becerik-Gerber and Rice (2010) identified increased profitability as a major benefit of BIM adoption in the US building industry. Improvement in visualization, productivity, coordination, cost efficiencies, improvement in profits and speed of delivery were identified as the main advantages of BIM adoption in a research report by the NBS in 2011.

Barlish and Sullivan (2012) also found that BIM adoption substantially reduced change orders and requests for information and they also saw an average reduction in construction costs. Lee et al. (2012), indicate that BIM application can lead to a reduction in costs stemming from design errors and delays.

In other studies, integration of design and construction, effective communication, improved construction processes, and value-added project delivery were seen as the major benefits of BIM adoption (Gayathri et al., 2013). Doumbouya et al. (2016) reported improvement in quality of design quality, cost reduction, sharing of information, ease of implementation, speed of work and project delivery, efficiencies in energy use and operational support for owners, and project managers as the benefits of BIM adoption in the construction industry.

2.9 Building Information Modelling (BIM) Adoption in Project Management

The success of a project is determined by its ability to deliver the project according to the set-out specifications; deliver it within the budgeted time and cost, and deliver it to the satisfaction of all stakeholders involved (Fazli et al. (2014).

Fazli et al. (2014) showed that project management practitioners can make more informed and effective decisions through the use of Building Information Modelling (BIM) technology. It was also realized that BIM allows for easy communication among stakeholders and helps the project management practitioner to have better control over the project leading to successful delivery of the project.

It is reported that several challenges within the traditional way of managing projects can be addressed by the employment of Building Information Modelling (BIM) in project management (Shizhao, 2005). Project management practitioners are urged to incorporate BIM in their activities.

Figure 2.3 is a representation of the nature of the transition of information using the traditional project management approach as against the BIM adoption approach.

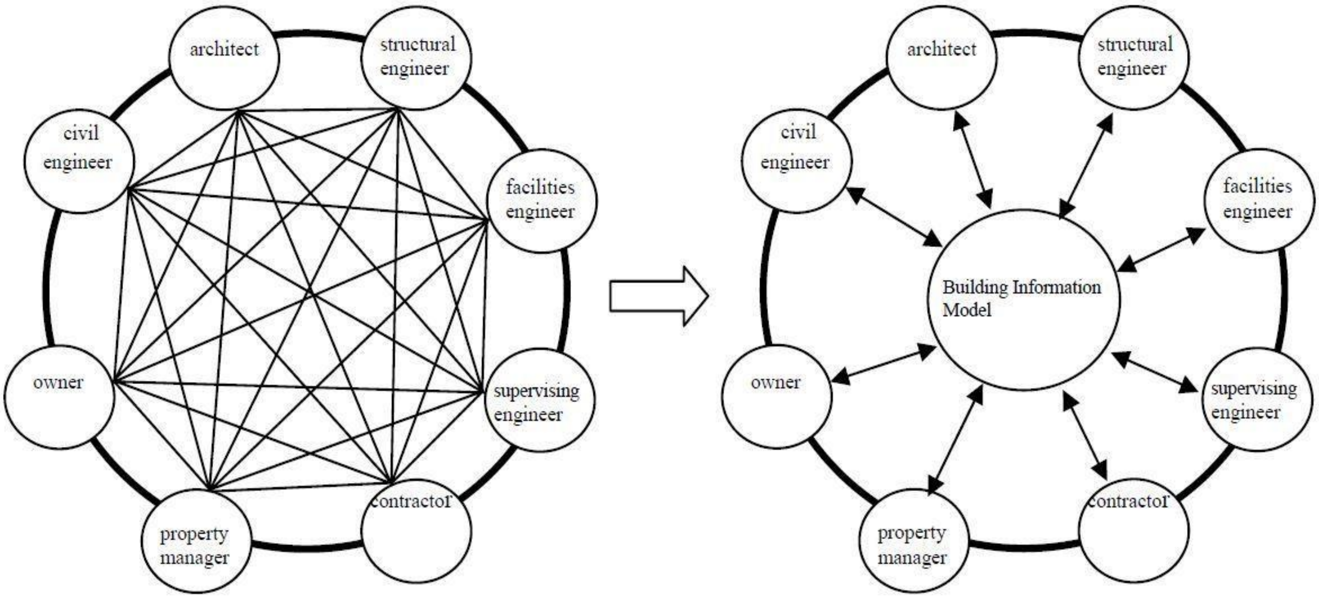

Figure 2.3: Transition of Information Sources in Traditional versus BIM Way (Source: Shizhao, 2005)

Table 2.2 also shows the BIM roles of project management practitioners and the BIM applications over the life cycle of the project (Sawhney et al., 2017).

Table 2.2: BIM Role and Applications of Project Management Practitioners

STAGE	BIM ROLE OF PROJECT MANAGEMENT PRACTITIONER	BIM APPLICATIONS

Briefing, Inception, and Pre-construction	Feasibility analysis (technical and financial)	BIM adoption question, Challenges to BIM adoption, Conceptstage BIM
	Value engineering	Options selection using BIM, Conceptual Estimating Modelling, Energy Analysis, Design Analysis
	Design management	BIM information exchange, 5D (rapid cost feedback to design changes), BIM Coordination
	Risk analysis and safety	Simulation, Virtual Reality (VR) and Augmented Reality (AR)
	Scheduling	4D Modelling
	Constructability analysis	4D Modelling, virtual mock-ups, VR and AR
	Procurement (design and construction)	BIM skills and capability mapping, BIM-enabled Supply Chain Management, Constraint Analysis
Construction	Phasing and prototyping	4D
	RFIs and issue resolution	BIM information exchange, BIM coordination
	Change management	BIM information exchange
	Monitoring and control	4D and 5D, Constraint Analysis, Progress Tracking and Production Planning
Project closure	Contract and financial closure	Record model
	Project closure	Record model, Asset Information Model
	Handover	Record model, BIM for FM, Asset Information Management

(Source: Sawhney et al. 2017)

Some benefits of BIM application in project management activities are provided in Table 2.3

Table 2.3: Benefits of BIM in Project Management

Stage of Construction Project	BIM Benefits	Type of Project Management Application
Pre-Design	Feasibility study	Scope, Integration, Human Resource, Environmental
	Virtual design of complete project	Risk, Time, Financial
Design Stage	Earlier and more accurate visualizations of Design with 3D model	Risk, Cost, Safety
	Automated corrections (low-level) when design changes are made	Communication, Risk, Time, Scope
	Early collaborate and simultaneous work by multiple design disciplines	Scope, Time, Human Resource, Quality, Integration
	Increased accuracy and consistency of 2D drawings from early stages and at any stage of the design production phase	Risk, Time, Procurement, Cost Management
	Extraction of bill of quantities for cost estimation	Cost, Financial Management
	Design intent checks using 3D visualizations as well as quantification of the space areas	Time, Risk, Integration and Procurement Management
Construction Stage	Synchronisation of design and construction	Integration, Time
	Clash detection	Risk Management
	Cross System updates	Risk, Time Management
	Fabrication	Time, Procurement, Quality
	Reduce wastage	Risk, Cost
Maintenance Stage	As built documentation	Quality, Risk, Financial Procurement
	Fit out documentation	Quality, Risk, Financial Procurement

(Source: Kiprotich, 2014)

Sawhney et al. (2017) further establish the important role BIM plays in enhancing and sharpening the central role of project managers in the successful achievement of projects. Effective project management contributes to the success of a project and through the application of BIM, project managers can improve the collaboration, communication, coordination, exchange and collation of information among all stakeholders in a project.

Table 2.4 shows the influence of BIM in the various project management knowledge areas.

Table 2.4: BIM Influence in Project Management Knowledge Areas

PMBOK Knowledge Areas	Influence of BIM
Project Integration Management	Development of the project charter and project management plan in sync with the BIM Execution Plan; develop integrated change control with BIM
Project Scope Management	Integrate BIM Execution Plan with Scope Definition; develop a Scope Control mechanism
Project Time Management	Incorporate standard processes and practices of 4D simulation, phasing, and prototyping; interface of project schedule and the BIM implementation plan
Project Cost Management	Incorporate standard processes and practices of quantity take-off, estimating; link cost assemblies with model objects to generate estimates
Project Quality Management	Interface of model quality management plan with the overall project quality plan
Project Human Resource Management	Coordination and communication protocols, training, and competency mapping about BIM
Project Communications Management	Collaboration, coordination and communication protocols
Project Risk Management	Accuracy and certainty in time, cost, and other project parameters
Project Procurement Management	Supply chain integration, Quantity take-off, estimating
Project Stakeholder Management	Visualisation, Collaboration, Information Sharing

(Source: Sawhney et al. 2017)

2.10 Barriers to Building Information Modelling (BIM) Adoption

Despite the enormous potential and benefits that can be derived from Building Information Modelling (BIM) in the AEC industry, there seem to be differences in the adoption and implementation of BIM in the sector in various countries across the globe. BIM adoption appears to be low especially in developing countries. The low adoption rates have been attributed to certain characteristic factors or barriers that tend to inhibit the adoption and implementation of BIM in various countries.

In a study by the National Institute of Building Sciences, it was realized that lack of awareness, lack of interest and lack of technical support for interoperability were some of the major inhabitants to BIM adoption in project management in the US construction industry (NIBS, 2007).

Some barriers to the adoption and implementation of BIM in the AEC industry in the UK reported by Yan & Damian (2008) are training costs and resistance to change.

Migilinskas et al. (2013) indicated that the effective adoption of BIM was constrained by the reluctance of stakeholders in the sector to put aside their individual benefits and adopt advanced and improved ways of increasing project results and effectiveness.

Seed (2015) identified the cost of BIM as the major barrier to BIM adoption. Olabode and Umeh (2018) in their study of the Architecture, Engineering and Construction industry in Nigeria established that lack of awareness, lack of trained professionals, cost of software, lack of clients' demand and ICT illiteracy were the top five barriers that were responsible for the slow adoption of BIM in the sector. These fell into categories of management barriers, people barriers, financial barriers, management barriers, and people barriers respectively.

CHAPTER THREE

RESEARCH METHODOLOGY

This chapter presents the research methodology used in this study to investigate the adoption of Building Information Modelling (BIM) technology in Project Management in the Architecture, Engineering, and Construction (AEC) industry in Ghana. The chapter begins with an overview of the research purpose and research method selected for the study. It is followed by the population identified for the study from which the sample is drawn, the sampling strategies or techniques and the sample size for the study. Afterward, the sources of data, the data collection process, and the data collection instruments are then looked at followed by a summary of the statistical methods and tools used in the data processing and analysis stage. The chapter closes with a section on the reliability, validity and ethical issues in the study.

3.1 Research Purpose and Research Method

Research can be carried out for a variety of reasons – for *exploratory reasons*, where it attempts to discover new information about certain phenomena; for *explanatory purposes*, where it strives to establish relationships between the cause of a problem and its effect through the use of well-defined research problems and hypotheses; and for *descriptive purposes*, where it seeks to only describe attributes of the phenomena (Saunders et al. 2003; Saunders, 2007).

This study seeks to explore knowledge areas of project management within the context of the Architecture, Engineering, and Construction (AEC) industry in the Ashanti region of Ghana to assess the adoption of Building Information Modelling (BIM) technology in these project management areas. Consequently, this study is seen as exploratory in nature, as it seeks to obtain new firsthand information about a specific matter. Kiprotich (2014) used a similar exploratory study purpose approach to investigate BIM adoption in project management in the South African AEC sector.

It is necessary to note that studies should be guided by a research method that aids in the achievement of the research goals and objectives. The major research methods employed in studies are qualitative research methods and quantitative research methods. Qualitative methods are used when a study seeks to explore social or cultural phenomena by situating it in its naturally occurring real-world settings and hence the use of statistical and quantitative procedures are not required. Examples include case study research, action research, among others. Quantitative research methods, on the other hand, are mainly applied in natural sciences wherein phenomena are reduced to measurable variables, collated from samples and analyzed statistically to draw conclusions. Examples include survey methods, laboratory experiments, among others (Strauss and Corbin, 1990; Patton, 2002; Myers et al., 2002; Saunders et al., 2007).

Saunders et al. (2007) indicate that no research method is superior on its own to another. Instead, the choice of a particular research method should be guided by the study purpose and its ability to achieve the research goals. Mingers (2001), argued that researchers can achieve greater reliability and validity by taking maximum advantage of both qualitative and quantitative research methods and in the process avoid the disadvantages of both methods.

Lee (1991) developed a third strategy called the mixed-method by integrating qualitative methods such as case study and quantitative methods such as survey study. Yin (1994) defined survey study as “systematic gathering of information from respondents, generally in the form of a questionnaire” and Yin (2003) defined case study as “an empirical inquiry that investigates a contemporary phenomenon within its real-life context”.

The selection of the research method depends on the goals of the study. This study is exploratory in nature as it seeks to determine the adoption of Building Information Modelling (BIM) technology in project management in the specific case of the Architecture, Engineering, and Construction (AEC) industry in the Ashanti region. This aspect falls under qualitative research methods. The study also requires gathering of information from respondents and so a quantitative method using a survey instrument is used in this part.

Consequently, this study adopts the mixed-method research strategy. A similar mixedmethod research strategy was employed by Kiprotich (2014) to investigate BIM adoption in project management in the South African AEC sector.

3.2 Population of the Study

The determination of the appropriate population of respondents for a study is extremely important for the collection of empirical data (Holme and Solvang, 1991). This study seeks to determine the adoption of Building Information Modelling (BIM) technology in project management in the Architecture, Engineering, and Construction (AEC) industry in Ghana mainly in the Ashanti region. It therefore requires respondents with experience in project management activities in the AEC industry who have undertaken or are undertaking projects in Ghana.

The AEC industry is a very broad and fast-growing industry comprising architecture firms, engineering firms, and construction firms. There are several professionals that are practicing project management in the small and major firms within the industry. For purposes of convenience and accessibility, the study is limited to the project management practitioners in the AEC sector within the Ashanti Region. As such, the population defined for this study includes all project management practitioners in the AEC industry operating within the Ashanti Region of Ghana.

3.3 Sampling Technique and Sample Size

Sanders et al. (2003) emphasize that the choice of a particular sampling technique or strategy for the selection of respondents for data collection depends mainly on the feasibility or practicability of the technique to acquire the data needed to address the research questions and objectives.

Sampling strategies for research purposes are grouped into two main categories – probability sampling techniques and non-probability sampling techniques. In probability sampling, each member of the population "has an equal chance of being included in the sample". Examples include random sampling, cluster sampling, among others. In nonprobability sampling, samples are taken in such a way that individuals in the population do not have equal chances of being included in the sample. Examples include convenience sampling, purposive or judgmental sampling, quota sampling, among others (Saunders et al., 2007; Taherdoost, 2016).

This study engages the purposive or judgmental and snowballing sampling techniques to draw the sample for data collection. Similar studies (Nani and Akwaah, 2015; Javed et al., 2015; Acquah et al., 2018) employed similar sampling techniques in their works. This technique is also used because it saves time and cost and allows for easy drawing of a sample that is best positioned to address the subject matter based on their professional knowledge and experience in project management in the construction industry (Nani and Akwaah, 2015; Javed et al., 2015; Taherdoost, 2016; Acquah et al., 2018).

In the study, a sample size of twenty-nine (29) project management practitioners is drawn from various firms within the Architecture, Engineering, and Construction (AEC) industry operating in the Ashanti Region. These individuals are project management practitioners whose firms have undertaken and/or are undertaking projects in Ghana.

They have expert knowledge and experience in project management activities and are therefore best suited to provide the responses that are needed for this study.

3.4 Data Sources and Data Collection Process and Instrument

Data for research purposes are obtained from a variety of sources. These include archival records, documentation, direct or participant observations, surveys, interviews, among others. However, it is worth noting that a particular data source has no complete advantage over the other sources. Rather, they complement each other and therefore the use of multiple data sources in a study is highly recommended since it further strengthens the validity of the research and yields many benefits (Yin, 2003; National Academies of Sciences, Engineering, and Medicine, 2018).

Data can also be grouped into two (2) main categories – primary data and secondary data. Primary data represents data collected originally or directly by the study through firsthand research surveys, interviews, observations, and so on while information obtained previously by other researchers, collected from journal articles and published documents and used in literature review serves as secondary data (Hox and Boeije, 2005).

The data sources for this study are survey and interview of the sampled project management practitioners which serve as primary data for the study. Literature review on specific subject areas in the form of journal articles, published articles and books make up secondary data.

3.4.1 Data Collection Instruments (Questionnaire and Interview)

The survey questionnaire and interviews are the instruments or tools used for primary data collection in this study. The survey questionnaire is a well-known and widely-used instrument employed in a variety of contexts ranging from health, through to rural development, construction, and many others, to easily gather data from a population for analysis (Hewitt et al., 2017). Kiprotich (2014), Nani and Akwaah, (2015) Javed et al. (2015), Acquah et al. (2018) and Olabode and Umeh (2018) adopted similar data collection instruments in their studies to examine adoption of BIM technology and project management knowledge areas. This approach is an easy way of gathering information from a number of respondents in a short time and at a lower cost.

The questionnaire for the survey is provided as Appendix I in this document. The questionnaire is divided into three (3) sections. Section A focuses on the background information of respondents in terms of their knowledge and experience in project management activities and Building Information Modelling (BIM) technology. There are nine (9) questions in this section and it includes questions on the period respondents have been practicing in project management, the education level and professional bodies they belong to, their awareness of and experience in BIM technology.

In Section B, the questionnaire aims to determine the use of Building Information (BIM) technology in the knowledge areas of project management. For each project management knowledge area, respondents indicated whether they employed BIM or not by responding 'Yes' or 'No'. After that, a Five-Point Likert scale ranging from (1) – 'Least Useful' to (5) – 'Extremely Useful' is used as the response measurement scale for the respondents to indicate their perception on how useful BIM technology application is in each of the project management knowledge areas in the AEC industry.

Finally, in Section C of the questionnaire, respondents are asked to indicate their level of agreement with identified perceived barriers to BIM adoption. This is adapted from Olabode and Umeh (2018) who investigated the adoption of BIM in the AEC industry in Nigeria. Seventeen (17) identified perceived barriers are further grouped into six (6) categories in the questionnaire and respondents use a Five-Point Likert scale ranging from (1) – 'Strongly Disagree' to (5) – 'Strongly Agree' to express their level of agreement. This section aims to establish barriers to the adoption of BIM in project management in the AEC industry in Ghana.

Follow up interviews of the respondents in the survey are conducted based on the availability of the respondents to participate. The interviews are however unguided and only seek detailed explanations on the adoption of BIM technology in project management activities in order to further strengthen the validity and reliability of their responses.

3.5 Data Processing and Analysis

The data is statistically processed and analyzed using the Microsoft Excel 2016 version and the IBM Statistical Package for Social Sciences (SPSS) version 23 software programs. Percentage weighted mean scores are mainly used in the assessment of the data. The data is presented in the form of tables, statistical diagrams, graphs, and charts as well as through written analysis.

3.6 Reliability, Validity and Ethical Issues

The reliability of a study describes the ability of the study to be reproduced under similar methodological conditions. A higher degree of reliability can be achieved through the use standard and logical flow of research procedure and information gathered through literature from multiple studies that are have employed similar methodologies (Joppe, 2000; Hansson, 2003).

Validity in research basically looks at ensuring that the set goals or objectives of the study are achieved with minimal errors. In other words, the study or data collection instrument should be able to measure what it seeks to measure. Three main types exist – Construct, Internal, and External Validity – and the validity of a study can be increased by relying on multiple data sources, standard measurement scales, conducting field tests or pilot studies, draft reviews, representativeness of samples, and so on (Yin, 1994; Golafshani, 2003).

This study ensures that recognized standard methodological procedures gathered from extensive literature are employed. The study relies on respondents from a sample that is representative of the population. Closed-ended questions and appropriate response measurement scales are used in the questionnaire. A pilot study is carried out to ensure that the right information is received from respondents and to allow for modification of any confusing areas. All of these are done in order to improve the reliability and validity of the study.

Ethical issues in the study are resolved by having prior engagements with the respondents informing them of the purpose and objectives of the study and providing them with the assurance that this study is exclusively for academic purposes.

CHAPTER FOUR

FINDINGS AND DISCUSSION OF RESULTS

This chapter presents the findings and results of the analysis of the data gathered in this study. The primary data comprised of the responses generated from respondents through the survey questionnaire. The data was statistically analyzed using SPSS and MS Excel software programs and displayed using tables, charts, and figures. The findings of the study that attempt to help answer the aims and objectives of this study (i.e. determining the level of experience or expertise of project management practitioners in BIM; determining BIM usage and BIM usefulness in Project management knowledge areas; and determining the barriers to BIM adoption in project management in the architecture, engineering and construction industry in the Ashanti region in Ghana) are also captured in this chapter.

4.1 Responses Received

The questionnaires were administered over a three-day period to twenty-nine (29) project management practitioners in the Architecture, Engineering, and Construction sector mainly in the Ashanti region through a purposive and snowballing sampling approach. Out of these, twenty-three (23) responses were received, resulting in a response rate of 79.31%. Most of those who could not participate indicated time constraints as the reasons for their failure to respond to the questionnaires.

4.2 Demographics of Respondents

Questions 1 to 6 of Section A of the questionnaire collected some demographic information about the respondents in the survey. These included questions on the period of practice in the project management field, types of organizations, types of professional memberships, and academic qualifications. Table 4.1 is a summary of the demographic details.

Table 4.1: Demographic Information of Respondents

ITEM	CATEGORIES	FREQUENCY	PERCENTAGE %
1. Period of practice in the project management field	a) 5 years or less	15	65.22
	b) 6–10 years	8	34.78
	c) 11–15 years	0	0
	d) 16–20 years	0	0
	e) More than 20 years	0	0
	Total	23	100
2. Type of organization	a) General Contractors	18	78.26
	b) Renovation Contractors	0	0
	c) Real Estate Developers	1	4.35
	d) Owner-builders	3	13.04
	e) Others	1	4.35
	Total	23	100
3. Type of professional body	a) Project Management Institute	10	43.49
	b) Ghana Institution of Surveyors	4	17.39
	c) Ghana Institute of Architects	1	4.35
	d) Ghana Institution of Engineering	9	39.13
	e) Ghana Institution of Construction	3	13.04
	f) Others	1	4.35
4. Level of education	a) Post Graduate (Ph.D./MSc)	13	56.52
	b) First Degree (BSc/BEng)	7	30.44
	c) Higher National Diploma (HND)	3	13.04
	d) Construction Technician Certificate	0	0

	e) Advance in Construction Certificate	0	0
	Total	23	100

(Source: Field data, 2019)

From Table 4.1, the data gathered on the demographics of the respondents reveal that 65.22 percent and 34.78 percent of the respondents have been practicing in the field of project management in the architecture, engineering and construction (AEC) sector for 1 – 5 years and 6 – 10 years respectively. Also, the results showed that 78.26 percent of the respondents worked as General Contractors, 4.35 percent were in the Real Estate Development sector, 13.04 percent belonged to the Owner Builder category while 4.35 percent fell into the Others category. This means that the respondents had the necessary field experience in project management in a variety of areas in the AEC sector and were best suited to provide the information required of needed for the study.

Again, the results on the professional memberships of the respondents showed that 43.49 percent of them were members of the Project Management Institute. 17.39 percent of them belongs to the Ghana Institution of Surveyors while 4.35 percent of the respondents belonged to the Ghana Institute of Architects. In the Ghana Institution of Engineering, it was realized that 39.13 percent of the respondents were professional members while 13.04 of them also belonged to the Ghana Institution of Construction. 4.35 percent of the respondents indicated that they belong to other professional bodies. At least, all of the respondents in the study were members of at least one professional body in the architecture, engineering and construction industry. Some respondents had memberships in two or more professional bodies.

Moreover, on the academic qualification level, the findings showed that 56.52 percent of the respondents had obtained a Post Graduate (Ph.D./MSc) qualification while 30.44 percent of them had a First Degree (BSc/BEng). In the Higher National Diploma (HND), only 13.04 percent of the respondents had obtained this academic level. This means that the respondents are seen to have the requisite academic and professional knowledge to provide the needed responses for the study.

4.3 Knowledge and Expertise of Respondents in Building Information Modelling (BIM)

In this section, the knowledge and expertise of respondents in Building Information Modeling (BIM) was determined. Questions 5 to 9 in Section A of the questionnaire touched on the awareness of respondents on BIM, formal training in BIM, application of BIM in project management, period of application of BIM and their level of expertise in BIM.

4.3.1 Awareness of BIM

To determine the awareness level of BIM among project management practitioners in the AEC sector in the Ashanti region in Ghana, participants in the survey were asked to respond Yes or No to the question on their awareness of BIM. The findings showed that 91.30 percent of the respondents answered Yes meaning they had heard or knew of BIM and 8.70 percent indicated that they had never heard of BIM. This is represented in Figure 4.1. This finding shows that the level of awareness of BIM among project management practitioners in the AEC sector in Ghana is very high.

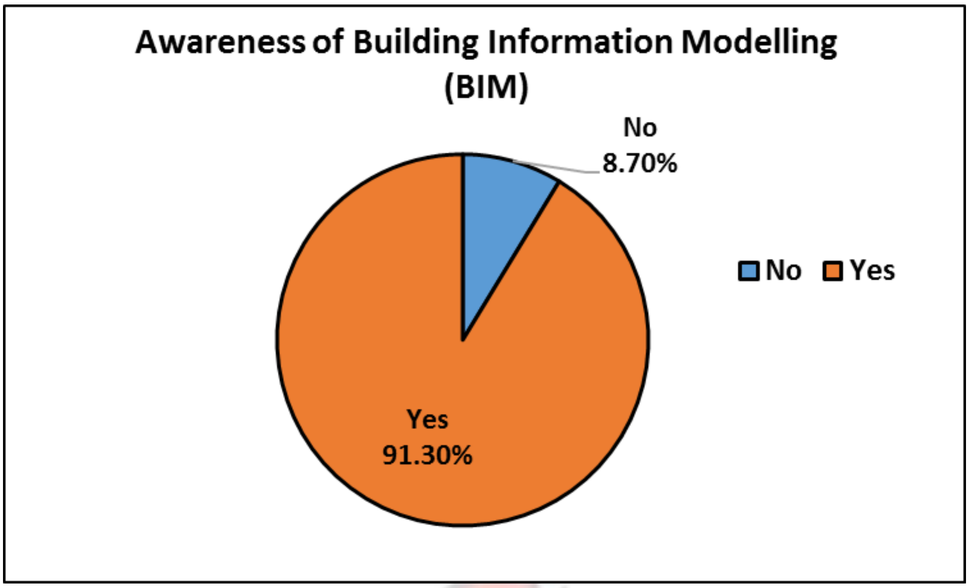

Figure 4.1: Awareness of BIM (Source: Field data, 2019)

4.3.2 Formal Training in BIM

The respondents that indicated that they were aware of BIM were further asked to answer whether they had had any formal training in BIM. Out of the 91.3 percent of the respondents that had an awareness of BIM, 52.4 percent of them had some formal training on BIM and the rest (47.6 percent) had no formal training on BIM. This means that more than half of the sampled project management practitioners in the AEC industry had sufficient knowledge of BIM through formal training. Figure 4.2 is a representation of this finding.

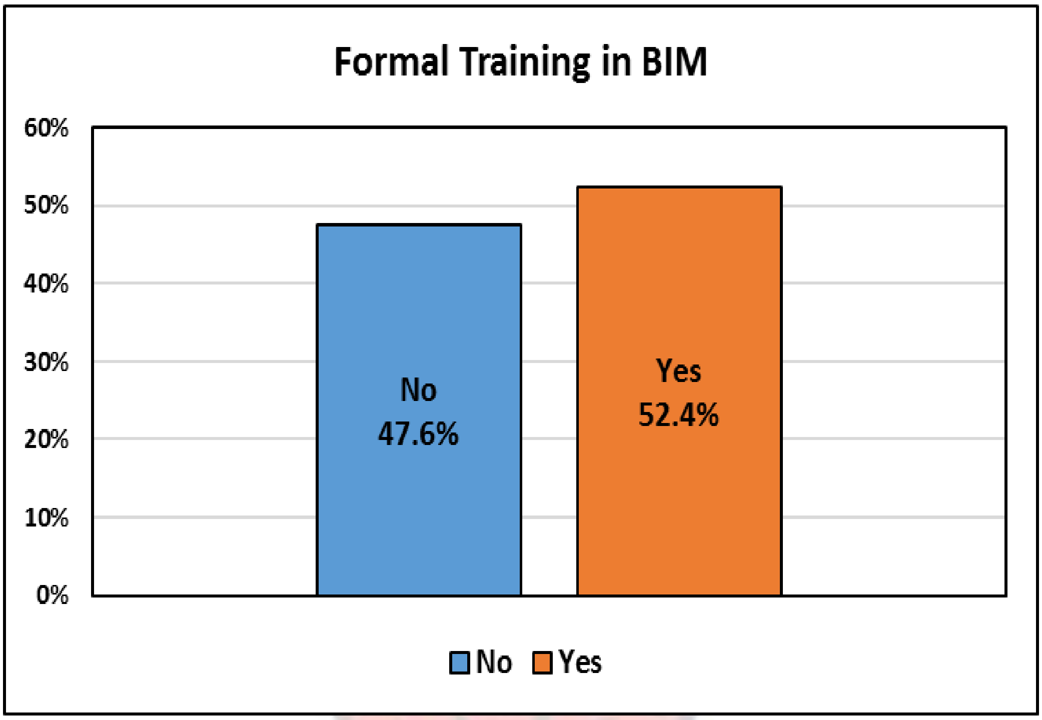

Figure 4.2: Formal Training in BIM (Source: Field data, 2019)

4.3.3 Application of BIM in Project Management

Again, asked whether they use BIM or had ever used BIM in project management activities, more than half (66.7 percent) of the participants responded in the affirmative. 33.3 percent of the respondents said that they had never used or do not use BIM in project management activities. This goes to show that although there was a high awareness of BIM among the sampled project management practitioners, a significant number of them did not apply BIM in their project management activities. The level of use of BIM was low. The results of this finding is represented in Figure 4.3.

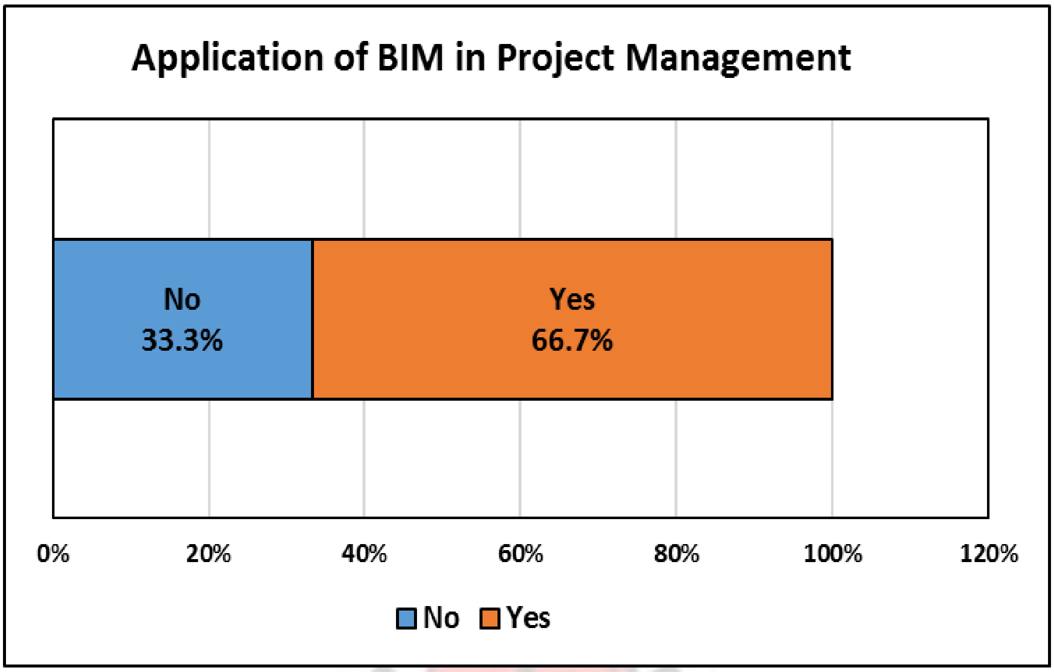

Figure 4.3: Application of BIM in Project Management (Source: Field data, 2019)

4.3.4 Period of Application of BIM in Project Management

Seeking to find out how long the respondents had been applying BIM in project management, analysis of the data showed that 52.4 percent had been using BIM in project management between 1 to 5 years while 14.3 percent had been applying BIM in project management between 6 to 10 years. On the other hand, the rest of them (33.3 percent) had never used BIM as established in section 4.3.3. This means that a good majority of the respondents had enough experience in BIM and its application in project management activities and are therefore in a good position to offer unbiased and accurate information on the subject matter. This is represented in Figure 4.4.

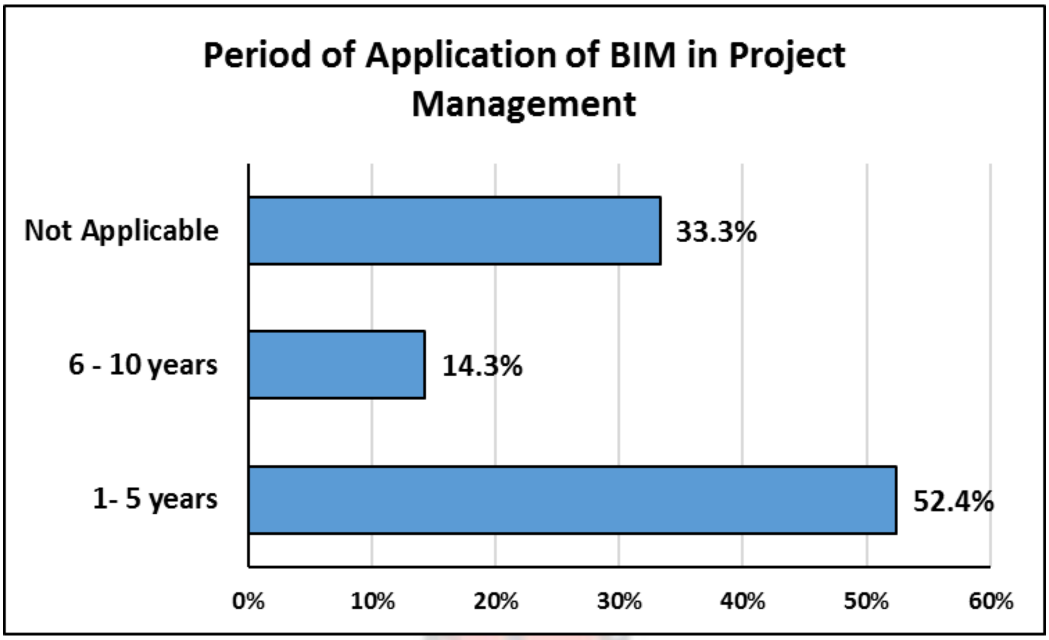

Figure 4.4: Period of BIM Application in Project Management (Source: Field data, 2019)

4.3.5 Level of Understanding and Expertise in BIM

Finally, Question 9 in Section A sought to determine the level of understanding and expertise in BIM among the respondents. Respondents were asked to rate their level understanding and expertise on a scale of 1 (Lowest) to 10 (Highest). The results are presented in Table 4.2.

A majority of the respondents were rated below the average rating of 5. Only 28.6% of respondents had a rating above the average mark. However, none of the respondents rated their understanding and expertise in BIM with a 9 or 10. The highest rating was 8 with three respondents falling in that category. This shows that in spite of the high awareness level and application of BIM among the respondents, the level of understanding and expertise in BIM is significantly low. This may be as a result of the inadequate formal training and the low period of practice among the respondents. The results of the finding are represented in Figure 4.5.

Table 4.2: Level of Understanding and Expertise in BIM

Rating	Frequency	Percentage (%)
1 (Lowest)	5	23.8
2	6	28.5
3	0	0
4	3	14.3
5	1	4.8
6	0	0
7	3	14.3
8	3	14.3
9	0	0
10 (Highest)	0	0
Total	**21**	**100**

(Source: Field data, 2019)

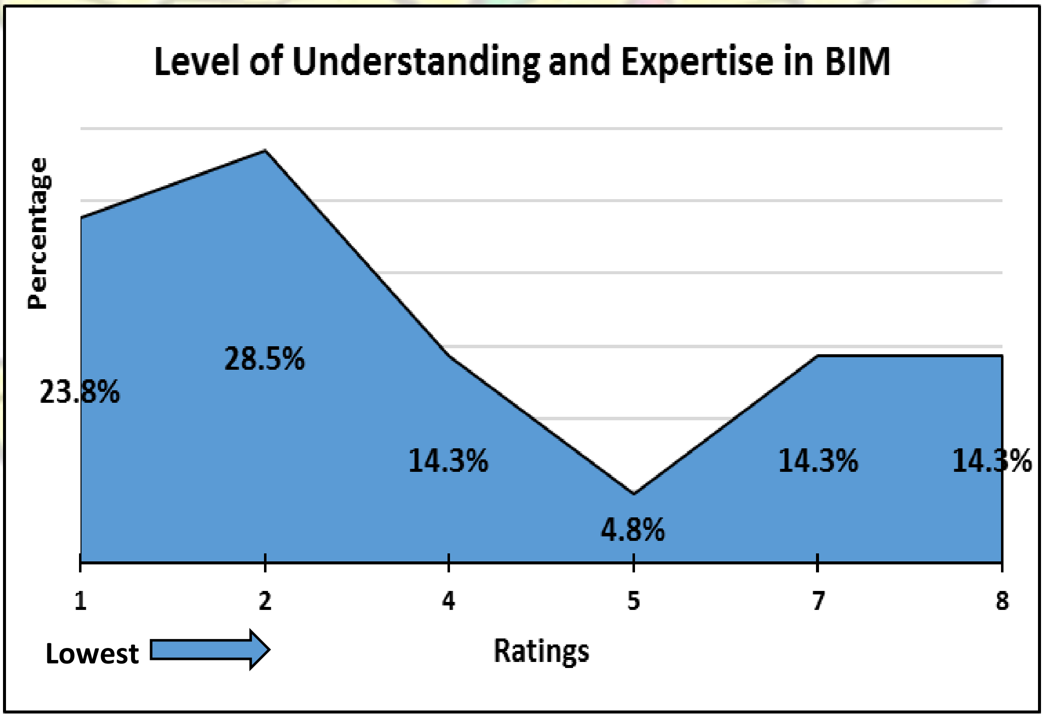

Figure 4.5: Level of Understanding and Expertise in BIM

(Source: Field data, 2019)

4.4 Usage and Perceived Usefulness of Building Information Modelling (BIM) in Project Management Knowledge Areas

Respondents' usage of Building Information Modelling (BIM) in the Project Management Knowledge Areas and respondents' Perceived Usefulness of BIM in these Knowledge Areas were measured in Section B of the questionnaire. For each of the ten Knowledge Areas in Project Management, respondents answered Yes or No to the question of whether they used BIM in the particular knowledge area. On a scale of 1 – Least Useful to 5 – Extremely Useful, respondents were further required to rate how useful they think using BIM in that particular knowledge area is.

These scores are then averaged to find the Weighted Average Scores of each knowledge area. The Weighted Average Scores reveal the perceived usefulness of BIM application in each knowledge area as seen from the view of the respondents. The weighted average scores are then finally ranked to determine which Knowledge Areas BIM usage is most useful. Table 4.3 presents a summary of the results.

4.4.1 BIM in Project Integration Management (PIM)

The results showed that 47.6% of project management practitioners used BIM in the Project Integration Management (PIM) knowledge area while 52.4% didn't. The perceived usefulness of BIM in PIM knowledge, however, fell between moderately useful and very useful with an average weighted score of 3.48 and was ranked first (1^{st}) among the ten knowledge areas.

4.4.2 BIM in Project Scope Management (PScM)

In the Project Scope Management (PScM) knowledge area, 61.9% of respondents used

BIM while 38.1% didn't. The weighted average score of 3.48 also placed its perceived usefulness between moderately useful and very useful. PScM was also ranked first (1st) together with PIM. Although PIM and PScM had the same score, a greater percentage of the respondents used BIM in PScM compared to PIM.

4.4.3 BIM in Project Schedule Management (PShM)

Also, in the Project Schedule Management (PShM) knowledge area, 61.9% of respondents used BIM while 38.1% didn't. 3.38 was the weighted average score recorded for the perceived usefulness of BIM in the PShM knowledge area. This meant that the perceived usefulness of BIM was between moderately useful and very useful. PShM came in fourth (4th) place on the ranking list.

4.4.4 BIM in Project Cost Management (PCoM)

BIM was used by a majority of the respondents (61.9%) in the Project Cost Management (PCoM) area as against 38.1% who didn't. The PCoM knowledge area also had 3.43 as its average weighted score and was third (3rd) on the ranking list. Its perceived usefulness rating was also between moderately useful and very useful.

4.4.5 BIM in Project Quality Management (PQM)

A switch in the percentage of BIM usage was observed in the Project Quality Management (PQM) knowledge area as more respondents indicated that they did not employ BIM in this area (33.3% Yes and 66.7% No). However, it received a fifth (5th) place ranking with a score of 3.29. This meant that although BIM was not used in PQM by most of the respondents, it was perceived to be rated between moderately useful and very useful.

4.4.6 BIM in Project Resource Management (PReM)

Again, the results showed that only 33.3% of the respondents applied BIM in the Project Resource Management (PReM) knowledge area and a majority (66.7%) did not use it even though it had a score of 3.14 falling between moderately useful and very useful BIM usefulness perceptions. The PReM was sixth (6^{th}) on the ranking list.

4.4.7 BIM in Project Communications Management (PCmM)

With a weighted average score of 2.86, the Project Communications Management (PCmM) was the eight (8^{th}) knowledge area out of the ten areas in terms of the perceived usefulness of BIM. It was also realized that few respondents employed BIM in this knowledge area (33.3%) compared to the percentage that did not use it (66.7%). The usefulness rating of BIM in PCmM was therefore in the range of slightly useful and moderately useful.

4.4.8 BIM in Project Risk Management (PRiM)

In the Project Risk Management (PRiM) knowledge area, it was again revealed that a lower percentage of respondents indicated that they applied BIM in the area (33.3% Yes and 66.7% No). The PRiM knowledge area was last (10^{th}) on the ranking list because of the low weighted average score of 2.71 on the perceived usefulness scale. Consequently, the perceived usefulness of BIM in PRiM knowledge area was between slightly useful and moderately useful.

4.4.9 BIM in Project Procurement Management (PPM)

The Project Procurement Management (PPM) knowledge area shared the eighth (8^{th}) position with PCmM, both having a weighted average of 2.86. This put the perceived usefulness rating of BIM in PPM in the region of slightly useful to moderately useful as perceived by the respondents. Also, the results of the BIM usage (33.3% Yes and 66.7% No) showed that fewer respondents employed BIM in PPM knowledge area.

4.4.10 BIM in Project Stakeholder Management (PStM)

The final project management knowledge area, Project Stakeholder Management (PStM) saw usage of BIM by 33.3% of the respondents while 66.7% failed to apply BIM. On the perceived usefulness scored, PStM received an above-average score of 3.05 and came in seventh (7th) place on the ranking list. The perceived usefulness of BIM in PStM was identified as lying between moderately useful and very useful.

The following table (Table 4.3) summarizes the perceived usefulness of BIM application in the ten project management knowledge areas.

Table 4.3: Perceived Usefulness of BIM Application in Project Management Knowledge Areas

Knowledge Area	Perceived Usefulness of BIM Application
Project Integration Management (PIM)	moderately useful – very useful
Project Scope Management (PScM)	moderately useful – very useful
Project Cost Management (PCoM)	moderately useful – very useful
Project Schedule Management (PShM)	moderately useful – very useful
Project Quality Management (PQM)	moderately useful – very useful
Project Resource Management (PReM)	moderately useful – very useful
Project Stakeholder Management (PStM).	moderately useful – very useful
Project Communications Management (PCmM)	slightly useful – moderately useful
Project Procurement Management (PPM)	slightly useful – moderately useful
Project Risk Management (PRiM)	slightly useful – moderately useful

(Source: Field data, 2019)

The results also showed that the overall mean weighted average score relative to the respondents' perceived usefulness of employing Building Information Modelling (BIM) in project management knowledge areas was 3.17. This then suggests that most of the respondents believe that overall, employing BIM in activities in project management knowledge areas is quite useful (i.e. 3.17 falls in the range of moderately useful to very useful).

Also, the top five project management knowledge areas in which respondents perceived BIM application to be useful are Project Integration Management (PIM)-1st, Project Scope Management (PScM)-1st, Project Cost Management (PCoM)-3rd, Project Schedule Management (PShM)-4th and Project Quality Management (PQM)-5th.

The rest were Project Resource Management (PReM)-6th, followed by Project Stakeholder Management (PStM)-7th, Project Communications Management (PCmM)8th and Project Procurement Management (PPM)-8th. The last knowledge area on the list is Project Risk Management (PRiM) in 10th place. Table 4.4 provides a summary of the results. Figure 4.6 presents an illustrated version of the results.

Table 4.4: Usage and Perceived Usefulness of BIM in Project Management Knowledge Areas

KNOWLEDGE AREA (KA)	CONTENT	USE OF BIM		PERCEIVED USEFULNESS OF BIM					WEIGHTED AVERAGE SCORE	RANK
		Yes (Y)	No (N)	Least Useful (1)	Slightly Useful (2)	Moderately Useful (3)	Very Useful (4)	Extremely Useful (5)		
1. Project Integration Management (PIM)	▪ Project charter & management plan development ▪ Directing, managing, monitoring & control of project work ▪ Perform integrated change control & closing project work	47.6%	52.4%	9.5%	14.3%	23.8%	23.8%	28.6%	3.48	1st
2. Project Scope Management (PScM)	▪ Planning scope management ▪ Collecting requirements & defining scope ▪ Creating work breakdown structure ▪ Validating & controlling scope	61.9%	38.1%	9.5%	4.8%	28.6%	42.9%	14.3%	3.48	1st
3. Project Schedule Management (PShM)	▪ Planning schedule management ▪ Defining & sequencing activities, estimating activity resources & durations ▪ Developing & controlling schedule	61.9%	38.1%	14.3%	4.8%	23.8%	42.9%	14.3%	3.38	4th
4. Project Cost Management (PCoM)	▪ Planning cost management ▪ Estimating costs, determining budgets & controlling costs	61.9%	38.1%	14.3%	0%	28.6%	42.9%	14.3%	3.43	3rd
5. Project Quality Management (PQM)	▪ Planning quality management, Managing ▪ & controlling quality	33.3%	66.7%	14.3%	0%	57.1%	0%	28.6%	3.29	5th
6. Project Resource Management (PReM)	▪ Planning resource management ▪ Estimating & acquiring activity resources ▪ Develop, manage team & control resources	33.3%	66.7%	14.3%	14.3%	28.6%	28.6%	14.3%	3.14	6th
7. Project Communications Management (PCmM)	▪ Planning communications management ▪ Managing and monitoring communications	33.3%	66.7%	14.3%	28.6%	28.6%	14.3%	14.3%	2.86	8th
8. Project Risk Management (PRiM)	▪ Planning risk management ▪ Identifying risks, performing qualitative & quantitative risk analysis ▪ Plan, implement responses & monitor risks	33.3%	66.7%	28.6%	14.3%	28.6%	14.3%	14.3%	2.71	10th
9. Project Procurement Management (PPM)	▪ Planning procurement management Conduct ▪ & control procurements	33.3%	66.7%	23.8%	28.6%	14.3%	4.8%	28.6%	2.86	8th
10. Project Stakeholder Management (PStM)	▪ Identification of stakeholders ▪ Planning stakeholder engagement ▪ Manage & monitor stakeholder engagement	33.3%	66.7%	19.0%	28.6%	9.5%	14.3%	28.6%	3.05	7th

		OVERALL MEAN WEIGHTED AVERAGE SCORE	**3.17**	

(Source: Field data, 2019)

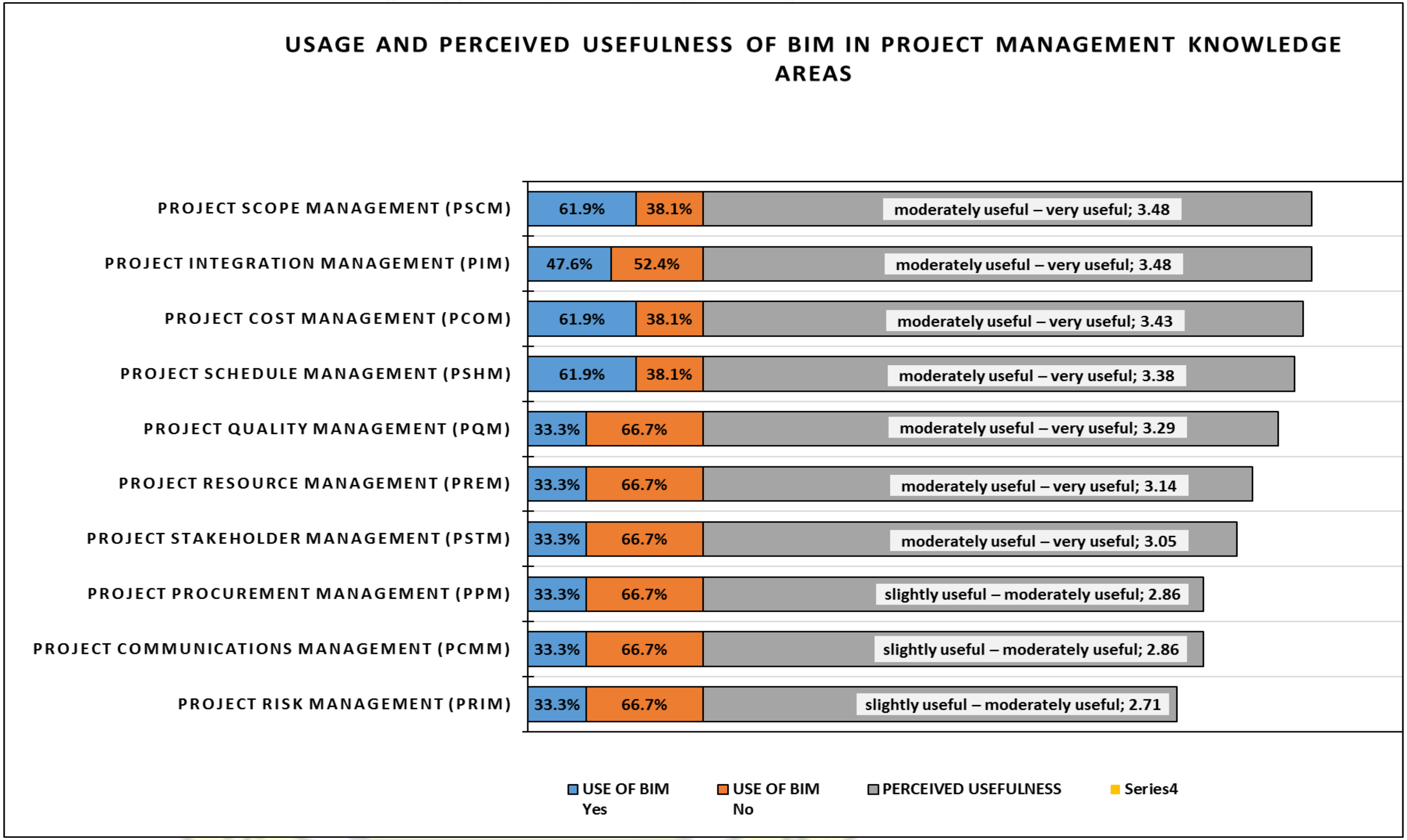

Figure 4.6: Usage and Perceived Usefulness of BIM in Project Management Knowledge Areas

(Source: Field data, 2019)

4.5 Barriers to Adoption of Building Information Modelling (BIM) in Project Management

The final section of the questionnaire, Section C, captured the perceived barriers that the respondents believed were the reasons inhibiting the adoption of Building Information Modelling (BIM) in project management knowledge areas. Respondents rated their level of agreement with some identified categorized barriers to BIM adoption in project management on a scale of 1 – Strongly Disagree to 5 – Strongly Agree.

These scores are then averaged to find the Weighted Average Scores of each barrier. The Weighted Average Scores reveal the respondents' perceived barriers of BIM adoption in project management. The weighted average scores are then finally ranked to determine the perceived barriers that affect the adoption of BIM adoption in project management. These perceived barriers are also ranked within their categories.

Table 4.5 presents a summary of the results.

From the results, three barriers were determined as the top-ranked (1st) barriers that inhibit the adoption of Building Information Modelling (BIM) in project management in the architecture, engineering and construction sector in Ghana based on the weighted rating scores of the respondents. These were *Professionals reluctance to change old work* *practices*, *Lack of trained professionals* and *Cost of BIM technology,* with all of them scoring 4.33. This means that respondents believed strongly that these barriers were the top reasons why BIM adoption in project management was low.

These were followed by *Lack of awareness by project managers*, *Lack of adequate IT infrastructure*, *Cost of BIM training*, L*ack of assured Return on Investment (ROI)* and *Uncertainty in interoperability among BIM technology* lying in the 4th, 5th, 6th, 7th and 8th positions.

Table 4.5: Perceived Barriers to the Adoption of BIM in Project Management

CATEGORY OF BARRIER	PERCEIVED BARRIERS TO BIM ADOPTION IN PROJECT MANAGEMENT ACTIVITIES	LEVEL OF AGREEMENT					WEIGHTED AVERAGE SCORE	OVERALL RANK
		Strongly Disagree (1)	Disagree (2)	Neither Agree nor Disagree (3)	Agree (4)	Strongly Agree (5)		
1. Management Barriers	Lack of awareness by project managers	4.8%	0%	0%	71.4%	23.8%	4.10	4th
	Lack of top-level management support	4.8%	0%	52.4%	19.0%	23.8%	3.57	11th
	Lack of demand from clients	14.3%	14.3%	28.6%	42.9%	0%	3.00	15th
	Lack of supply chain buy-in	28.6%	14.3%	19.0%	38.1%	0%	2.67	16th
2. Financial Barriers	Cost of BIM technology	0%	4.8%	0%	52.4%	42.9%	4.33	1st
	Cost of BIM training	0%	14.3%	14.3%	38.1%	33.3%	3.90	6th
	Lack of assured Return on Investment (ROI)	0%	19%	9.5%	42.9%	28.6%	3.81	7th
3. Technology Barriers	Lack of adequate IT infrastructure	0%	14.3%	4.8%	52.4%	28.6%	3.95	5th
	Uncertainty in interoperability among BIM technology	4.8%	14.3%	9.5%	42.9%	28.6%	3.76	8th
	Other equally competitive innovations	4.8%	14.3%	19.0%	33.3%	28.6%	3.67	9th
4. People Barriers	Lack of trained professionals	0%	0%	4.8%	57.1%	38.1%	4.33	1st
	IT illiteracy among professionals	4.8%	28.6%	9.5%	38.1%	19.0%	3.38	13th
5. Process Barriers	Professionals reluctance to change old work practices	0%	0%	4.8%	57.1%	38.1%	4.33	1st
	BIM not suitable for projects in Ghana	57.1%	19.0%	4.8%	14.3%	4.8%	1.90	17th
6. Legal Barriers	Risks associated with ownership and intellectual property	0%	0%	61.9%	33.3%	4.8%	3.43	12th
	Risks associated with contractual arrangements	0%	0%	47.6%	38.1%	14.3%	3.67	9th
	Risks associated with product authenticity and liability	0%	0%	66.7%	28.6%	4.8%	3.38	13th

(Source: Field data, 2019)

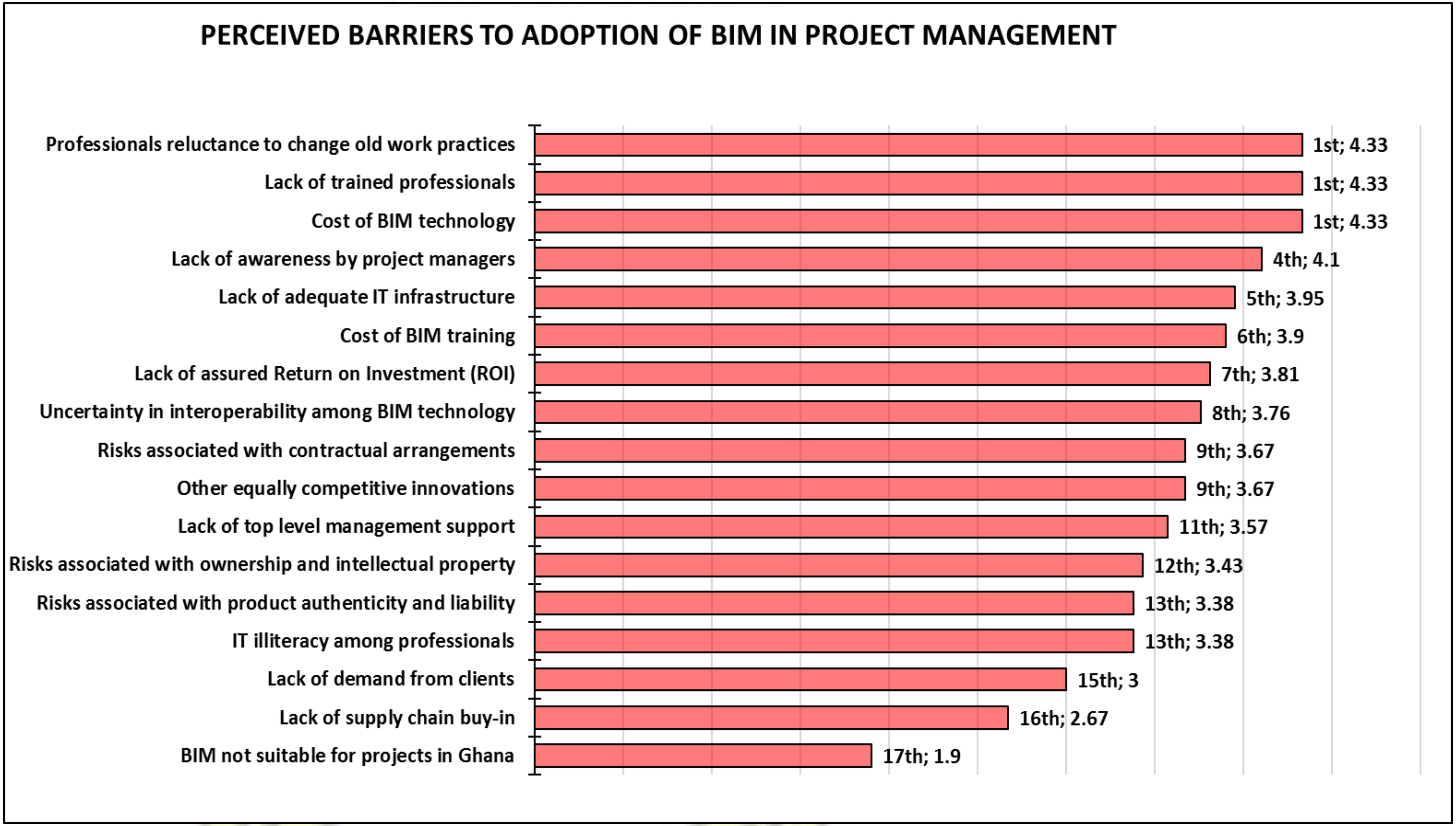
PERCEIVED BARRIERS TO ADOPTION OF BIM IN PROJECT MANAGEMENT
Professionals reluctance to change old work practices
1st; 4.33
Lack of trained professionals
1st; 4.33
Cost of BIM technology
1st; 4.33
Lack of awareness by project managers
4th; 4.1
Lack of adequate IT infrastructure
5th; 3.95
Cost of BIM training
6th; 3.9
Lack of assured Return on Investment (ROI)
7th; 3.81
Uncertainty in interoperability among BIM technology
8th; 3.76
Risks associated with contractual arrangements
9th; 3.67
Other equally competitive innovations
9th; 3.67
Lack of top level management support
11th; 3.57
Risks associated with ownership and intellectual property
12th; 3.43
Risks associated with product authenticity and liability
13th; 3.38
IT illiteracy among professionals
13th; 3.38
Lack of demand from clients
15th; 3
Lack of supply chain buy-in
16th; 2.67
BIM not suitable for projects in Ghana
17th; 1.9

Figure 4.7: Perceived Barriers to the Adoption of BIM in Project Management

(Source: Field data, 2019)

The barriers *Other equally competitive innovations* and *Risks associated with contractual arrangements* both occupied the 9th position. *Lack of top-level management support* was identified as the 11th barrier to the adoption of BIM in project management. Respondents rated the *Risks associated with ownership and intellectual property* barrier as the 12th most important barrier on the list. The barriers *IT illiteracy among professionals* and R*isks associated with product authenticity and liability* shared the 13th place.

At the bottom of the ranking list with the least scores from respondents were the *Lack of demand from clients* barrier, the *Lack of supply chain buy-in* and the *BIM not suitable for projects in Ghana* barrier in the 15th, 16th and 17th positions. This meant that, the respondents believed that issues concerning demand from clients for BIM application in projects, buy-ins from players in the industry supply chain and the notion that BIM was not suitable for projects in Ghana did not prove to be a hindrance to the use and adoption of BIM in project management in the Ghanaian AEC sector.

CHAPTER FIVE

SUMMARY OF FINDINGS, CONCLUSION, AND RECOMMENDATIONS

The chapter is a summary of the findings of the study and the conclusions drawn from them in an attempt to answer the research questions. The chapter also includes the recommendations of the study.

5.1 Summary of Findings

The findings from the study showed that the respondents had between one to ten years of experience in the project management field in the Architecture, Engineering and Construction sector in Ghana. Most of them practiced as general contractors and almost all of them were members of one professional body in the sector. All of the respondents had a tertiary education with more than half of them earning a post-graduate education qualification.

The findings on the respondents' knowledge and expertise in Building Information Modelling (BIM) also revealed that a greater majority of project management practitioners in the AEC sector had an awareness of BIM and a little over half of them had obtained some formal training on BIM. Also, a majority of the respondents who were aware of BIM had actually used BIM in project management between one and 10 years. However, only a small number of them had a level of understanding and expertise in BIM above the average rating, thus a majority of them had below-average understanding and expertise in BIM.

The study again showed that majority of the respondents employed BIM in the Project Scope Management (PScM), Project Cost Management (PCoM) and Project Schedule Management (PShM) knowledge areas of project management. In the rest of the knowledge areas – Project Integration Management (PIM), Project Quality Management

(PQM), Project Resource Management (PReM), Project Stakeholder Management (PStM), Project Communications Management (PCmM), Project Procurement Management (PPM), and Project Risk Management (PRiM) – the use of BIM was low since only a minority of the respondents used BIM.

It was further revealed in the study that respondents perceived the application of BIM in each of the following project management knowledge areas – Project Integration Management (PIM), Project Scope Management (PScM), Project Cost Management (PCoM), Project Schedule Management (PShM), Project Quality Management (PQM), Project Resource Management (PReM) and Project Stakeholder Management (PStM) – to be moderately useful and very useful while in the Project Communications Management (PCmM), Project Procurement Management (PPM) and Project Risk Management (PRiM) knowledge areas, BIM application was perceived to be between slightly useful and moderately useful.

BIM application in and usefulness in Project Integration Management (PIM), Project Scope Management (PScM) were the highest and the lowest was in Project Risk Management (PRiM). Overall, BIM application in project management knowledge areas was perceived to be between moderately useful and very useful.

The study on the other hand ranked the barriers to BIM adoption from the highest barrier to the lowest and revealed that the barriers that hindered the adoption of BIM in project management in the AEC industry in Ghana were – Professionals reluctance to change old work practices, Lack of trained professionals, Cost of BIM technology, Lack of awareness by project managers, Lack of adequate IT infrastructure, Cost of BIM training, Lack of assured Return on Investment (ROI), Uncertainty in interoperability among BIM technology, Other equally competitive innovations, Risks associated with contractual arrangements, Lack of top-level management support, Risks associated with ownership and intellectual property, IT illiteracy among professionals, Risks associated with product authenticity and liability, Lack of demand from clients, Lack of supply chain buy-in, and BIM not suitable for projects in Ghana.

5.2 Conclusion

The objective of this study was to investigate the adoption of Building Information Modelling (BIM) in Project Management in the Architecture, Engineering and Construction sector mainly in the Ashanti region in Ghana. Specifically, the study sought to determine the level of knowledge and expertise of project management practitioners in BIM in the AEC sector; to identify the project management knowledge areas for which BIM is employed, and to determine the barriers that affect the adoption of BIM in project management activities in the AEC sector. Using a questionnaire as the survey instrument, relevant data was obtained from respondents, who were project management practitioners in the sector, and analyzed in an effort to achieve the objectives of the study.

The study showed that the level of knowledge and expertise of project management practitioners in Building Information Modelling (BIM) in the AEC sector mainly in the Ashanti region in Ghana was averagely low even though most of them were aware of BIM.

Moreover, it was identified from the study that there were only three project management knowledge areas for which BIM usage was significantly high among the project management practitioners in the AEC industry. These were the Project Scope Management (PScM), Project Cost Management (PCoM) and Project Schedule Management (PShM) knowledge areas. However, it was realized that overall, BIM application in project management activities was found to be useful. The top five knowledge areas for which practitioners perceived that employing BIM is useful are

Project Integration Management (PIM), Project Scope Management (PScM), Project Cost Management (PCoM), Project Schedule Management (PShM) and Project Quality Management (PQM).

Finally, the study determined that the reluctance of project management practitioners to change their old working practices, the lack of trained professionals and the cost of procuring the BIM technology were the top three barriers that affected the adoption of Building Information Modelling in project management in the architecture, engineering and construction industry. It was also observed that project management practitioners thought that the idea of BIM not being suitable for projects in Ghana was not a major barrier to BIM adoption in the architecture, engineering and construction sector.

5.3 Recommendations

The findings of this study have established vital information about Building Information Modelling adoption in project management activities in the Architecture, Engineering and Construction sector mainly in the Ashanti region. Technological changes such as BIM are rapidly advancing and it will be of great advantage for project management practitioners to leverage the benefits of such technology for project success.

It is therefore recommended that project management practitioners should be encouraged and oriented to embraced new and advanced practices in the architecture, engineering and construction sector instead of opposing it.

It is also recommended that to improve the level of knowledge and expertise of project management practitioners in Building Information Modelling (BIM), regular formal training should be undertaken.

Furthermore, industry players should explore innovative and cost-effective ways of procuring BIM technology.

The study was undertaken with data obtained from respondents mainly in the Ashanti region. It is recommended that further studies should be carried out in other regions in order to get a broader view of the national situation.

REFERENCES

Acquah, R., Eyiah, A. K, & Oteng, D. (2018). Acceptance of Building Information Modelling: A survey of professionals in the construction industry in Ghana. *Journal of Information Technology in Construction (ITcon). 23*, pp. 75-91

Akwaah, G. (2015). *Guideline For Building The Capacity of Contractors for Adoption and Implementation of Building Information Modeling (BIM) In Ghana*. (Doctoral Dissertation).

Autodesk (2019) *What is BIM*. Available at: www.autodesk.com/solutions/bim.

Azhar, S., Carlton, W., Olsen, D., & Ahmad, I. (2011). Building information modelling for sustainable design and LEED rating analysis. *Automation in construction. 20*(2), 217-224.

Azhar, S., Khalfan, M. & Maqsood T., (2012) Building information modelling (BIM): now and beyond. *Australasian Journal of Construction Economics and Building. 12*(4) Pages 15-28.

Barlish, K & Sullivan, K. (2012). How to Measure the Benefits of BIM. *Automation in Construction* 24 (2012) 149-159.

Barlish, K. & Sullivan, K. (2012). How to Measure the Benefits of BIM – A Case Study Approach. *Automation in Construction*, 24**,** 149-159.

Becerik-Gerber, B., and Rice, S. (2010). The Perceived Value of Building Information Modelling in the U.S. Building Industry. *Journal of Information Technology in Construction. 15* pp. 185-201.

Benator, P. E. & Thumann, A. (2003). *Project Management and Leadership Skills for Engineering and Construction Projects*. The Fairmont Press, Inc. Lilburn, Georgia. Marcel Dekker, Inc. New York and Basel.

BIM Task Group. (2011). *A report for the Government Construction Client Group. Building Information Modelling (BIM) Working Party Strategy Paper*.

British Standards Institute. (2010) BS 6079-1:2010: *Project Management – Principles and guidelines for the management of projects*. London: British Standards Institute.

Construction Industry Council (CIC) and the BIM Task Group. (2013). *BIM Protocol*. London: CIC.

CRC Construction Innovation. (2007). *Adopting BIM for facilities management: Solutions for managing the Sydney Opera House*. Cooperative Research Centre for Construction Innovation, Brisbane, Australia.

Dastbaz, M., Gorse, C. & Moncaster, A. (2017). *Building Information Modeling, Building Performance, Design and Smart Construction*. Springer International Publishing.

Doumbouya, L., Gao, G. & Guan, C. (2016). Adoption of Building Information Modeling (BIM) for Constructing Project Effectiveness: The Review of BIM Benefits. *American Journal of Civil Engineering and Architecture. 4*. 74-79

Eastman, C., Teicholz, P. Sacks, R. & Liston, K. (2011). *BIM Handbook: A Guide to Building Information Modelling for Owners, Managers, Designers, Engineers and Contractors.* 2nd edn. New Jersey: John Wiley & Sons, Inc.

Fazli, A., Fathi, S., Enferadi, M. H, Fazli, M. Fathi, B. (2014). Appraising effectiveness of Building Information Management (BIM) in project management. *Procedia Technology 16* 1116 – 1125

Flórez, M., Guevara, J., Ozuna, A. & Vargas, H. (2014). The Process of Implementing Project Management and BIM in The Colombian AEC Industry. *In Proceedings of CIB World Building Congress, Brisbane. (pp.5-9)*

Ford, S., Aouad, G., Kirkham, J., Brandon, P., Brown, F., Child, T., Cooper, G., Oxman, R., Young, B. (1995). An information engineering approach to modelling building design, *Automation in Construction 4*(1), pp. 5-15.

Gayathri, N., Himal, S. J. & Ranadewa, K. A. T. (2013). BIM and future Quantity Surveying practice in Sri Lankan Construction Industry. *The 2nd World Construction Symposium 2013: Socio-Economic sustainability in construction.* 14-15, June 2013, Colombo, Sri Lanka.

Golafshani, N. (2003). Understanding Reliability and Validity in Qualitative Research. *The Qualitative Report. 8*(4). 597-607. http://ww.nova.edu/ssss/QR/QR84/golafshani.pdf

Gu, N. & London, K. (2010). Understanding and facilitating BIM adoption in the AEC industry. *Automation in Construction. 19*(8). pp. 988-999

Hansson, J. (2003). *Total quality management – aspects of implementation and performance: investigations with a focus on small organizations*. Doctoral Thesis. Department of Business Administration and Social Science, Lulea University of Technology, Sweden.

Hewitt, R. J., Hernandez-Jimenez, V., Zazo-Moratalla, A., et al. (2017). Strategies and techniques: A living, changing process. *Developments in Environmental Modelling. 30.* pp.11.48. https://doi.org/10.1016/B978-0-444-63982-0.00002-1

Holme, I. M. & Solvang, B. K. (1991). *Research methodology – Qualitative and quantitative methods*. Studentlitteratur, Lund.

Hox, J. J. & Boeije, H. R. (2005). Data Collection, primary versus secondary. *Encyclopedia of Social measurement*. pp. 593-599.

Javed, S. A., Javed, S. & Said, A. (2015). Assessing the Managerial Perception of Relative Significance of Ten Knowledge Areas on Project Success – A Case from Pakistan. *Journal of Management and Science. Vol.5.* No.3.

Joppe, M. (2000). *The Research Process*. http://www.ryerson.ca/-mjoppe/rp.htm
Kiprotich, C. J. K. (2014). *An Investigation on Building Information Modelling in Project Management: Challenges, Strategies and Prospects in the Gauteng Construction Industry, South Africa*. Unpublished Thesis in Building Department, University of Witwatersrand, Johannesburg.

Lee, A. S. (1991). Integrating positivist and interpretive approaches to organization research. *Organizational Science, 2* (4), 342–365.

Lee, G., Park, H. K. & Won, J. (2012). D3 City Project - Economic Impact of BIMAssisted Design Validation. *Automation in Construction*, 22**,** 577-586.

Lester, A. (2017). *Project Management, Planning and Control: Managing Engineering, Construction and Manufacturing Projects to PMI, APM and BSI Standards.* 7th edn. Butterworth-Heinemann. Oxford OX5 1GB, United Kingdom.

McGraw-Hill Construction (2014) T*he Business Value of BIM for Construction in Major Global Markets: How contractors around the world are driving innovation with Building Information Modeling.* Bedford: McGraw Hill Construction

McPartland, R. (2018) *BIM dimensions - 3D, 4D, 5D, 6D BIM explained*. Available at: https://www.thenbs.com/knowledge/bim-dimensions-3d-4d-5d-6d-bimexplained.

Migilinskas, D., Popov, V., Juocevicius, V. & Ustinovichius, L. (2013). The Benefits, Obstacles and Problems of Practical BIM Implementation. Vilnius Gediminas Technical University, Civil engineering faculty, Saulėtekio al. 11, LT-10223 Vilnius, Lithuania. *Procedia Engineering 57* (2013) 767 – 774

Mingers, J. (2001). Combining IS research methods: Towards a pluralist methodology. *Information Systems Research*. 12, 240–259.

Myers, M. & Tan, F. (2002). Beyond models of national culture in information system research. *Journal of Global Information Management. 10* (1), 24–32.

Nani, G. & Akwaah, G. (2015). *Guidelines for Capacity Building of Construction Firms for Building Information Modelling (BIM) Adoption in Ghana*. Conference Paper: Applied Research Conference in Africa (ARCA).

National Academies of Sciences, Engineering & Medicine. (2018). *Changing Sociocultural Dynamics and Implications for National Security*. Proceedings of a Workshop. Washington, DC: The National Academies Press.

National Institute of Building Sciences-NIBS (2007). Part 1: *Overview, principles and Methodologies*. National Building Information Modelling Standard - Version 1.0.

NBS (2011)a. Briefing: BIM in Construction. UK - January 2011.

NBS (2011)b. Building Information Modelling, Report March 2011.

Olabode, E. O. & Umeh, S. (2018). *Adoption of BIM in the Nigerian Architecture Engineering and Construction (AEC) Industry*. Master's Thesis. School of

Architecture and Built Environment, University of Newcastle, Callaghan 2308, New South Wales, Australia and Construction Nigeria Limited, Yaba, Lagos State, Nigeria.

Patton, M. Q. (2002). *Qualitative evaluation and research methods* (3rd ed.). Thousand Oaks, CA: Sage Publications, Inc.

Philp, D., Swaddle, P. & Mordue, S. (2015). *Building Information Modeling for Dummies*. For Dummies Publishers.

Project Management Institute-PMI (2017). *A guide to the project management body of knowledge* (*PMBOK*) – 6th edn. Newtown Square, PA: Project Management Institute, Inc.

RICS (2015a) *Assessment of Professional Competence: Project Management Pathway Guide*. London: RICS. Available at: http://www.rics.org/Global/20102-RICSAPCPathwayGuide–Projectmanagement-Feb 2015-WEB.pdf

Riese, M. (2009). Update on the Swire Properties Hong Kon One Island East Tower BIM Success Story. *In:* Shen, G. Q., Brandon, P. & Baldwin, A. (eds.) *Collaborative Construction Information Management.* London: Spon Press.

Royal Institute of British Architects (2012) *BIM overlay to the RIBA outline plan of work*. London, RIBA publishing.

Saunders, M., Lewis, P. & Thornhill, A. (2003). *Research methods for business Students*, 3rd ed. Harlow: Pearson Education Ltd.

Saunders, M., Lewis, P. & Thornhill, A. (2007). *Research methods for business students*. 4th Edition.

Sawhney, A. (2017). *Building Information Modelling for Project Managers*. Royal Institution of Chartered Surveyors (RICS).

Seaman, E. A. C. A. (2007). Likert scales and data analyses. *Statistics roundtable*.

Sears, S. K., Sears, G. A. & Clough, R. H. (2008). *Construction Project Management: A Practical Guide to Field Construction Management.* 5th Edition. John Wiley & Sons, Inc.

Seed, L. (2015). The Dynamics of BIM Adoption: A Mixed Methods Study of BIM as an Innovation within the United Kingdom Construction Industry. Doctoral thesis, University of Huddersfield.

Shizhao. D. (2005) *The Introduction Theory on Construction Project* [M]. Beijing: China Architecture & Building Press,

Smart Market Report. (2012). *Business Value of BIM in North America*. McGraw-Hill Construction.

Strauss, A. & Corbin, J. (1990). B*asics of qualitative research: Grounded theory procedures and techniques.* Newbury Park, CA: Sage Publications, Inc.

Succar, B., (2009). Building information modelling framework: a research and delivery foundation for industry stakeholders. *Automation in Construction 18* (3), 357–375.

Taherdoost, H. (2016). Sampling Methods in Research Methodology; How to choose a sampling technique for research. *International Journal of Academic Research in Management. 5.* 18-27. doi: 10.2139/ssrn.3205035.

Telaga, A. S. (2017). Exploitation and Benefits of BIM in Construction Project Management. doi: 10.1088/1757-899X/245/6/062056.

UK Government (2011) *Government Construction Strategy*. Available at: http://www.cabinetoffice.gov.uk/content/major-proj.

Velasco, A. U. (2013). Assessment of 4D BIM applications for project management functions. University of Cantabria, Polytechnic University of Valencia. Master's Thesis.

Yan, H. and Damian, P. (2008) *Benefits and Barriers of Building Information Modelling.* 12th international conference on computing in civil and building engineering, Beijing, China.

Yin, R. K. (1994). *Case study research: Design and methods.* (2nd ed.). Sage Publications, Thousand Oaks, CA.

Yin, R. K. (2003). *Case study research.* (3rd ed.). Sage Publications, London, England.

APPENDIX I

QUESTIONNAIRE

This questionnaire seeks the opinions of project management practitioners in the Architecture, Engineering and Construction (AEC) industry on the adoption of Building Information Modelling (BIM) technology in project management activities. This is an academic exercise and your response is highly appreciated.

The questionnaire is in three (3) parts:

i. The first part, (Section A), looks at the level of knowledge and experience of respondents in Project Management and BIM technology.

ii. Section B addresses the respondents' "Use of BIM" in Project Management Knowledge Areas and their "Perceived Usefulness of BIM" technology application in Project Management Knowledge Areas.

iii. Section C focuses on respondents' perceived barriers to the adoption of BIM in Project Management.

Please read each question carefully and answer them as frankly as you can.
Please circle/tick where appropriate and supply information where necessary.

SECTION A

(Level of knowledge and experience in Project Management and BIM technology)

1. How many years have you been practicing in the field of Project Management?
   a) 5 years or less b) 6–10 years c) 11–15 years d) 16–20 years e) More than 20 years

2. Specify the type of your organization.
   a) General Contractors b) Renovation Contractors c) Real Estate Developers d) Owner-builders

3. Which professional body/bodies do you belong to?
   a) Project Management Institute b) Ghana Institution of Surveyors c)Ghana Institute of Architects
   d) Ghana Institution of Engineering e) Ghana Institution of Construction f) Others

4. Indicate your highest education level?
   a) Post Graduate (PhD/MSc) b) First Degree (BSc/BEng) c) Higher National Diploma (HND)
   d) Construction Technician Certificate e) Advance in Construction Certificate

5. Are you aware of technology known as Building Information Modelling (BIM)?
   a) Yes b) No *(If "No" please end the questionnaire) If "Yes", specify: ………………*

6. Do you have any formal training in any Building Information Modelling (BIM) technology?
   a) Yes b) No *If "Yes", specify:* ……………………………………………………….

7. Do you employ Building Information Modelling (BIM) technology in project management?
   a) Yes b) No *If "Yes", specify: ………………*

8. How long have you been employing BIM in project management?

a) 5 years or less   b) 6–10 years   c) 11–15 years   d) 16–20 years   e) More than 20 years   f) NA

9. How would you rate your level of expertise in the application of Building Information Modelling (BIM) technology? *(on a scale of 0–No Experience to 10–Highest Experience).*

[0 – 1 – 2 – 3 – 4 – 5 – 6 – 7 – 8 – 9 – 10]

SECTION B

(Use of BIM & Perceived Usefulness of BIM in Project Management Knowledge Areas)

Please complete the following by indicating your "Use of BIM and Perceived Usefulness of BIM" in each Project Management Knowledge Area.

KNOWLEDGE AREA (KA)	CONTENT	USE OF BIM		PERCEIVED USEFULNESS OF BIM				
		Yes	No	Least Useful	Slightly Useful	Moderately Useful	Very Useful	Extremely Useful
		(Y)	**(N)**	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**
7. Project Integration Management (PIM)	▪ Project charter & management plan development ▪ Directing, managing, monitoring & control of project work ▪ Performing integrated change control & closing project work	Y	N	1	2	3	4	5
8. Project Scope Management (PScM)	▪ Planning scope management ▪ Collecting requirements & defining scope ▪ Creating work breakdown structure ▪ Validating & controlling scope	Y	N	1	2	3	4	5
9. Project Schedule Management (PShM)	▪ Planning schedule management Defining ▪ & sequencing activities, estimating activity resources & durations ▪ Developing & controlling schedule	Y	N	1	2	3	4	5
10. Project Cost Management (PCoM)	▪ Planning cost management ▪ Estimating costs, determining budgets & controlling costs	Y	N	1	2	3	4	5
11. Project Quality Management (PQM)	▪ Planning quality management, ▪ Managing & controlling quality	Y	N	1	2	3	4	5
12. Project Resource Management (PReM)	▪ Planning resource management ▪ Estimating & acquiring activity resources ▪ Develop, manage team & control resources	Y	N	1	2	3	4	5
13. Project Communications Management (PCmM)	▪ Planning communications management ▪ Managing and monitoring communications	Y	N	1	2	3	4	5

14. Project Risk Management (PRiM)	▪ Planning risk management ▪ Identifying risks, performing qualitative & quantitative risk analysis ▪ Plan, implement responses & monitor risks	Y	N	1	2	3	4	5
15. Project Procurement Management (PPM)	▪ Planning procurement management ▪ Conduct & control procurements	Y	N	1	2	3	4	5
16. Project Stakeholder Management (PStM)	▪ Identification of stakeholders ▪ Planning stakeholder engagement ▪ Manage & monitor stakeholder engagement	Y	N	1	2	3	4	5

SECTION C

(Perceived Barriers to adopting BIM in Project Management Activities)

Please complete the following by indicating your Perceived Barriers to employing BIM in Project Management activities.

- What is your level of agreement with the following perceived barriers to employing BIM in Project Management activities?

CATEGORY OF BARRIER	PERCEIVED BARRIERS TO BIM ADOPTION IN PROJECT MANAGEMENT ACTIVITIES	Strongly Disagree (1)	Disagree (2)	Neither Agree nor Disagree (3)	Agree (4)	Strongly Agree (5)
1. Management Barriers	Lack of awareness by project managers	1	2	3	4	5
	Lack of top level management support	1	2	3	4	5
	Lack of demand from clients	1	2	3	4	5
	Lack of supply chain buy-in	1	2	3	4	5
2. Financial Barriers	Cost of BIM technology	1	2	3	4	5
	Cost of BIM training	1	2	3	4	5
	Lack of assured Return on Investment (ROI)	1	2	3	4	5
3. Technology Barriers	Lack of adequate IT infrastructure	1	2	3	4	5
	Uncertainty in interoperability among BIM technology	1	2	3	4	5
	Other equally competitive innovations	1	2	3	4	5
4. People Barriers	Lack of trained professionals	1	2	3	4	5

	IT illiteracy among professionals	1	2	3	4	5
5. Process Barriers	Professionals reluctance to change old work practices	1	2	3	4	5
	BIM not suitable for projects in Ghana	1	2	3	4	5
6. Legal Barriers	Risks associated with ownership and intellectual property	1	2	3	4	5
	Risks associated with contractual arrangements	1	2	3	4	5
	Risks associated with product authenticity and liability	1	2	3	4	5

Thank you for participating in this survey!