EVALUATION OF BUILDING INFORMATION MODELLING (BIM) ADOPTION, CAPABILITY AND MATURITY WITHIN SOUTH AFRICAN CONSULTING AND CONSTRUCTION FIRMS

By

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A dissertation submitted in fulfilment of the requirements for the Degree of Master of Philosophy (MPhil) in Construction Management

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PREFACE

This dissertation dissertation is submitted to the Department of Construction Economics and Management in the Engineering and the Built Environment Faculty, University of Cape Town, towards the fulfilment of the requirements for the Degree of Master of Philosophy (MPhil) in Construction Management.

DECLARATION

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Kube chosi!

ABSTRACT

The Construction Industry Indicators (CIIs) continue to reflect a steady growth in the level of client dissatisfaction with the performance of contractors and consultants on construction projects whilst firms in the industry battle for survival. In order to survive in the highly competitive construction market, firms within the industry, need a paradigm shift. To move from traditional project delivery methodologies which continue to yield unsatisfactory results to innovative project delivery methods and practices. With the advancements in computational technologies and processes, the industry needs to move towards integrated, collaborative and computable processes, to increase productivity, efficiency, infrastructure value, quality and sustainability, reduce lifecycle costs, lead times and duplications. Building Information Modelling (BIM) is the innovative project delivery method that helps reduce fragmentation and provides opportunities for enhanced collaboration and distributed project development. BIM is slowly gaining momentum in the South African construction industry. Even though there is an abundance of industry discussions and academic literature professing the ability of BIM methodologies to increase productivity, scholars have found that it has not yet been coupled with the availability of useful metrics, knowledge and tools to reliably measure BIM benefits. Few organisations and individuals have been exposed to some BIM tools whilst many still lack thorough understanding of BIM as a project delivery method. To capture the full benefit of BIM methodologies, firms in project networks must coordinate and develop interoperable business practices and procedures. This study assessed the level of BIM adoption, capability and maturity in consulting and construction firms and evaluated if there were differences in the level of adoption, capability and maturity of BIM between consulting and construction firms. The study also evaluated the relationship between level of BIM maturity and project performance of consulting and construction firms. The study found that there is a statistically significant relationship between the level of BIM capability and project performance. Lastly, the study reports on the current perceived benefits of BIM in the South African construction industry.

Keywords: BIM, adoption, maturity, consulting firms, construction firms, technology

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LIST OF ACCRONYMS

AEC	Architectural, Engineering and Construction
AECO	Architectural, Engineering, Construction and Operations
BDS	Building Description Systems
BIM	Building Information Modelling
BPM	Building Product Modelling
CAD	Computer-Aided Design
cidb	Construction Industry Development Board
CII	Construction Industry Indicator
CPD	Continuous Professional Development
DOI	Diffusion of Innovation
GBM	Generic Building Model
GIS	Geographical Information System
GLIDE	Graphical Language for Interactive Design
HD	High Definition
ICMM	Interactive Capability Maturity Model
ICT	Information and Communication Technology
IFC	Industry Foundation Classes
IT	Information Technology
NIBS	National Building Information Modelling Standard
NIST	National Institute of Standards and Technology
NQF	National Qualification Framework
TAM	Technology Acceptance Model
TOE	Technology, Organisation and Environment

LIST OF EQUATIONS

CHAPTER ONE

1 INTRODUCTION

This research evaluates Building Information Modelling (BIM) adoption, capability and maturity within South African consulting and construction firms. The background of the study will look at the emergence of BIM, starting off by highlighting the Construction Industry's inefficiencies (both in consulting and construction) that result in the need for new approaches to project delivery methods. This chapter is divided into the following sections: the introduction of the topic and definitions of key terms used in the research; the background of the study entailing the general statement and context of this research; the problem statement, research question, research aim, hypothesis, objectives and research method are indicated. The limitations to the study are outlined and lastly, the structure of the full dissertation is laid out.

1.1 Background of the study

The construction industry has had numerous drivers of change in order to improve performance as clients report dissatisfaction with the price, quality and delivery of the construction products (Rwelamila, 1996; Egan, 1998; cidb, 2015). In South Africa, the Construction Industry Indicators (CIIs) reflect a steady growth in the level of client dissatisfaction with the performance of contractors and consultants on construction projects (cidb, 2015). The construction industry's drivers of change include but not limited to: a reaction to the increasing competition, locally and globally and by technological innovations, resulting in changes in the way people do business (Tatum, 1991; Mbuthia, 2001; Becerik-Gerber *et al.*, 2011). The evolution in the manner construction business and activities are carried out has led to the development of different project delivery systems (Thompson *et al.*, 1998; Ball, 2014). The introduction of new project delivery systems in construction poses further challenges, as the industry is characterised by highly complex, fragmented and unique combination of business relationships and processes where construction projects are carried out by different firms and in various project phases such as feasibility, design, construction and maintenance. Each phase requiring effective communication of underlying knowledge and coordination between many project participants such as the owner, contractor, designer, consultant, subcontractors and suppliers (Harvey, 2003; Dave and Koskela, 2009; Fellows and Liu, 2012).

Building Information Modelling (BIM) is the innovative project delivery method that helps reduce fragmentation and provides opportunities for enhanced collaboration and distributed project development (Arayici and Aouad, 2010). BIM emerges as a technological and procedural shift within the construction industry and is continuing its proliferation in both industrial and academic circles as the “new [Computer Aided Design] CAD paradigm” (Ibrahim *et al.*, 2004; Succar, 2009). BIM, enabled by Information Technology (IT) is an approach that allows design integrity, virtual prototyping, simulations, distributed access, retrieval and maintenance of computable building data. The advantages of BIM are that it enables the creation of the construction industry’s information value chain by using multiple applications with the ability to directly exchange building information between them and it allows for the use of construction technologies to construct buildings virtually on a computer before commencing the physical construction process (Fadeyi, 2017). According to the Cooperative Research Centre (CRC) Construction Innovation (2007), the key benefit of BIM is its accurate geometrical representation of the parts of a building in an integrated data environment (Azhar, Nadeem, Mok & Leung, 2008). However, related benefits include: faster and more effective processes through sharing and reusing information; better design through rigorous reviews and analysis using simulations and amendments to design; controlled whole-life cycle costs and environmental data; automated assembly as a result of using digital data for fabricating and assembling; enhanced client service through visualization and the use of lifecycle data in facilities management (Smallwood et al, 2012). The application of BIM however requires abstract and conceptual thinking as well as knowledge of the abstract modelling concepts that are commonly used in BIM (Van Nederveen, 2010).

In terms of the formal definition, BIM is a term with manifold definitions within literature and multi-layered applications in industry. Wang *et al.* (2015) , Matthews (2015) and Yalcinkaya and Singh (2015) describe BIM as a shared knowledge resource for information about a facility forming a reliable basis for decisions during its lifecycle from inception to demolition. However, Gu and London (2010) and Yan (2011) place the emphasis on the digital representation of all building information, enabled by Information Technology. Some studies (e.g. Smallwood et al. (2013); Succar (2010) Kassem et al., (2005); Barlish and Sullivan,

(2012) and McGraw Hill (2014)) have noted that BIM is more than the digital representation of building information, contending that it is the interaction of the processes, policies and technologies for planning, designing, constructing and maintaining facilities. Underwood (2009) places the emphasis on the *model* and defines BIM as a model of information about a facility with complete and sufficient information (with detailed properties of components and objects) that can be interpreted directly by computer applications throughout the building life cycle. In all definitions, the biggest commonality in defining BIM is that, it is detailed computable information about a facility in digital accessible format.

According to Dib *et al.* (2012) BIM is multi-dimensional and the 'M' in the abbreviation 'BIM' is sometimes interpreted differently in different contexts: Building Information Modelling, Building Information Model and Building Information Management. Modelling focuses on the process of generating and using information about a building during its whole lifecycle and collaboration across disciplines-efficiency and clash control are aspects that are addressed in this process. The model is the digital presentation of the physical and functional features of a building and is the basis for the above explained process. Management is less commonly known and is about the organisation and control of the business process by using the Building Information Model (buildingSMART 2012; (Isikdag and Zlatanova, 2009). BIM models include both geometric and non-geometric data such as object attributes and specifications. The model has built-in intelligence which allows automated extraction of 2D drawings, documentation and other building information directly from the BIM model. This built-in intelligence also provides constraints that reduce modelling errors and prevent technical flaws in the design, based on the rules encoded in the software (Gu *et al.*, 2010). For this research, BIM is deemed to be Building Information Modelling, all the other variations shall be add-ons on BIM, such as BIM models, BIM management and so forth.

Scholars such as van Merendonk *et al.* (1989) and (Björk, 1992) acknowledge that the concept of modelling building information is not new but has rather evolved. The crucial feature of BIM systems however, is that they enable a much broader, more extensive range of properties to be associated with the objects they support. The properties can be stored in a database and retrieved by other participants using various applications. The object properties include: Physical attributes; Economic attributes; Relationships (to other objects); Behaviour (through parametric properties); Intelligence (rules embodied into objects); Self-awareness (artificial intelligence, enables clash detections alerts and avoidance); Implicit knowledge and embedded knowledge (mesh of human imagination and the computing machine).

BIM technologies are unique when compared to earlier advances in CAD technology because when coupled with integration of work practices among architects, engineers, fabricators, and contractors they are noted to improve project productivity (Taylor, Phillip, Bernstein 2009). BIM technologies are tools that, beyond 3D capabilities, also contain intelligence at object level, which provide support for data integration, analysis, can be used to adjust positioning and proportions using parametric intelligence and where changes could be automatically effected in all integrated model views (Eastman *et al.*, 2011).

The focus of this study is on evaluating the levels of BIM adoption, capability and maturity within South African Consulting and Construction firms. BIM adoption is described as the successful implementation of object-based modelling, tools, workflows and protocols, achieved through well-defined revolutionary stages (i.e., object-based modelling, model-based collaboration, and network-based integration) separated by numerous evolutionary steps by an organization (Succar and Kassem, 2015). BIM adoption is an ongoing process through which an organisation modifies its practices to suit the emerging capabilities offered by the transition to a parametric, information rich, digital method of project delivery (NIST 2007). Akintola *et al.* (2016) posit that for informed adoption and implementation decisions for construction organisations in South Africa, an understanding of the implications of BIM to organisations workflow is required. While, BIM Capability is the basic ability to perform a task or deliver a BIM service or product. BIM capability defines the minimum BIM requirements that need to be reached by teams or organisations to be able to implement or deliver a BIM product or service (Succar, 2010). BIM capability cover many technology, process and policy topics (Succar and Kassem, 2015).

BIM Maturity refers to the quality, repeatability and degree of excellence within a BIM capable environment (Succar, 2010). BIM Maturity benchmarks are performance improvement levels that teams and organisations aspire to and work towards. Organisations that implement BIM must be able to measure BIM performance (Coates *et al.*, 2010; Sebastian and van Berlo, 2010; Azzouz *et al.*, 2015). BIM project performance is closely related to maturity in that, the BIM maturity level of an organisation or a project network will influence the performance of the project (Sebastian and van Berlo, 2010; Succar, 2010). In general, the progression from low to higher levels of maturity indicate (i) better control through minimising variations between performance targets and actual results, (ii) better predictability and forecasting by lowering variability in competency, performance and costs, and (iii) greater effectiveness in reaching defined goals and setting new more ambitious ones (Lockamy III and McCormack, 2004; McCormack, Ladeira and Oliveira, 2008; Succar, 2009a). There are a number of BIM-specific maturity frameworks developed (Dib *et al.*, 2012; Giel *et al.*, 2012; Mom and Hsieh, 2012) and these is discussed later in the dissertation.

1.2 Justification of the study

The construction industry plays a significant role in the economy of a country and has the responsibility of creating, defining and maintaining the built environment (cidb, 2004; Cain, 2003; Morton, 2002; Ganesan, 2000; Ofori, 1988). For an industry with a crucial role to play in the socio-economy of the country (Kajimo-Shakantu, 2007), it is prone to challenges in the delivery of construction projects. These include the inevitable changes during the design and construction of projects. These changes are caused by various factors and could be client, design, contractor, external or project related. The impact of these changes on construction projects could affect time, cost, quality, risk and productivity. The consequences of these effects may include time and cost overruns resulting from rework, revision of work, disputes, claims and increased risk from coordination failures. The success of a construction project, to a large extent, is determined by the ability of the project team to manage the inevitable changes during project delivery (Sun and Meng, 2009). Design changes and outstanding information are ranked in the top three causes of delays and disruptions to construction projects (Kikwasi, 2013). Causes of delays and disruptions on construction projects attributed to the design firms include: mistakes and discrepancies in design documents; delays in producing design documents; unclear and inadequate details in drawings; complexity of project design; insufficient data collection and survey before design; misunderstanding of owners requirements; inadequate design-team experience and minimal-to-no-usage of advanced design software (Sun and Meng, 2009; Baloyi and Bekker, 2011; Kikwasi, 2013; Ahady *et al.*, 2017). There is a proclivity for contractors to be supplied with incomplete, conflicting and erroneous documents (Tilley and Barton, 1997). Each firm may rely upon external services, subcontracting and outsourcing. This may lead to timing and technical content communication-transfer problems. Added to this, each project is unique in its construction type, location and project participants (Peansupap and Walker, 2006).

A growing number of design, engineering and construction firms have made attempts to adopt BIM to enhance their services and products. However, there remain many uncertainties in the implementation strategies and actual performance (Sebastian & Berlo, 2010). The transition to BIM has reinforced the need for organisations to assess their performance such as evaluating benefits and impact of BIM, measuring capability and maturity and evaluating return on investment. An exploratory study conducted in South Africa (Smallwood, Emuze, & Allen, 2012: 144-145) found that there is limited use of BIM in South Africa. The realisation of the increased functionality and productivity associated with BIM tools requires firms to successfully adopt and implement the associated technologies. However, it has been shown that consulting and construction firms are adopting BIM tools slowly when compared to earlier adoption of 2D CAD (Whyte *et al.*, 1999; Whyte *et al.*, 2002)

The abundance of industry discussions and academic literature professing the ability of BIM methodologies to increase productivity has not yet been coupled with the availability of metrics and knowledge tools to reliably measure BIM benefits (Sebastian and van Berlo, 2010; Won *et al.*, 2013; Won and Lee, 2016). Also, organisations attempting to generate new or enhance existing BIM deliverables can find little guidance towards identifying and prioritizing their respective requirements (Won *et al.*, 2013). The level and quality of BIM implementation varies radically across organisations within the construction industry and the development of BIM performance metrics is a pre-requisite for BIM performance improvement. Without metrics, teams and organisations are unable to consistently measure their own successes or failures. Without measurement, no meaningful performance improvements may be achieved, financial investments may be misplaced and much efficiency may be lost.

Bernstein and Pittman (2004) posit that the construction industry would benefit from a clear set of guidelines outlining an effective strategy and methodology of implementing BIM at the organisational level. Available studies in market-scale BIM implementation and diffusion are dominated by survey ratings generated by commercially-driven service providers. The most prominent of these include BIM diffusion in the UK, France and Germany (Construction, 2010); Autodesk software uptake in Europe (Autodesk, 2011); BIM diffusion in the U.S. and Canada (Construction, 2012b) ; BIM diffusion in the UK (NBS, 2013) (NBS, 2014); and The Business Value of BIM in Australia and New Zealand (Construction, 2014). While these reports include useful information, they suffer from a number of shortcomings – they: have unknown, remedial or biased population sampling and data collection methodologies; do not differentiate between software acquisitions and actual adoption (Fichman and Kemerer, 1999); mostly neglect non-software aspects of BIM adoption; are neither based on an existing conceptual framework, nor propose a new one; do not identify market gaps or reflect market-specific criteria; and cannot be used by policy makers to facilitate BIM diffusion. This study will use objective measures in evaluating BIM adoption, capability and maturity within consulting and construction firms. Consulting and construction firms are targeting specifically in this study for the major role they play in project delivery. Consulting firms being responsible for the blueprint which construction firms use for the delivery and benchmark for performance. The amount of information transfer and management that takes place between consulting and construction firms raises concerns when it is the same firms that (Whyte *et al.*, 1999; Whyte *et al.*, 2002) observed to not adapt to technological advancement that would yield better performance at institutional and project level.

1.3 Problem statement

The shift to the BIM project delivery method requires changes in the manner construction businesses function within the project delivery process. Currently, there are no industry adopted measures of BIM assessment and performance for BIM adoption, capability and maturity within the South African construction industry and as such, there is no collection of best practice or guidelines for effective strategies of implementing BIM successfully.The problem statement is:

Consulting and construction firms in the South African construction industry continue using traditional methods to deliver construction projects even though these methods continue to yield poor results.

Construction projects record poor performance with time and cost overruns. A major cause of this problem is that the project environment is fragmented and uncollaborative. A possible solution to this problem is the use of BIM. However, there is limited research in the context of South Africa that evaluates BIM adoption, capability and maturity within the industry towards the development of an objective performance framework that can be used in BIM performance assessment.

1.4 Research question

The research question to be addressed by this study may be stated as:
What is the extent and level of BIM adoption, capability and maturity within South African consulting and construction firms and how do these differ?

1.5 Research aim

The intended aim of this research is to:
The aim of the study is to evaluate whether the extent of BIM usage differs between consulting and construction firms.

1.6 Research hypothesis

The research hypotheses to be tested in this study are as follows:
H_1: *There is a significant difference in the level of adoption, capability and maturity of BIM between consulting and construction firms*

H_2: *There is a significant relationship between BIM maturity levels and project performance of consulting and construction firms.*

1.7 Research objectives

The research objectives of this study to be achieved are to:

a) *Assess the level of BIM adoption, capability and maturity in consulting and construction firms*
b) *Assess if there is any difference in the level of adoption, capability and maturity of BIM between consulting and construction firms*
c) *Evaluate if there is any relationship between level of BIM maturity and project performance of consulting and construction firms*
d) *Establish perceived benefits of BIM in the South African construction industry*

1.8 Research method

To achieve the previously mentioned objectives, the study will follow a sequential mixed method research approach of quantitative and qualitative methods. The research employs a systematic review of literature in identifying the construction industry inefficiencies; methods of construction project delivery; existing BIM performance assessment measures around the globe and current levels of BIM adoption, capability and maturity. Literature on the impact and benefits of BIM is also reviewed. For the development of a theoretical framework for the study, existing theories aligned to the study are reviewed and synthesised. The methods of data collection employed in the study are: Online-questionnaires; Face-to-face interviews. The data was analysed using descriptive and inferential statistics. Thereafter, the results obtained were discussed and appropriate conclusions and recommendations were made.

1.9 Scope of the study

The scope of the study is limited to the all practitioners working in consulting and construction firms in South Africa. Consulting firms in this study refers to all the consulting organisations or professional individuals who are core in the conceptual, design and development phase of construction projects. The practitioners within the traditional design and development stage include the various architects, engineers, project managers and or principal agents, health and safety consultants, and cost consultants. The construction firms are represented by all construction professionals operating in the physical erection of buildings and infrastructure.

1.10 Structure of the dissertation

This dissertation is structured as follows:

Chapter 1 Introduction

This chapter provides in-depth opening statements for the research, it provides an overview and background of the research topic, highlighting the problem of construction project performance. It encompasses the plan of what the study intends to do and how it is going to achieve the aim and objectives mentioned.

Chapter 2 Literature review

This chapter presents a review of the literature pertinent to BIM innovation in construction, BIM adoption, barriers to BIM adoption, perceived benefits of BIM and BIM performance assessments. A conceptual framework is developed from the literature to elucidate the relationship levels of BIM adoption and performance.

Chapter 3 Research Methodology

In this chapter, the methodologies used in the works cited in literature review are reviewed and justified for this study. The method and procedure for administering the questionnaire and conducting the interviews, methods of data collection and analyses are highlighted. The various statistical methods are discussed.

Chapter 4 Data analysis, research results, findings and discussions

This chapter comprises the analysis and interpretation of the questionnaire survey data, together with a discussion of the findings by critically discussing the findings in relation to the research objectives and previous research.

Chapter 5 Conclusions and recommendations

This is the final chapter that presents the implications of the research findings. It also outlines recommendations deemed relevant for practice, society and theory. Proposals for future research are also outlined.

References and appendices

A full list of References used on the research report and Appendices containing the research instruments utilised are also outlined at the end of the dissertation.

CHAPTER TWO

2 REVIEW OF RELATED LITERATURE

This section reviews relevant related literature to the study area towards understanding the interrelationships between theories, knowledge base of subjects. The intention of this section is to determine the extent of work done on the research topic to assist in obtaining a guide in fulfilling the research objectives; identify any gaps in the related existing body of knowledge; and to further look for particular research methodologies that have been applied in similar studies, which are discussed in the following chapter. This chapter firstly reviews the construction industry and existing construction project delivery methods and performance. Relevant literature is then reviewed on BIM adoption, capability and maturity. Furthermore, this chapter examines the theoretical framework shaping the study and develops a synthesised conceptual framework for the research.

2.1 Review of construction project delivery and performance

The design phase of a construction project presents the best opportunity to influence cost and the sustainability of the whole life cycle of a building. This makes targeting the design stage very important for incorporating building performance issues (Herath *et al.*, 2018). The current practice with 2D CAD tools brings about some inefficiencies such as timescales, deadline pressures, duplications, lengthy lead times, lack of continuity in the supply chain, over processing, reworking, overproduction, distractive parallel tasks, lack of reliability of data and plan predictability, lack of rigorous design process, lack of effective design management and communication. These inefficiencies then feed onto the construction stage of a project (Minato, 2003; Shane *et al.*, 2009; Yang and Wei, 2010; Doloi, 2012). Information exchange in construction project delivery continues to be a challenge due to the fragmented structure of the industry (Baldwin *et al.*, 1999; Dave and Koskela, 2009). Bernstein and Pittman (2004) explain that the building industry has adopted the non-computable data approach to documenting building designs and information over the past 20 years. CAD tools have been primarily used to create electronic drawings of buildings. In these drawings, buildings are depicted by abstract graphical representations such as lines, arcs, circles, and polygons. These representations are meaningful when read by humans but contain little information that can be used for purposes other than of plotting a drawing. Even the 3D models used for visualization purposes are little more than three-dimensional drawings. In most of these applications, the computer has no implicit knowledge of building elements such as doors, walls, windows, roofs, HVAC equipment, furnishings, and columns. These are represented by graphical elements that, at best, are tagged with a label indicating their type. Further, complex systems such as structural grids, HVAC networks, and plumbing, are represented by graphical elements and their fundamental relationships, topology, and functions are unknown to the computer. Design information that flows through the building process for most buildings is documented using pictorial data, not computable information (Bernstein and Pittman, 2004).

In light of the above challenges within the construction industry, there is a need for a paradigm shift, to move from non-computable data, towards integrated, collaborative and computable processes, to increase productivity, efficiency, infrastructure value, quality and sustainability- reduce lifecycle costs, lead times and duplications (Egan, 1998; Dlungwana *et al.*, 2002; Becerik-Gerber and Kensek, 2009; Arayici *et al.*, 2011). In order to survive, firms within the industry will have to adopt an appropriate culture, systems and tools. To achieve performance excellence, they will need the support of all other stakeholders to work with, exchange and collaborate with computable construction project data.

In addition, the Integrated Project Delivery (IPD) system acknowledges that more actors than the traditional design team possess knowledge that is important for the design of construction work. Consequently, constructors (contractors) and trade constructors (subcontractors) are involved from early stages. Therefore, tasks that are traditionally performed later in the course of design and planning construction, such as procurement, work planning and estimation, become parallel tasks with the design. The traditional gates are minimised and communication occurs continuously. IPD as a collaborative approach can result in poor information flow and redundancy within the construction industry (Gallaher *et al.*, 2004; Sun *et al.*, 2015), thus collaborative work using innovative integrated Information Communication Technology systems in construction has to be a reality (Arayici and Aouad, 2010). This leads to the focus of this research on BIM.

2.2 Overview of BIM evolution in the construction industry

2.2.1 BIM Evolution

One of the earliest trace of BIM in construction is from Eastman's 1975 paper on the use of computers in building design, where he discussed the idea of parametric design and deriving 2D drawings from models. BIM related technologies, applications and processes have since evolved to improve the efficiencies of BIM systems (Eastman, 1975; Latiffi *et al.*, 2014). Figure 2-1 presents BIM evolution from the year 1970 to date. In 1975, Building Description Systems (BDS) was developed as a design application and the use thereof was limited to certain elements in building. The Graphical Language for Interactive Design (GLIDE) was then introduced in 1977, which offered a platform to visualise and make estimations from the design. The accuracy of the design produced by GLIDE was more reliable. However, the application of BDS and GLIDE was only limited to design stage in the pre-construction phase. In 1989, Building Product Model (BPM) had been introduced to replace BDS and GLIDE. BPM could be expanded to construction phase where it focused on design, estimation and construction process. BPM also had the functionality to translate information regarding the projects and make relationship between the activities in construction life cycle such as earthworks, structural works, architectural works and infrastructures. The data in BPM was used in making significant changes in the project delivery process. However, BPM was only concentrated on the communication of the product information. In 1995, the Generic Building Model (GBM) was introduced, GBM used the concept of BPM to improve the integration of information with construction activities . Until 2000, BIM had been introduced to overcome the complexity of construction projects, which involves the collaboration of construction players throughout the construction projects phases (Latiffi *et al.*, 2014).

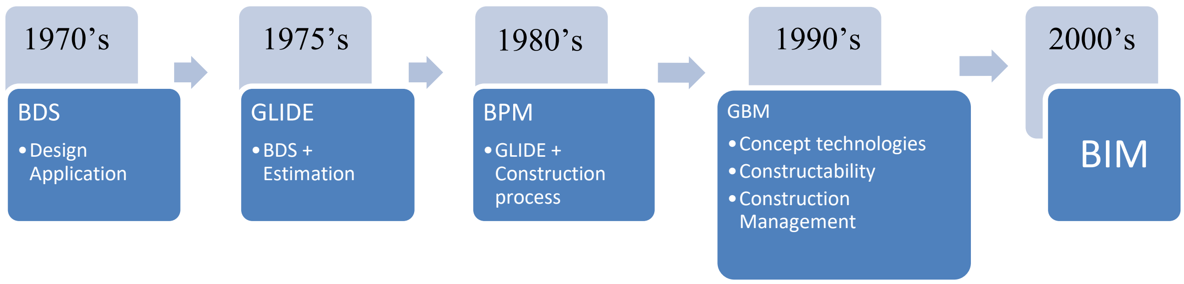

Figure 2-1 Evolution of BIM adapted from Latiffi et al. (2014)

Van Nederveen and Tolman (1992) in their paper on Modelling Multiple views on buildings also contributed to concepts such as product modelling and aspect models, where they evaluated multiple views of a building facility that can also be modelled using simplified models. The concept of these models was to show how building information can be modelled in various views and with different layers of information.

The evolution of BIM is better understood in categories of dimensions: 2D(pre-BIM), 3D, 4D, 5D, 6D and 7D (Cerovsek, 2011). 3D involves design models and space programming tools, that is the use of spatial dimensions of width, length and depth to represent a model, which enables 3D visualisations and walkthroughs, clash detection and coordination, and item scheduling. 4D – is 3D plus "time" and refers to the ability to link the individual 3D parts or assemblies with the project delivery timeline, including the scheduling of resources and quantities, and modular prefabrication to assist tracking and project phasing. In addition to collaboration, 4D visualisations of the model function as communication tools to reveal potential bottlenecks, and used onsite for verification, guidance and tracking of construction activities. 5D – is 4D plus "cost" and allows for the integration of design with estimating, and scheduling and costing, including the generation of material quantities and the application of productivity rates and labour costs. 6D provides the information needed to use the model in asset operation, which includes specification, maintenance schedules and FM information, taking the asset right through to remodel or disposal. While 7D specifies information needed to use the model for sustainability assessments, green building, environmental impact assessments and nD – undefined Dimension symbolises future dimensions of BIM

BIM technology in construction falls under the broad view of innovation . Innovation in the construction industry is defined as the use of a significant alteration and enhancement in a process, product, or system that is new and original to the institution developing the change (Slaughter, 1998). This broad view incorporates governments, building materials suppliers, designers, general contractors, specialist contractors, the labour workforce, owners, professional associations, private capital providers, end users of public infrastructure, vendors and distributors, testing services companies, educational institutions, certification bodies as BIM is both a technical and an organisational innovation. The following section on BIM adoption will expand on these two concepts of technological and organisational interface of BIM.

2.3 BIM Adoption

BIM adoption is described as the successful implementation of BIM technologies, processes and policies (Succar and Kassem, 2015). BIM adoption involves tools that support and partly automate existing processes and practices within consulting and construction firms (Davies and Harty, 2013). Scholars from developing countries have argued for how construction management could all benefit from increased BIM adoption (Bui *et al.*, 2016) as BIM models are far more time and cost effective than manual calculations, and are accurate as well (Bernstein *et al.*, 2010). According to Mihindu and Arayici (2008) owners request that architects and other design professionals, construction managers and construction companies adopt BIM in Integrated design processes. Integrated design process facilitates higher building performance by bringing major issues and participants into the project early in the design process (Bernstein and Dreamer, 2012). The BIM tools provide a platform from which all project stakeholders can actively engage in analysing a best case solution and enable highly sustainable, efficient outcomes through energy simulation and prefabrication (Bernstein *et al.*, 2010).

(Bernstein and Pittman, 2004) argue that it is both unhealthy and unlikely that any one BIM system would provide all of the capabilities necessary to address and solve the diversity and breadth of design and analysis problems in the building industry, as discussed earlier under Section 2.1. BIM adoption involves the use of a wide range of applications for various purposes that form a part of the BIM project delivery approach, ranging from application and software suites to very specific tools for design, analysis and product libraries. The introduction of BIM based tools to support the work of construction management organisations is a problematic task in practice and many researchers have tried to address the problem by trying to explain why and how implementations were successful or unsuccessful (Hartmann *et al.*, 2012).

A number of academic investigations covering market-scale BIM adoption have been conducted in recent years. These studies covered multiple countries including: Australia (Gu & London, 2010); China (Cao, Li, & Wang, 2014); Finland (Lehtinen, 2010); Iceland (Kjartansdóttir, 2011); India (Luthra, 2010); South Africa (Froise & Shakantu, 2014); Sweden (Samuelson & Björk, 2013); Taiwan (Mom, Tsai, & Hsieh, 2011); United Kingdom

(Khosrowshahi & Arayici, 2012); United States (Gilligan & Kunz, 2007) (Liu, Issa, & Olbina, 2010), and multiple markets (Smith, 2014) (Panuwatwanich & Peansupap, 2013) (Wong, Wong, & Nadeem, 2010) (Zahrizan, Ali, Haron, MarshallPonting, & Abd, 2013). However, while these studies provide more rigorous information than industry reports, and contribute valuable insights into BIM diffusion trends and paths, they offer little practical assistance to policy makers intent on assessing current or developing new market-specific BIM diffusion policy.

Arayici *et al.* (2011) argue that BIM adoption studies follow the socio-technical view, in that BIM studies not only consider the implementation of the technology but also considers the socio-cultural environment that provides the context for its implementation. The socio-technical system as illustrated in Figure 2-2 by Oosthuizen and Pretorius (2016), is composed of the social and technical systems. The social system side is made up of people (cognitive and social) and the organisation (structure). The technical system side consists of the physical (hardware, tools, software, facilities, infrastructure) and the non-physical (task, processes, networks). Individuals contribute in the decision process and organisations follow their procedures. Both individual and organisational factors are considered for BIM adoption prediction (Hong *et al.*, 2016; Tan *et al.*, 2017). Mom and Hsieh (2012))Mom and Hsieh (2012))Mom and Hsieh (2012))Mom and Hsieh (2012))Mom and Hsieh (2012))Mom and Hsieh (2012)) developed a BIM specific BIM implementation model at corporate level.

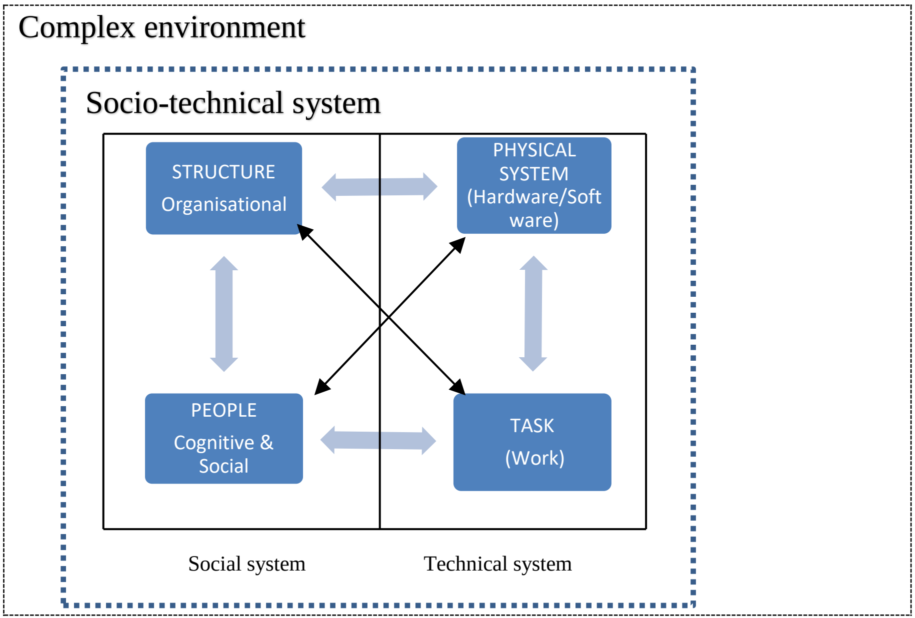

Figure 2-2 Socio-Technical System (Oosthuizen and Pretorius, 2016)

Mom and Hsieh (2012) developed a visualised BIM implementation model at corporate level. BIM concepts, where BIM technology and BIM value are seen as interactive factors outside the system core organisational factors of structure, people, process and culture, as shown in Figure 2-3. The BIM unit interacts with the internal divisions of a company and is constrained by the business environment. It is directly impacted by the BIM technology deployed, and in turn creates BIM value in the form of tangible and intellectual (intangible) capital (Mom and Hsieh, 2012).

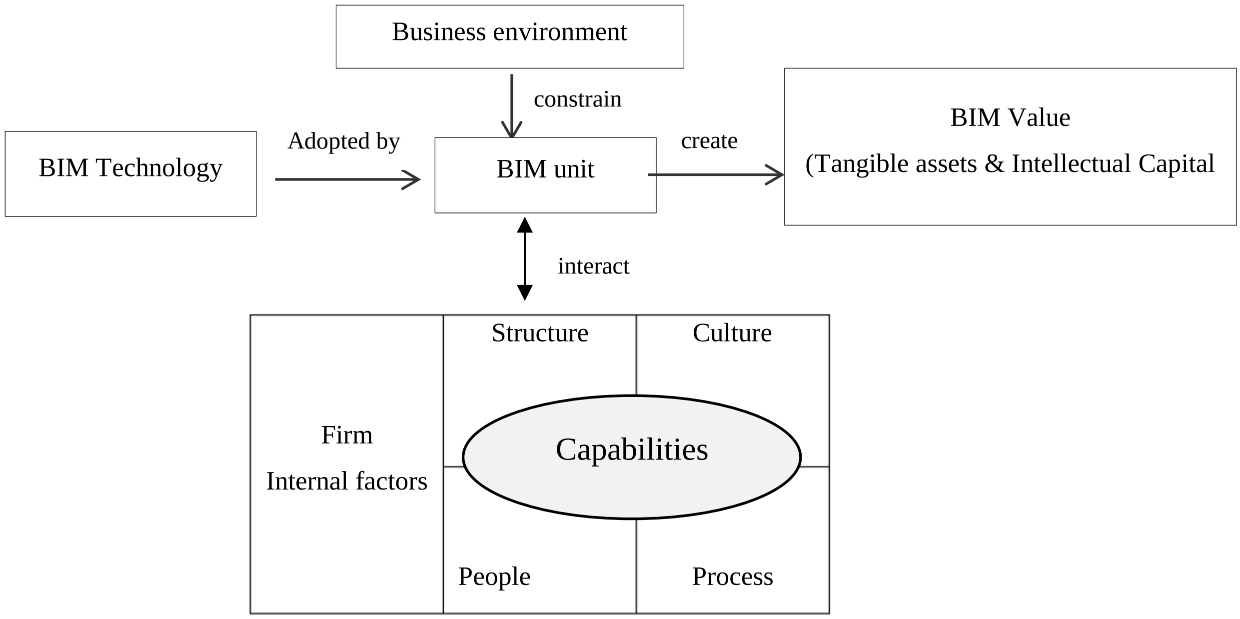

Figure 2-3 BIM Implementation at corporate level (Mom & Hsieh, 2012)

BIM adoption studies are also aligned with innovation diffusion theories (Froise and Shakantu, 2014; Jung and Lee, 2015; Hosseini *et al.*, 2016). Everett (1995) defines diffusion as the process when an innovation is shared through networks amongst the members of a social system. The diffusion of innovation is a theory of how, why and at what rate new ideas and technology spread through cultures at individual and firm level (Rogers and Shoemaker, 1971). The Diffusion of Innovation (DOI) theory at firm level (Rogers, 1995) states that innovativeness is related to independent variables such as individual leader characteristics, internal organisational structural characteristics and external characteristics of the organisation as shown in Figure 2-4 Diffusion of innovations (Rogers, 1995). There is inter-firm (number of firms using or owning a technology) diffusion and intra-firm diffusion intensive use of the technology by the firm. Diffusion is also identified as the third and final phase of the well-noted Schumpeterian Trilogy: "invention (the generation of new ideas), innovation (the development of those ideas through to the first marketing or use of a technology) and diffusion (the spread of new technology across its potential market)" (Stoneman and Diederen, 1994). Diffusion of innovation is a function of the organisations': competitive advantage, process problems, technological opportunity, and institutional requirements, rather than of the technology itself (Mitropoulos and Tatum, 2000; Read, 2000).

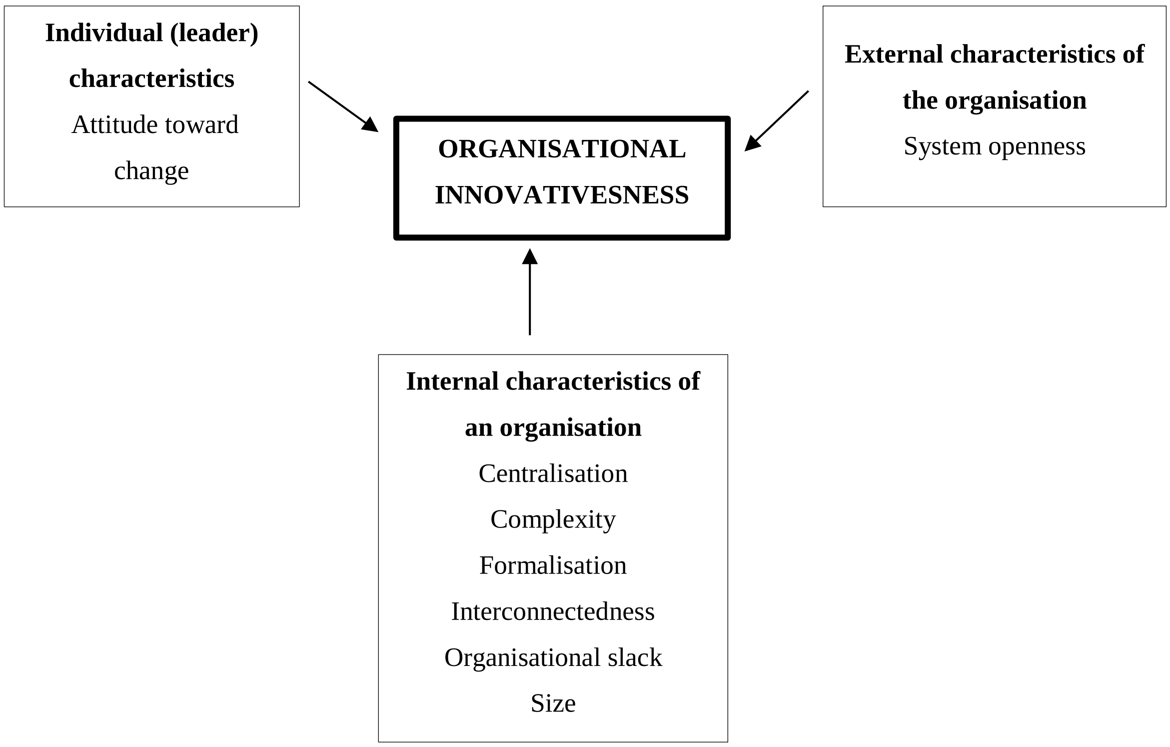

Figure 2-4 Diffusion of innovations (Rogers, 1995)

As BIM adoption increases and the development of BIM processes and technology continues to evolve, the level and quality of its implementation varies radically across organisations within the construction industry (Giel *et al.*, 2012). The ability to realise increasing functionality and productivity from BIM tools is dependent on firms successfully adopting and implementing BIM associated technologies. However, it has been shown that consulting and construction firms are adopting BIM tools slowly when compared to earlier adoption of 2D CAD (Whyte *et al.*, 1999; Whyte *et al.*, 2002). The status of BIM adoption in Africa is found to be in the "beginner phase" (Jung and Lee, 2015) and BIM adoption continues to be low in developing countries (Bui *et al.*, 2016). A study by Froise (2014) showed that only 12% of contractors had used some form of BIM in South Africa, which contrasts sharply with BIM adoption in the USA, where more than 74% of contractors had adopted BIM (Construction, 2012a) . Studies of BIM adoption in developing countries revealed that coercive or "authoritative pressures" have a great impact on the attitudes of clients/owners towards BIM adoption, while architects and contractors are mostly motivated by mimetic pressures seeking to imitate "successful conduct" of others (Cao *et al.*, 2014; Bui *et al.*, 2016).

Attaining governmental support is crucial for BIM adoption, this has proven effective in the United States of America, United Kingdom and Norway (Eadie *et al.*, 2013; Ganah and John, 2014) . The US government assisted in the development of BIM implementation standards and creating BIM awareness (Broils, 2014). The UK government has also set a mandatory Level 2 BIM requirement for firms to adopt BIM for all public sector procured construction projects (Department for Business, Innovation & Skills, 2012). The USA is amongst the earliest adopters of BIM (Becerik-Gerber and Rice, 2010; Azhar *et al.*, 2015; Lee and Yu, 2015) and this was achieved through governments mandate for the implementation of BIM in infrastructure spending. Hong Kong Housing Authority has mandated BIM on all new projects since 2024, South Korea has mandated BIM on projects over SKW50million (about ZAR607,000.00), since 2016 (Månsson and Lindahl, 2016). Singapore developed and e-submission system that requires the submission of building models for the use by planning authorities (Shen *et al.*, 2016)

Table 2-1 lists BIM technologies commonly used in the design and construction phase of project delivery as reviewed from literature. Design phase mainly uses 3D functionalities while construction adds on and builds 4D and 5D functionalities and information into building models.

Table 2-1 Review of BIM technologies

Technology	Use/Benefit	Reference
RFID/Laser Tagging/ bar coding/Sensors	to track plant, material, equipment, labour; for progress and quality purposes	(Matthews *et al.*, 2015) (Bosché *et al.*, 2015; Park *et al.*, 2017)
Time Lapse Camera's	real-time monitoring	(Matthews *et al.*, 2015)
Tablet personal computers (PCs), smart phones and personal digital assistants (PDAs)	real-time monitoring	(Matthews *et al.*, 2015)
ArchiCAD/AutoDesk Revit/Bentley	3D Design tool	(Matthews *et al.*, 2015)
Augmented Reality (AR)	Simulations	(Matthews *et al.*, 2015)
Cloud-based computing	real-time collaboration	(Bosché *et al.*, 2015; Matthews *et al.*, 2015)
Laser scanners	Scan-to-BIM	(Bosché *et al.*, 2015)

Some of the BIM technologies currently in use are listed in Table 2-1 and these include technologies for tracking plant, materials, equipment, labour and also allow for the generation of reports for progress updates. Tools such as time lapse camera's and personal digital assistance allow for real-time monitoring. Cloud-based applications allow for real-time collaboration and laser scanners allow for Scan-to-BIM where scanned objects are modelled by software's into building models. The real time are used when updating a BIM models construction progresses, the design team and contractor can monitor actual against planned performance in real-time. As a result, strategies can be developed to improve workflows and mitigate rework and delays. In addressing this issue, the effectiveness of cloud-based BIM for real-time progress management

2.4 Review of BIM performance assessment measures

2.4.1 BIM Capability

BIM Capability is the basic ability to perform a task or deliver a BIM service or product . BIM capability defines the minimum BIM requirements that need to be reached by teams or organisations to be able to implement or deliver a BIM product or service (Succar, 2010). BIM capability cover many technology, process and policy topics, as shown in Figure 2-5 on

BIM fields (Succar and Kassem, 2015). BIM Fields are conceptual clusters of domain players interacting and overlapping within the design, construction and operations industry (Succar, 2009). Where Technology sets include software, hardware and networks, Process sets include leadership, infrastructure, Human Resources and products/services and Policy sets include contracts, regulations and research/education

Figure 2-5 BIM adoption fields (Succar, 2015)

Figure 2-6 BIM capability stages (Succar, 2010) shows BIM stages, which are a measure of BIM capabilities. Succar (2013) proposed the following stages: Pre-BIM: the status of the construction industry before the introduction/innovation and use of BIM**;** Stage 1 – Object-based modelling; Stage 2 – Model-based collaboration; Stage 3 – Network-based integration; and Post-BIM: Virtually integrated construction industry.

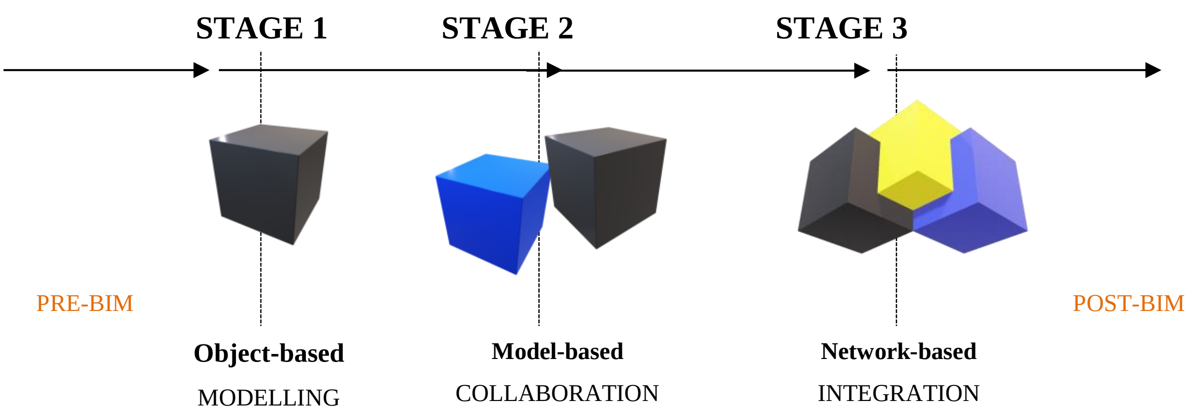

Figure 2-6 BIM capability stages (Succar, 2010)

BIM Stages are defined by their minimum requirements (Succar, 2010) where:

1. BIM Capability Stage 1, an organisation needs object-based modelling software tool (similar to ArchiCAD, Revit, Tekla or Constructor)
2. BIM Capability Stage 2, an organisation needs to be part of a multidisciplinary 'model-based' collaborative project.
3. BIM Capability Stage 3, an organisation needs to be using a network-based solution (like model servers).

What differentiates stages from steps is that stages are transformational while steps are incremental (Henderson and Clark, 1990; Taylor and Levitt, 2005). The collection of steps required when working towards or within a BIM Stage - across the continuum from pre-BIM to post-BIM - is driven by different prerequisites for, challenges within and deliverables of each BIM Stage. In addition to their type in the form of the competency set they belong to, BIM Steps can be also identified according to their location on the continuum. As this study is focusing at firm level, BIM capability describes and defines what an organisation is able to do based on its organisational competence(Månsson and Lindahl, 2016).

2.4.2 BIM Maturity

BIM Maturity refers to the quality, repeatability and degree of excellence within a BIM Capable (and adopting) environment (Succar, 2010). The Interactive Capability Maturity Model (ICMM) from the National Building Information Modelling Standard (NBIMS), (NIBS 2007) is an elaborate assessment tool with 11 topics (A – K) assessed against ten maturity levels (1 – 10). The details of these topics and maturity levels are found in Table 2-2. It is the most commonly used BIM maturity assessment tool followed by the BIM QuickScan (Sebastian and van Berlo, 2010). ARUP in South Africa uses a BIM performance framework that is more for the design team selection and is not applicable throughout the construction project delivery phases(ARUP, 2015).

Table 2-2 BIM Maturity Levels (NIBS, 2007)

Maturity Level	***A Data Richness***	***B Life-cycle Views***	***C Roles or Disciplines***	***G Change Management***	***D Business process***	***F Timeliness/ Response***	***E Delivery Method***	***H Graphical Information***	***I Spatial Capability***	***J Information Accuracy***	***K Interoperability / IFC Support***
1	Basic Core Data	No Complete Project Phase	No Single Role Fully Supported	No CM Capability	Separate Processes Not Integrated	Most Response Info manually re-collected -	Single Point Access No IA	Primarily Text - No Technical Graphics	Not Spatially Located	No Ground Truth	No Interoperability
2	Expanded Data Set	Planning & Design	Only One Role Supported	Aware of CM	Few Bus Processes Collect Info	Most Response Info manually re-collected	Single Point Access w/ Limited IA	2D Non-Intelligent as Designed	Basic Spatial Location	Initial Ground Truth	Forced Interoperability
3	Enhanced Data Set	Add Construction/ Supply	Two Roles Partially Supported	Aware of CM and Root Cause Analysis	Some Bus Process Collect Info	Data Calls Not in BIM But Most Other Data Is	Network Access w/ Basic IA	NCS 2D Non-Intelligent as Designed	Spatially Located	Limited Ground Truth - Int Spaces	Limited Interoperability
4	Data Plus Some Information	Includes Construction/ Supply	Two Roles Fully Supported	Aware CM, RCA and Feedback	Most Bus Processes Collect Info	Limited Response Info Available In BIM	Network Access w/ Full IA	NCS 2D Intelligent as Designed	Located w/ Limited Info Sharing	Full Ground Truth - Int Spaces	Limited Info Transfers Between COTS
5	Data Plus Expanded Informatio	Includes Constr/Supply & Fabrication	Partial Plan Design&Constr Supported	Implementing CM	All Business Process(BP) Collect Info	Most Response Info Available In BIM	Limited Web Enabled Services	NCS 2D Intelligent As-Builts	Spatially located w/Metadata	Limited Ground Truth - Int & Ext	Most Info Transfers Between COTS
6	Data w/Limited Authoritati	Add Limited Operations & Warranty	Plan, Design & Construction Supported	Initial CM process implemented	Few BP Collect & Maintain Info	All Response Info Available In	Full Web Enabled Services	NCS 2D Intelligent and Current	Spatially located w/Full Info Share	Full Ground Truth - Int And Ext	Full Info Transfers Between COTS
7	Data with Mostly Authoritative Information	Includes Operations & Warranty	Partial Ops & Sustainment Supported	CM process in place and early implementation of root cause analysis	Some BP Collect & Maintain Info	All Response Info from BIM & Timely	Full Web Enabled Services w/IA	3D - Intelligent Graphics	Part of a limited GIS	Limited Comp Areas & Ground Truth	Limited Info Uses IFC's For Interoperability
8	Completely Authoritative Information	Add Financial	Operations & Sustainment Supported	CM and RCA capability implemented and being used	All BP Collect & Maintain Info	Limited Real Time Access From BIM	Web Enabled Services - Secure	3D - Current and Intelligent	Part of a more complete GIS	Full Computed Areas & Ground Truth	Expanded Info Uses IFC's For Interoperability
9	Limited Knowledge Mngmt	Full Facility Life-cycle Collection	All Facility Life- Cycle Roles Supported	Business processes are sustained by CM using RCA and Feedback loops	Some BP Collect&Maint In Real Time	Full Real Time Access From BIM	Netcentric SOA Based CAC Access	4D - Add Time	Integrated into a complete GIS	Comp GT w/Limited Metrics	Most Info Uses IFC's For Interoperability
10	Full Knowledge Mngmt	Supports External Efforts	Internal and External Roles Supported	Business processes are routinely sustained by CM, RCA &	All BP Collect&Main t In Real Time	Real Time Access w/ Live Feeds	Netcentric SOA Role Based CAC	nD - Time & Cost	Integrated into GIS w/ Full Info Flow	Computed Ground Truth w/Full Metrics	All Info Uses IFC's For Interoperability

The following frameworks presented in Table 2-3 are amongst several tools developed around the globe to evaluate BIM maturity levels over the past years (Månsson and Lindahl, 2016). These frameworks are intended to measure the performance of organisations and teams but are not applicable across all organisational scales (Succar, 2010) and or countries:

Table 2-3 BIM Maturity Measures

BIM Assessment Measure	**Year**	**Origin**	**CPS**
BIM Level 2 BRE certification	2015	United Kingdom	-
The TOPC evaluation criteria		Australia	-
Goal-driven method for evaluation of BIM project	2014	South Korea	2
BIM-MM	2014	United Kingdom	213
Owners BIMCAT	2013	United States	2
VDC Scorecard - BIMScore	2012	United States	130
Organisational BIM Assessment Profile	2012	United States	-
CPIx BIM Assessment Form	2011	United Kingdom	-
Characterisation Framework	2011	United States	40
VICO BIM Score	2011	Global company	-
BIM QuickScan	2009	The Netherlands	130
BIM maturity matrix	2009	Australia	-
BIM Proficiency matrix	2009	United States	-
BIM Excellence	2009	Australia	-
NBIMS-CMM	2007	United States	11

Source 1: Azzouz, 2016 (https://bit.ly/2pUk0uN)

Table 2-3 shows that the United States has developed more BIM performance assessment measures.

2.4.3 BIM competency to assess level capability and maturity

While BIM assessment measures offer a detailed score result, given the components measured for BIM capability and maturity, BIM competency sets are a reflection of either an individual or a team, which is a sum of the competencies of individuals (Succar *et al.*, 2013). The focus of this research is on the organisational competencies.

Table 2-4 Levels of competencies (Succar et al., 2013)

Competency Index	Competency Level	Detail
0	None	Minimal to no possession of conceptual knowledge with no practical application
1	Basic	Basic level of applied knowledge and initial practical application
2	Intermediate	Intermediate level of applied knowledge and practical application
3	Advanced	Advanced level of applied knowledge and practical application
4	Expert	Expert level of applied knowledge and practical application and repetition

Table 2-4 lists the competency levels that can be applied to indivudals where the sum of the individual competencies would thus represent team or organisational competencies. BIM competencies are the personal traits, professional knowledge and technical abilities required by an individual to per-form a BIM activity or deliver a BIM-related outcome. These abilities, activities or outcomes must be measurable against performance standards and can be acquired or improved through education, training and or development (Succar *et al.*, 2013). Competencies includes those attained through formal education, vocational or on-the-job training typically on skill improvement and professional development. Competencies assists organisations: set BIM goals and objectives through competencies expressed as abilities; measure the capability of organisations and using a common reference; define and meet project requirements through standardised competencies expressed as abilities or requirements; facilitate organisational and project workflows through competencies expressed as activities or tasks; identify pre-qualification criteria through competencies expressed as outcomes or deliverables; and develop training and continuing professional development (CPD) modules expressed as outcomes within organisations and industry associations.

2.5 Benefits of BIM

Adoption motivation is measured by a combination of perceived benefits, awareness and innovativeness. Table 2-5 summarises perceived benefits of BIM as reviewed from related similar studies.

Table 2-5 Perceived benefits of BIM

Perceived benefits BIM adoption	References
BIM enables design information to be made explicit	(Smallwood *et al.*, 2012); Matthews *et al.* (2015)
BIM can reduce the need for re-gathering or re-formatting information [19].	Matthews et al., 2015 (GSA, 2007)
An increase in the speed and accuracy of transmitted information	(Hosseini *et al.*, 2016); Matthews et al., 2015; UK USA Hosseini et al; CRC Construction Innovation; (Azhar, Nadeem, Mok & Leung, 2008); (Bernstein, Jones & Russo, 2010); UK Motawa_2013
Reduction of costs associated with a lack of interoperability; Design information in the BIM can be linked to a contractor's Cost and constructability information to create the near continuous cost data analysis required for target value design	Matthews et al., 2015; Smallwood et al., 2012) (Bernstein, Jones & Russo, 2010);
Automation – checking and analysis,	Matthews et al., 2015; Smallwood et al., 2012)
Support of operation and maintenance activities; improving logistics and supply chain systems	Matthews et al., 2015; (Hosseini *et al.*, 2016)
Enable the design team and contractor to monitor actual against planned performance in real-time.	Matthews et al., 2015
Improve workflows and mitigate rework and delays	Matthews et al., 2015; (Hosseini *et al.*, 2016)
Real time synchronisation of project data	Matthews et al., 2015

Table 2-5 shows a summarised literature on the perceived benefits of implementing BIM. At the top of the list, BIM is perceived to enable design information to be made explicit. Literature shows that BIM enables an increase in the speed and accuracy of transmitted information, and can reduce the need for re-gathering of information by the various project stakeholders in the various construction stages. BIM reduces the costs associated with the project.

2.6 Barriers and causes of gradual BIM adoption

Table 2-6 lists a summary of drivers and barriers of BIM adoption as reviewed from literature. Relevant authors are referenced next to each driver and or barrier. The drivers of BIM adoption are attributed to client awareness and request of BIM as reported by Froise and Shakantu (2014), Bin Zakaria et al., (2013); Gerrard et al., (2010) and Khosrowshahi and Arayici, (2012). Barriers included "Resistance to change" as reported by Hosseini et al, 2016, UK Arayici Coates Koskela Kagioglou 2011, Abubakar et al., 201, Azhar, Khalfan and Maqsood, 2015, Forsythe, 2014, Gerrard et al., 2010, Khosrowshahi and Arayici, 2012, Poirier, Staub-French and Forgues, 2015a and Rodgers et al., 2015

Table 2-6 Drivers and Barriers of BIM adoption

Drivers and or Barriers to BIM adoption	Author(s) Year
Lack/Awareness by: large clients, government and industry bodies, use of uncollaborative methods in project procurement	Froise and Shakantu (2014) Bin Zakaria et al., 2013; Gerrard et al., 2010; Khosrowshahi and Arayici, 2012
Lack/Evidence for BIM implementation (benefits)	Hosseini *et al.* (2016)
Adoption motivation, organizational competency and ease of implementation	Hong *et al.* (2016)
Lack/Support from top management, bureaucracy, competitive advantages, personnel training, BIM benefits	Tsai *et al.* (2014)
inadequate interoperability	National Institute of Standards and Technology in the United States (Gallaher et al. 2004); USA Shahron_2009 Azhar, Khalfan and Maqsood, 2015; Manderson, Jefferies and Brewer, 2015; Rodgers et al., 2001; (Anonymous; Hong *et al.*, 2016; Tan *et al.*, 2017)
Lack of knowledge and awareness/Lack of demand	Hosseini et al, 2016;
Lack of support from policy makers	Hosseini et al, 2016; Abubakar et al., 2014; Bin Zakaria et al., 2013
Unavailability of standards and guidelines	Hosseini et al, 2016;
Initial costs	Hosseini et al; UK Motawa_2013; (Hong *et al.*, 2016)
Training and learning issues/Lack of skilled personnel	Hosseini et al, 2016; UK Arayici Coates Koskela Kagioglou 2011
Resistance to change	Hosseini et al, 2016; UK Arayici Coates Koskela Kagioglou 2011; Abubakar et al., 2014; Azhar, Khalfan and Maqsood, 2015; Forsythe, 2014; Gerrard et al., 2010; Khosrowshahi and Arayici, 2012; Poirier, Staub-French and Forgues, 2015a; Rodgers et al., 2015

2.7 Theoretical framework of the study

The theoretical framework guiding the study is the Technology Organisation and Environment (TOE) framework, by Tornatzky and Fleischer (1990). Before discussing the TOE framework, this study recognises that BIM adoption, capability and maturity is beyond the adoption of just technology but that technology is an enabler for the BIM processes, procedures and policies. As such, the Technology Acceptance Model (TAM) and the Institutional Adoption of Innovation are presented first, so as to show the factors that influence the acceptance of technological innovations. The TOE framework as the theoretical point of departure of the study, is presented lastly.

2.7.1 Technology Acceptance Model

The technology acceptance model (TAM) by Davis *et al.* (1989) is based on the theory of Reasoned Action and specifically models the user acceptance of information technologies. The model posits that perceived usefulness and perceived ease of use are of primary relevance to the acceptance or rejection of using a technology as shown in Figure 2-7 Technology acceptance model (Davis et al. 1989).

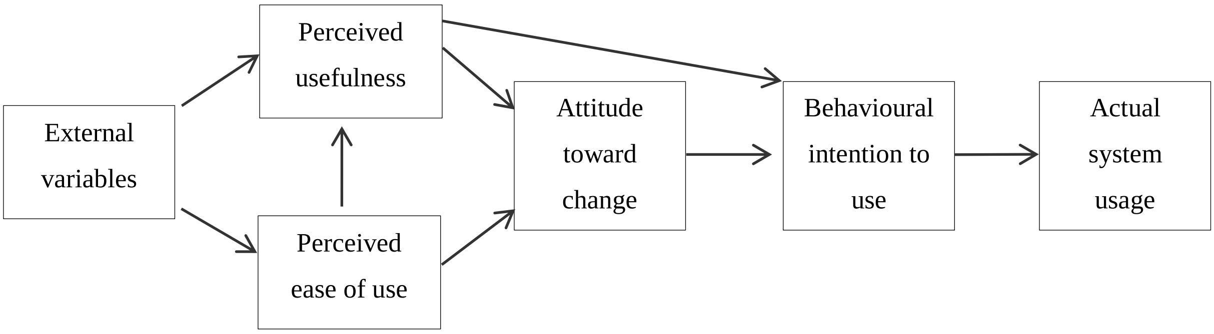

Figure 2-7 Technology acceptance model (Davis et al. 1989)

The frameworks neither factor in the importance and the influence of BIM implementation at project level nor the context of the implementation. BIM has inter and intra organisational factors, where intra-organisational factors are focused on factors involved within the organisation (such as management issues, individual issues, technical issues and workplace environment issues). Inter-organisational factors are focussed on the [BIM] use issues of dealing with externally linked project team supply chain members – consultants, sub-contractors, fabricators, and suppliers (Peansupap and Walker, 2006).

2.7.2 Institutional theory

Adoption models are conceptual structures describing how adoption – a term overlaying the definitions of implementation and diffusion – occurs across a population of organizations. Adoption models do not employ mathematical formulae to explain past or predict future diffusion patterns but use inductive inference to generate graphical representations that reduce topic complexity and promote understanding (Michalski, 1987). Each adoption model is formulated through a process of identification, classification and clustering, which simplify a large system, by decomposing it into smaller sub-systems (Michalski and Stepp, 1987). Academic enquiries have been aimed at determining specific factors that drive or inhibit the adoption and implementation of BIM and on a larger scale in the construction industry. Institutional theory model (Iacovou *et al.*, 1995) explains the adoption of an innovation to be influenced by organisational readiness, perceived benefits and external pressure as shown in Figure 2-8. Empirical studies on the drivers of BIM adoption in construction organisations acknowledge that adoption motivation/knowledge, organizational competency/cultural readiness and ease of implementation of BIM/"know-how" influences the adoption of BIM at the organizational level (Hosseini et al., 2016; Hong et al., 2016; Tsai et al., 2014; Froise and Shakantu, 2014; and (Mehrtens *et al.*, 2001).

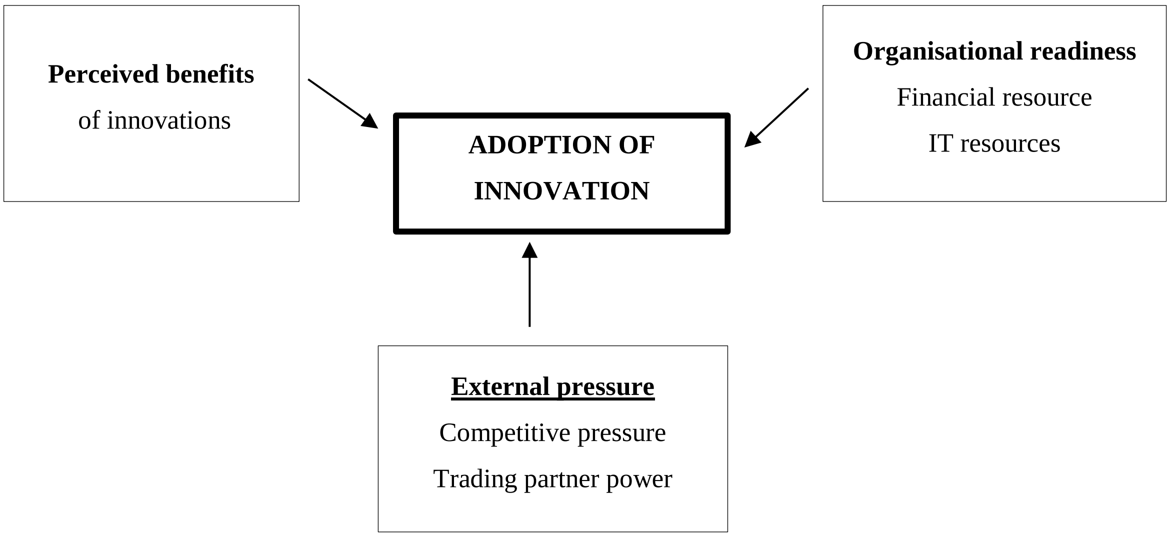

Figure 2-8 Institutional Theory Adoption of innovation model (Iacovou et al, 1995)

2.7.3 Technology, Organisation and Environment

Technology, organisation and environment (TOE) framework as presented under Figure 2-9 synthesizes the Diffusion of Innovation and institutional theories. This study recognizes that BIM is more than a technology and adoption is influenced by organisational factors, as well as the environment within which the organisation operates and that the organisational context and technology are both determinants of the organisations readiness to implement BIM.

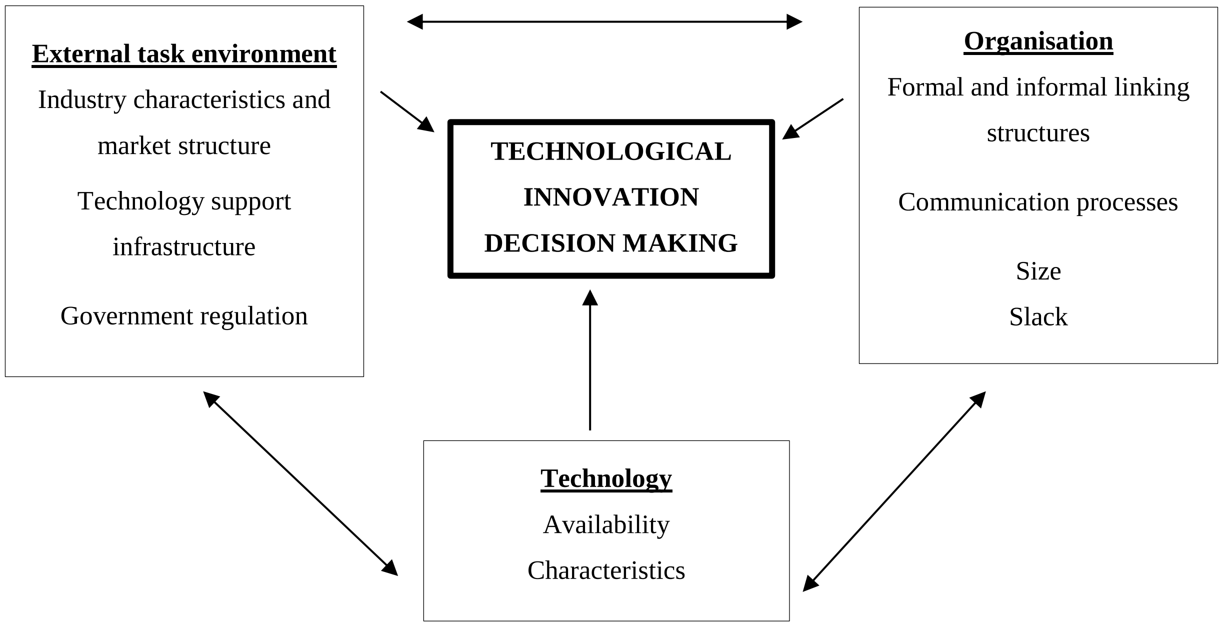

Figure 2-9 Technology, organisation and environment framework (Tornatzky & Fleisher 1990)

Adoption of technological innovation involves a rich embroidery of events, which could be many activities, decisions, behaviour on the part of individuals and social units, most of whom are not even self-consciously aware of being part of such a process (Tornatzky *et al.*, 1990).

2.8 Conceptual model of the study

The frameworks and models mentioned prior, suggest that External environment, Organisational and Technological contexts impact on BIM adoption, capability and maturity. The environment within which organisations operate and the organisational context and technology, are determinants of the organisations readiness to implement BIM. Figure 2-10 shows the conceptual model of the study, synthesized from literature reviewed and the theoretical framework of the study. BIM capability is a function of the BIM fields (technology, process and policies), which, when assessed, measure organisational competency for implementing BIM and identifying organisational BIM capability stage. This conceptual model is used in data collection and discussed further in later chapters.

- BIM capability (competency) affects BIM adoption (actual use), where, if organisations have the minimum BIM requirements, they can adopt BIM and vice versa, when firms adopt BIM, the competency levels are increased through learning and use of BIM related tools and workflows

- BIM adoption affects BIM maturity, where, as firms adopt BIM, the levels of BIM maturity increase (or decrease) due to the achievement (or not) of the perceived benefits and usefulness of using BIM (derived from the Technology Acceptance model). This relationship is also vice versa, where the levels of BIM Maturity influence BIM adoption, as firms mature and realised the full benefits of using BIM, their adoption levels can increase.

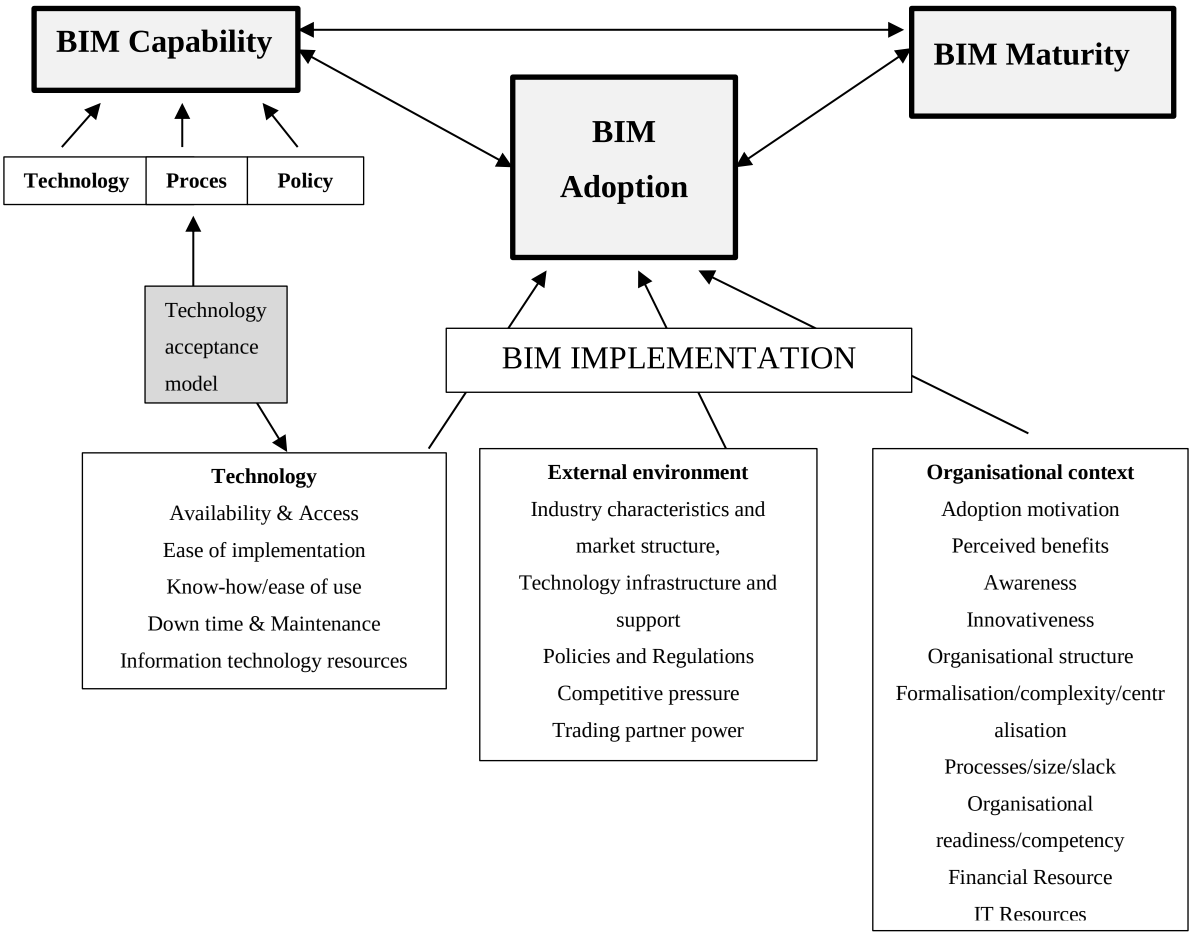

Figure 2-10 Conceptual model of the study

Recapping on the various theories in relation the conceptual model:

BIM adoption has inter and intra organisational factors, where intra-organisational factors are focused on factors involved within the organisation (such as management issues, individual issues, technical issues and workplace environment issues). Inter-organisational factors are focussed on the [BIM] use issues of dealing with externally linked project teams.

The technology acceptance model (TAM) by Davis *et al.* (1989) is based on the theory of Reasoned Action and specifically illustrates the user acceptance of information technologies. The model posits that perceived usefulness and perceived ease of use are of primary relevance to the acceptance or rejection of using a technology

This insight is useful for the study as the research questionnaire design will need to be informed by what literature, the theoretical framework and the conceptual model has identified as the key factors, variables and concepts that will inform the study. Furthermore, the tentative and presumed relationships can then be tested to achieve the research objectives of: assessing if there is any difference in the level of adoption, capability and maturity of BIM between consulting and construction firms and evaluating if there is any relationship between level of BIM maturity and project performance of consulting and construction firms.

2.9 Chapter Summary

This chapter reviews the construction industry and existing construction project delivery methods and performance. Relevant literature was then reviewed on BIM adoption, capability and maturity. Furthermore, this chapter examined the theoretical framework shaping the study and developed a synthesised conceptual model for this research. This section has reviewed relevant related literature and determined the extent of work done on the development of BIM performance assessment measures. Drivers and barriers to BIM adoption were also documented in this chapter and a synthesis of authors who have made contributions and published work on the relevant study topics have been referenced through the chapter.

CHAPTER THREE

3 RESEARCH METHODOLOGY

This chapter is about the plans and procedures taken in the research. Philosophical assumptions, procedures of enquiry and specific research methods are selected and justified. To achieve the previously mentioned Research objectives. The study will follow a sequential mixed method research approach. This chapter will justify the chosen research strategy by looking at the research paradigm, research design, research instruments and chosen criteria.

3.1 Philosophical approach

3.1.1 Research paradigm and the research proposition

Neuman (2007) describes a research paradigm as a general organising framework for theory and research that includes basic assumptions, key issues, models of quality research, and methods for seeking answers. Nieuwenhuis (2007) describes a paradigm as a set of assumptions or beliefs about fundamental aspects of reality which give rise to a particular world view. A paradigm addresses fundamental assumptions, such as beliefs about the nature of reality (ontology) and the relationships between knower and known (epistemology). In BIM research, there is no explicit paradigm as BIM research combines different research traditions and has not yet built a shared paradigm across scholars universally.

Philosophical ideas in BIM research are largely hidden and do not yet discuss knowledge, theory, and methodology in detail. Closely related fields therefore, serve as a paradigmatic guide (Berard *et al.*, 2012). BIM adoption studies follow the socio-technical view in that they not only consider the implementation of the technology but also considers the socio-cultural environment that provides the context for its implementation (Arayici *et al.*, 2011). Revisiting the research question and hypothesis as shown in Section 1.4 and 1.6, the study needs to answer if there are any differences in the levels of BIM adoption, capability and maturity between consulting and construction firms in South Africa and to further evaluate whether there is a relationship between the BIM performance measures (adoption, capability and maturity) and perceived benefits. This means that the research aims to discover if there are any patterns between (for example) BIM adoption levels and perceived benefits. This process is referred to as induction. Furthermore, the study needs to determine whether the research hypothesis is true (deduction). This research is therefore retroductive as it combines induction (interpretivist) and deduction (positivist) research strategies. Through retroduction, events are explained by postulating and identifying structures and causal powers capable of generating them (Clegg and Haugaard, 2009); and by locating the underlying structure that is responsible for producing the observed regularity (Blaikie, 2007). Retroduction uses creative imagination and analogy to work back from data to an explanation and involves the building of hypothetical models as a way of uncovering the real structures and mechanisms which are assumed to produce empirical phenomena. In constructing these hypothetical models, ideas are borrowed from known structures and mechanisms in other fields (Malhotra, 2017).

3.1.2 Postpositivist paradigm

Socio-technical empirical research hold the deterministic philosophy in which causes determine the effects of outcomes (Creswell, 2014). Post-positivism is influenced by a philosophy called critical realism (Trochim, 2002). The ontology of postpositivist paradigm adopts the stance that there is one reality out there, to be discovered and knowable within probability. The epistemology of this paradigm maintain that the nature of knowledge is inherent in the natural science paradigm, where knowledge is defined as those statements of belief or fact that can be tested empirically, be confirmed and verified or disconfirmed, and are stable and can be generalized (Eichelberger, 1989). The Axiology of this paradigm holds that theories, hypothesis and background knowledge held by the investigator can strongly influence what is observed, how it is observed and the outcome of what is observed. Since the research tests a hypothesis and finds the strength of relationships between variables or a cause and effect relationship, the study has identified and defined the variables adoption, capability and maturity of organisations to be studied, these variables also are operationally defined to enable others to replicate, verify and confirm the results. Operationally defining a variable means that the trait to be measured is defined according to the way it is used or measured or observed in the study.

3.2 Research Approach

This study adopts a sequential mixed method research approach involving a cross sectional survey and interviews research design. It is a mixed method research approach as it involves the use of qualitative and quantitative methods. It is sequential as the quantitative method (surveys) is performed first and this informs the qualitative method in terms of selection of participants for interviews and follow up interview protocols and document reviews. The research problem is firstly a technical problem, as the research addresses how BIM (as an information technology) is currently being used within the industry. However, it is also a social issue, as it addresses the use of BIM by organisations as BIM is also an innovation that requires changes in organisational processes. Consulting and construction firms cover both technical and social disciplines within their operations. The technical discipline addresses the technical aspects of designing and erecting a building while the social discipline is about the management of the people and organisations that are involved with the design and erection of a building. Philosophically, mixed research makes use of the pragmatic method and system of philosophy. Its logic of inquiry includes the use of induction, deduction and abduction (Berard *et al.*, 2012).

3.2.1 Quantitative Research Approach

Quantitative research methods enable researchers to collect data on perceptions and attitudes of a wide range of respondents, and thus the findings become applicable to a population (Neuman, 2007). From the quantitative method, deductions can be made, as this method supports context free generalisation by observing patterns from responses. The quantitative research objectives in this study are a "how much" problem, which can be paraphrased as follows:

- *How many consulting or construction firms use BIM?*
- *What is the extent of BIM use?*
- *What is the level of BIM maturity?*

3.2.2 Qualitative Research Approach

The qualitative research objectives answer the "why", "what" and the "how" question and lead to inductive approach of findings, where propositions can be tested based on patterns of data analysed. The attitudinal research is adopted to "subjectively" analyse the "opinion", "view" or "perception" of a person towards a particular object (Naoum, 2012). The attitudinal approach is used to study the following research objective:

- *Perceived benefits of BIM adoption*
- *How do firms implement BIM?*

3.2.3 Questionnaire design

The following questionnaire design as illustrated in Table 7 list the various sections of the research survey tool. The tool has been designed to obtain information from the respondent pertaining to how they deliver their project objectives and deliverables, especially the technological resources, platforms and software applications as these form the basis of BIM enabled environments. Due to misinformation of what BIM is and is not, this study used a two-way approach by designing questions that encompass BIM implementation at individual or single organisational level, section two-to-four of the questionnaire design whilst BIM at team or multi organisational level has been covered in section six of the questionnaire design. The intention of this distinction is that – literature has shown the myths around what is perceived as BIM and this study aims to assess the true BIM adoption levels across the various capability stages and maturity levels.

Table 7 Survey questionnaire design

SECTION	CONSULTING	CONSTRUCTION	QUESTIONS
1	Research information and consent form		1
2	Background information of respondent		2 - 5
	Individual Technological Competencies, Organisational Function, Technological Resources and Professional Registration		6 - 15
3	Organisational context, size, function, capacity and technological resources		16 - 18
4		Organisational context, size, function, capacity and technological resources	19 - 21
5	Related project performance information		22 - 24
6	Direct BIM based questions		25 - 32
7	Contact details for further interview, if/where necessary		33 - 34

3.2.4 Research structure

This cross-sectional research is designed, structured and carried out as shown in Figure 3-1.

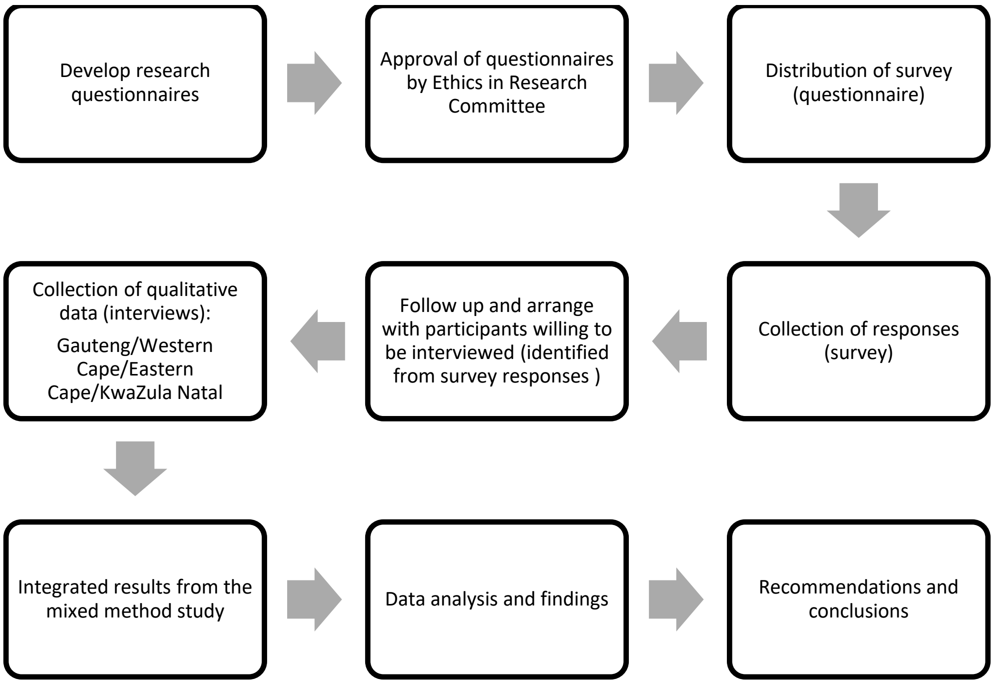

Figure 3-1 Flow chat – Research design

For the collection of survey data, interviews and observations are used in this study.

3.3 Population of the study and Sampling strategy

3.3.1 Population of the study

The population for this study is all practitioners working in consulting and construction firms in South Africa. Data collection through targeting clusters of population of interest or "cluster sampling" as termed by Neuman (2006) is appropriate for administration of questionnaires where the population is in a wide geographic area such as a country. As such, the targeted cluster for this study are all consulting and construction firms practitioners (n = 5472) as listed in the Construction Professions Register, 2015 (TimesMedia, 2016) across South Africa. The major geographical areas of focus are Gauteng, Western Cape, Eastern Cape and KwaZulu Natal, as these provinces have the highest number of active construction projects on the cidb register projects (cidb, 2018) and thus, highest number of practicing consulting and construction professionals.

3.3.2 Sampling technique

Due to the impossibility of obtaining data from the entire population within the scope of a study, sampling is commonly used to obtain data from a part of the population that will be representative of the population being studied {Fellows, 2008 #151}. Random sampling has been implemented in this study. The random sampling targeted any practitioner operating in consulting and construction organisations as listed in the Construction Professions Register based in four provinces of Gauteng, Western Cape, Eastern Cape and KwaZulu Natal and willing to take part in the study (n = 4377).

3.3.3 Sample size

To determine the acceptable sample size from the study population, the Central Limit Theorem has been used in this study, which states that the sampling distribution of the sample means approaches a normal distribution as the sample size gets larger — no matter what the shape of the population distribution and that this fact holds especially true for sample sizes over 30. The survey questionnaire was distributed to five hundred and sixty participants. At the end of the study period (August 2018), 73 responses were received from the survey questionnaire. 37 Interviews from 15 consulting and construction firms were also conducted as part of the qualitative data collection method. For the quantitative method, only 49 responses were found complete and usable for the analysis of the survey results. The research used all the responses received from the questionnaire survey and the interviews in data analysis

3.4 Methods of Data Collection

The data for this study comprised of both primary and secondary data. The primary instrument used in data collection comprised of questionnaires and interview protocol. Secondary data are the general observations of consulting and construction workspaces, offices and general environment.

The University of Cape Town's Ethics in Research Committee (EIRC) requires a complete questionnaire design before approving the ethics application. The survey questionnaire for this study is presented in APPENDIX A - SURVEY QUESTIONNAIRE. The first section of the questionnaire asked for the background information of the person completing the questionnaire and the construction firm for whom he/she works in. The second section comprised questions on BIM adoption, capability and maturity of the firm. These questions were to design to extract reliable information from the participants by using multiple questions asking for similar information and in the crucial aspects of the research, the participants were rather asked to detail their practice and technology use without clouding it with the "BIM" term. This separation of actual practice is captured by the questions that asks the participants to identify in detail the type of software and other forms of technologies used and the extent of use. The length of the questionnaire was kept to a minimum and responses were given by ticking the desired option.

3.4.1 Interview Protocol

The semi-structured Interview Protocol comprised two sections, A and B. Section A obtained general information about the work category of the respondents, years of corporate existence of their company, work designation of respondents, and geographical spread of the business. Section B sought information about the technological abilities of the respondent's company in terms of capacity, capability and BIM adoption.

3.4.2 Pre-testing of the Questionnaire

According to (Walliman, 2001) questionnaires should be pre-tested on a small population before administering it to a large sample size, to test the validity of the questions. The research supervisor read through the questionnaire to check for duplication of questions and to ensure that the questions addressed the research question and objectives. After revising the questionnaire based on the supervisor's comments, the draft questionnaire was sent to three BIM experts so as to ascertain the maximum time required to complete the questions and to obtain feedback on any items that were not clear. The pre-test indicated that the questionnaire could be completed by knowledgeable respondents within 20 minutes, that the questions were clear and understandable.

3.4.3 Data collection procedure

The research instruments were administered using the following methods:

- Online survey, distributed via survey links though emails and web collectors (https://bit.ly/2p1S9s2)
- Hardcopy distribution of questionnaire followed by manual entry of responses into the survey collector function.
- Interview protocol as approved by EIRC, distributed to participants.

3.5 Methods of Data Analysis

The data collected was analysed using qualitative and quantitative techniques.

3.5.1 Qualitative

The qualitative data were analysed using thematic analysis. This form of analysis examines patterns across data sets that are important to the research objectives. The data transcribed, analysed, verified and reported from interviews containing the views of the respondents is used in the thematic analysis. Information presented in the company annual audit reports was also decoded using themes.

3.5.2 Quantitative

The quantitative data collected was analysed using descriptive and inferential statistical techniques. The different techniques and use are presented in Table 3-1

Table 3-8 Methods of data analysis

Method	**Explanation and use**
Cronbach's alpha (α)	is a measure of internal consistency, that is, how closely related a set of items are as a group. It is considered to be a measure of scale reliability. A "high" value for **alpha** does not imply that the measure is unidimensional. Internal consistency **Cronbach's alpha Internal consistency** $0.7 \leq \alpha < 0.8$ Acceptable $0.6 \leq \alpha < 0.7$ Questionable $0.5 \leq \alpha < 0.6$ Poor

	α < 0.5 Unacceptable
Simple additive weights (SAW)	also known as **weighted** linear combination or scoring methods is a **simple** and most often used multi attribute decision technique.
Kolmogorov-Smirnov test	the **Kolmogorov**–**Smirnov test** (K–S **test** or **KS test**) is a nonparametric **test** of the equality of continuous, one-dimensional probability distributions that can be **used to** compare a sample with a reference probability distribution (one-sample K–S **test**), or to compare two samples (two-sample K–S **test**).
Shapiro-Wilk test	The **Shapiro-Wilk test** for normality is available when using the Distribution platform to examine a continuous variable. The null hypothesis for this **test** is that the data are normally distributed. The Prob < W value listed in the output is the p-value. The **test** rejects the hypothesis of **normality** when the **p-value** is less than or equal to 0.05. Failing the **normality test** allows you to state with 95% confidence the data **does** not fit the **normal distribution**. Passing the **normality test** only allows you to state no significant departure from **normality** was found. Most statistical **tests** rest upon the assumption of **normality**. Deviations from **normality**, called non-**normality**, render those statistical **tests** inaccurate, so it is **important** to know if your data are **normal** or non-**normal**. **Tests** that rely upon the assumption or **normality** are called parametric **tests**
Lilliefors Significance Correction	In statistics, the Lilliefors test is a normality test based on the Kolmogorov–Smirnov test. It is used to test the null hypothesis that data come from a normally distributed population, when the null hypothesis does not specify which normal distribution; i.e., it does not specify the expected value and variance of the distribution.
T-test	A *t*-test is most commonly applied when the test statistic would follow a normal distribution if the value of a scaling term in the test statistic were known. When the scaling term is unknown and is replaced by an estimate based on the data, the test statistics (under certain conditions) follow a Student's *t* distribution. The *t*-test can be used, for example, to determine if two sets of data are significantly different from each other.

Pearson Correlation Coefficient (rho)	A **Pearson correlation** is a number between -1 and 1 that indicates the extent to which two variables are linearly related. The **Pearson correlation** is also known as the "product moment **correlation coefficient**" (PMCC) or simply "**correlation**".

Source: Ali and Bhaskar (2016) https://bit.ly/2nvCoIw ; https://bit.ly/1UxY5ir

3.5.3 Assessing BIM performance

The following methods are used in assessing the level of BIM capability, adoption, maturity and performance on construction projects.

3.5.3.1 BIM Capability

The capability of a firm calculated using Simple additive weights (SAW) is shown in Equation 1:

Equation 1 Calculating BIM Capability

$$[Equation\ 1]\ Level\ of\ Capability = \sum_{i=1}^{n}(Technology_i) + \sum_{i=1}^{n}(Expertise_i) + \sum_{i=1}^{n}(Firm\ Size)$$

…………equation 1

Where:

i. Technology – sum of scaled and weighted technological factors (hardware, software, extent of use, networks)

ii. Expertise – sum of scaled and weighted qualification and experience

iii. Size – the size of the organisation, where consulting firms are scaled from the number of employees and construction firms are scaled using the construction firms grade on the cidb Register of Contractors.

3.5.3.2 BIM Adoption

Equation 2 Calculating BIM Adoption

$$[Equation\ 2]\ Level\ of\ Adoption = \sum_{i=1}^{n}(Level\ of\ Capability) \times \sum_{i=1}^{n}(Level\ of\ use)$$
…………equation 2

Where:

i. Level of use is derived from data received pertaining to the organisational level of use of BIM related tools and workflows

3.5.3.3 BIM Maturity

Equation 3 Calculating BIM maturity

$$[Equation\ 3]\ Level\ of\ Maturity = \left\{\sum_{i=1}^{n}(Adoption)\ x \sum_{i=1}^{n}(Extent\ of\ use)\right\}$$
…………equation 3

Where:

i. Extent of use is derived from data received from respondents relating to the extent of use which include the assessment of capability levels in using BIM related tools, platforms and workflows.

3.5.3.4 Project performance

Equation 4 Calculating Project performance

$$[Equation\ 4]\ Project\ Performance = \left\{\sum Cost\ performance + time\ performance + Quality\ performnace\right\}$$
…………equation 4

Where:

i. cost overrun, delay and not meeting quality requirements are equal to -1,
ii. Finishing on time, to budget and meeting quality requirements are equal to +1
iii. and no data is equated to zero .

3.5.4 Test of Normality

Parametric tests such as T-test are more appropriate for data that shows normality. The test of normality for the data collected for each of the variables – capability, maturity and adoption are presented in the following sub-sections.

3.5.4.1 Test of Normality for data collected for the level of maturity

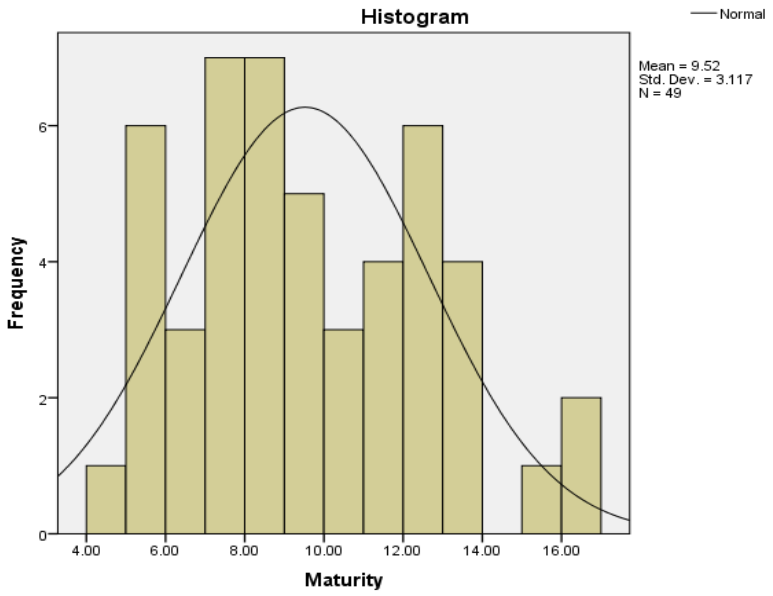

Figure 3-2 Test of normality - Histogram

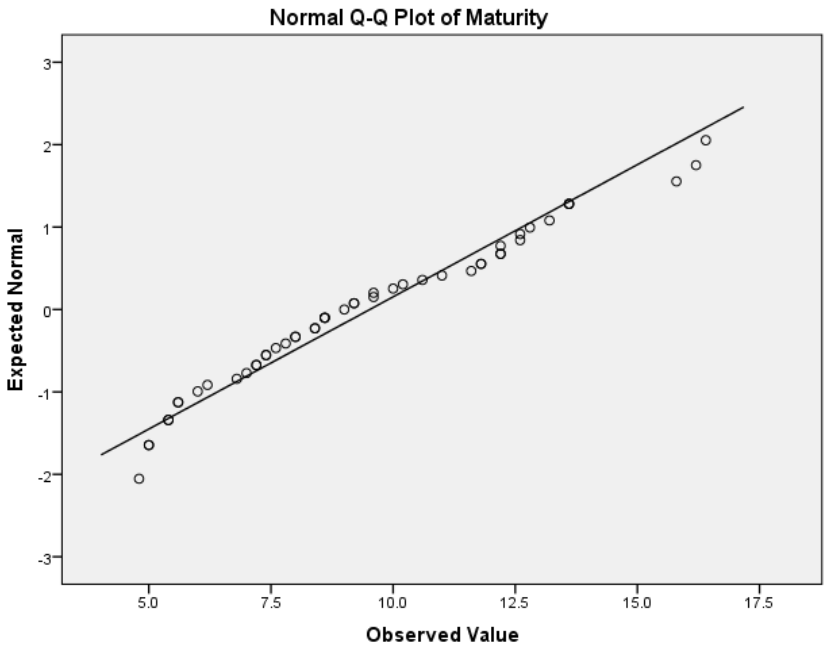

Figure 3-3 Test of normality Q-Q plot

Figures 3-2 (histogram) and 3-3 (Q-Q plot) shows that the distribution of the maturity score follows a normal distribution. Additional to these plots the results of Kolmogorov-Smirnov and Shapiro-Wilk test shown in Table 3-2 prove that the maturity score is distributed normally.

Table 3-9 Tests of Normality for Maturity scores

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Maturity	.106	49	.200*	.957	49	.068

*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

3.5.4.2 Test of normality for data collected for size of firm

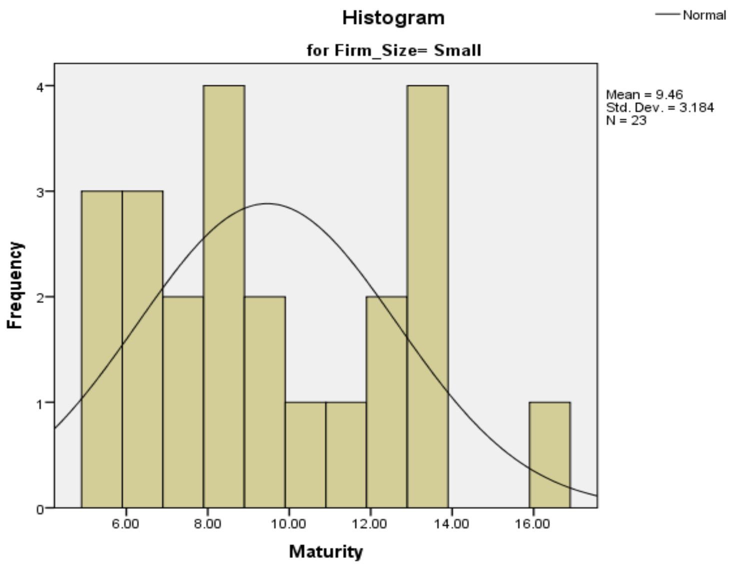

Figure 3-4 Test of normality - size of firm, small

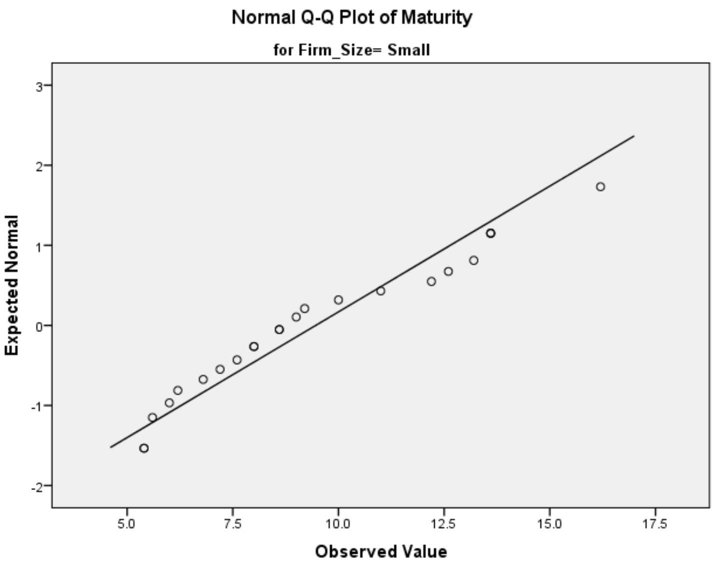

Figure 3-5 Q-Q plot for size of firm, small

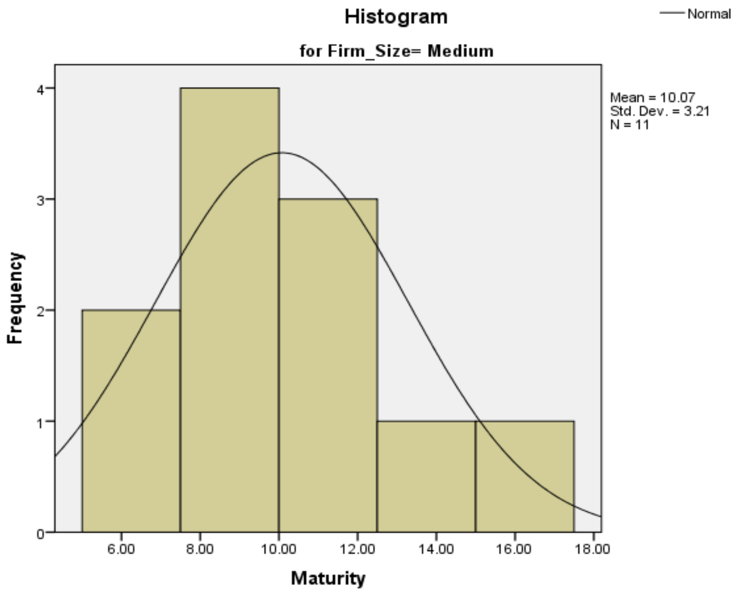

Figure 3-6 Test of normality - size of firm, medium

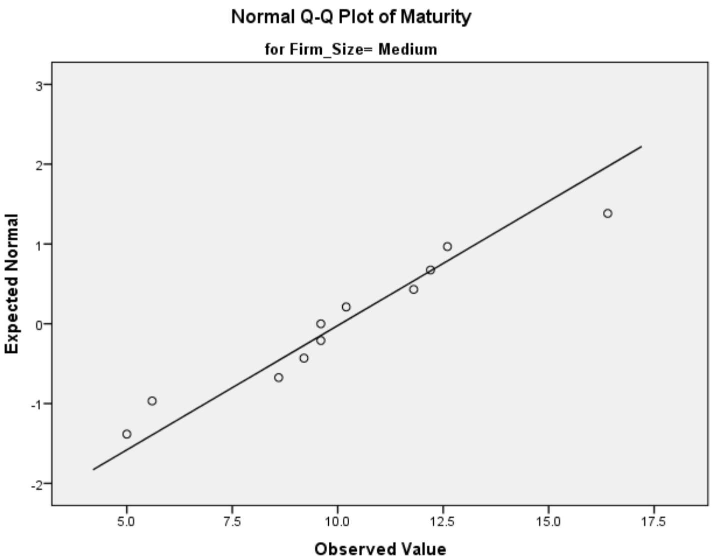

Figure 3-7 Q-Q plot for size of firm, medium

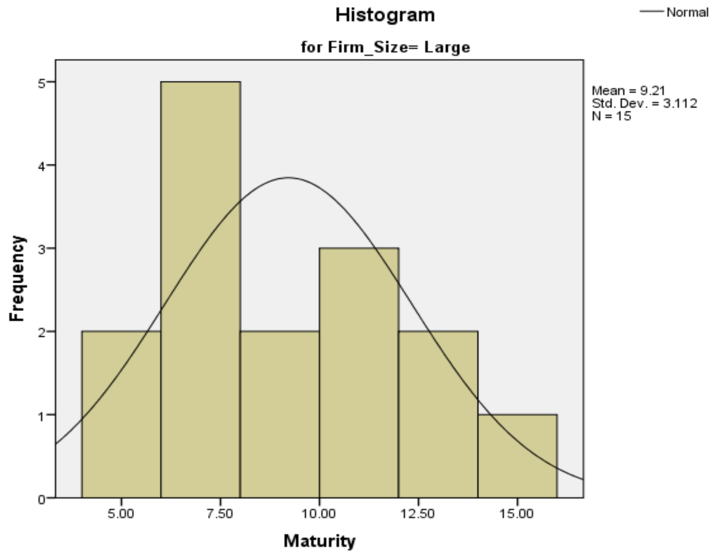

Figure 3-8 Test of normality - size of firm, large

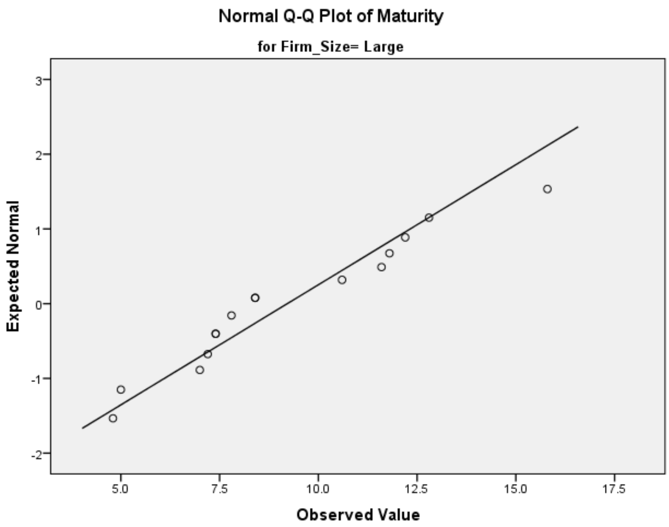

Figure 3-9 Q-Q plot for size of firm, large

The three histograms and Q-Q plot show the distribution of maturity in different size of firms follows the normal distribution, which to prove this further investigation is undertaken using the Shapiro-Wilk test.

Table 3-10 Tests of Normality

		Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Firm Size	Statistic	df	Sig.	Statistic	df	Sig.
Maturity	Small	.141	23	.200*	.926	23	.092
	Medium	.141	11	.200*	.957	11	.738
	Large	.203	15	.097	.939	15	.370

*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

The result of Shapiro-Wilk test which is more appropriate for small size data proved that the maturity is normally distributed in all three sizes of firms.

Sig Small =0.092>0.05

Sig Medium=0.738>0.05

Sig Large=0.370>0.05

3.6 Research quality

Research quality refers to the validity, reliability and trustworthiness of the data collected, and instruments used in the research.

3.6.1 Internal and external validity

Internal validity refers to the research measuring what it is supposed to measure (Joppe, 2000) while external validity refers to the findings being able to be generalized beyond the specific context of the research (Bryman, 2004). The concept of validity refers to the probability that an assertion or finding is true (Dooley, 1984). Internal validity was ensured through the Pre-testing of the research questionnaire as discussed earlier in section 3.4.3.

3.6.2 Reliability

Reliability refers to consistency of the results over time, which can be replicated or repeated by other researchers (Hussy and Hussy, 1997; Joppe, 2000). Similar outcomes should be obtainable if the research is repeated. Another researcher following the same method with the same data would offer similar conclusions, even though the opinions of a different researcher would add a degree of subjectivity. This is because the review method is a summary and synthesis of existing empirical research, thus reliability would be reasonably high. The reliability of the results was tested by means of the Cronbach Alpha statistical technique. The result obtained is shown in Table 3-11 and Table 3-12. Table 3-11 shows that Cronbach alpha statistics is 0.777 which indicates a high level of internal consistency for the data used in analysis.

Table 3-11 Cronbach Alpha Reliability statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	No of Items
0.777	0.716	18

Table 3-12 shows the test for measurement scales in the questionnaire. The Cronbach's Alpha statistic in the sixth "if Item Deleted column" in Table 3-12 indicates the value that Cronbach alpha would be if that particular question is deleted from the analysis. This shows that the removal of any question would lead to a small change in the Cronbach alpha, therefore, all the collected data are reliable and are considered for analysis. The Table 3-12 shows the Cronbach internal consistency measure of how closely related the data set is.

Table 3-12 Cronbach measure of internal consistency

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Squared Multiple Correlation	Cronbach's Alpha if Item Deleted
Q1	44.6957	165.040	-.097	.723	.782
Q2	43.1304	166.119	-.128	.816	.787
Q3	43.4783	179.715	-.434	.689	.818
Q4	43.5217	145.170	.344	.888	.768
Q5	43.5217	152.170	.168	.957	.785
Q6	43.6957	139.221	.444	.939	.760
Q7	43.3043	130.494	.672	.945	.738
Q8	44.3913	148.340	.555	.984	.758
Q9	43.4783	142.079	.538	.893	.754
Q10	44.7826	141.087	.770	.992	.744
Q11	45.0435	143.771	.743	.983	.748
Q12	43.6522	135.601	.515	.967	.753
Q13	42.7826	140.632	.422	.971	.762
Q14	43.5652	129.621	.724	.837	.734
Q15	44.1304	140.482	.540	.905	.753
Q16	42.9565	137.771	.444	.975	.760
Q17	45.3043	166.221	-.220	.834	.784
Q18	44.6957	166.858	-.181	.948	.787

3.6.3 Trustworthiness

Trustworthiness of research consists of credibility (parallels internal validity), transferability (parallels external validity), dependability (parallels reliability), and confirmability (parallels objectivity) (Berard *et al.*, 2012).

3.6.3.1 Credibility

In qualitative research, credibility depends on the ability and effort of the researcher (Popper, 1963; Golafshani, 2003). Credibility, as described by Lincoln and Guba (1986) is achieved by lengthy and intensive studies of the phenomena of interest, including persistent observations of outstanding elements. Another important element is the search for what Popper (1963) called the falsifiability of science. This involves looking for cases that do not conform and exposing the research to impartial peers. The last element is to repeatedly check understanding of the phenomena with a sample of stakeholders. Credibility is addressed by applying lengthy studies (until nothing new showed up); triangulation of methods (interviews and observations), sources (people and documentation), and different actors; and discussion of results with the participants and with focus groups of peers and practitioners

3.6.3.2 Transferability

Transferability, according to Lincoln and Guba (1986), is achieved by rich accounts and detailed narratives on the research phenomena. Bijker *et al.* (1989) argued for detailed descriptions of the situation being researched. A detailed description enables other researchers to make their own judgments about the possible transferability of the findings to another setting. Transferability is achieved by documenting the research tasks in the dissertation to be published on OpenUCT, which enables other scholars and practitioners to consider whether the findings are transferable to their situation.

3.6.3.3 Dependability and Confirmability

Dependability refers to the stability of the findings over time (Bowen, 2005). It is parallel to reliability in quantitative research, which is concerned with whether the same results would be obtained if the same phenomenon was observed twice. However, when studying social situations, no two are alike. Thus, dependability must account for the ever-changing context within which research is conducted (Trochim, 2006). According to Trochim (2006), confirmability is the degree to which others can confirm the findings. Dependability and confirmability are the "establishment of an audit trail and the carrying out of an audit by a competent external, disinterested auditor" (Lincoln and Guba, 1986). External audits of the research design, method, and progress judge's dependability, while judgment of the data and findings address confirmability. Bryman (2004) stated that external auditing is not popular due to the effort and time involved in an exhaustive audit. If an external audit is not viable, evaluation of dependability and conformability can be left to the reader.

3.6.3.4 Demonstration of dependability of this research

Dependability can be shown by having acted in good faith (Bryman, 2004) by describing choices and changes made during the research. Trochim (2006) suggested achieving confirmability by documenting the procedures of checking and rechecking, a documented process of another researcher as a "devil's advocate" with respect to the results or describing negative instances that contradict prior observation. Dependability is accounted for by describing the choices and changes made during the research to show that this author has acted in good faith. Confirmability is difficult to document, since it is hard to show that another researcher has reached the same conclusions from the same data. The researcher will do this by providing the data that can be digitized to interest parties on request, and it would also be made available to the examination committee.

3.6.3.5 Authenticity

According to Lincoln and Guba (1986), authenticity is not defined in its parallel to quantitative research, but rather by unique requirements of the qualitative research paradigms. Authenticity consists of fairness, ontological authenticity, educative authenticity, catalytic authenticity, and tactical authenticity. According to Lincoln and Guba (1986), fairness is about presenting a balanced view of all values and constructions. Ontological authenticity improves the individual's or group's conscious experience of the world, while educative authenticity increases appreciation of other individual's or group's conscious experience of the world, but does not necessarily mean agreement. Catalytic authenticity stimulates action based on inquiries and their analysis. Tactical authenticity empowers individuals or groups to act (Lincoln and Guba, 1986).

3.7 Ethical considerations

In this study, ethics and the protection of the dignity of all respondents were ensured through ethical considerations such as obtaining informed consent, confidentiality, providing anonymity and honesty. This study has been approved by the ethics in research committee and APPENDIX E – APPROVED ETHICS CLEARANCE details this approval. Part of this approval includes the submission of consent forms and in this study, the survey has its own consent form at the beginning of the survey APPENDIX A - SURVEY QUESTIONNAIRE. The interviewees had to offer their consent as well and APPENDIX B – CONSENT TO INTERVIEWS. Part of the interview process included the general observations around the participants site area or office space and APPENDIX D – COVER LETTER FOR GENERAL OBSERVATIONS details this consent.

3.7.1 Informed Consent

Informed consent is the participants autonomy, capability, ability and liberty to decide on their participation in the research (Marzano, 2007). All participants in the research are made aware of the purpose of the research and participation in the study is voluntary and can be withdrawn at any point during the study and will not result in any penalty, legal action or loss of any nature. Sufficient information detailing the purpose of the research is offered in the cover page of the research survey questionnaire and participants indicate whether (after being informed about the research), they would like to proceed and contribute to the study.

3.7.2 Confidentiality

Any personal information provided during the study is to be kept confidential and will not be included in the reporting of the results in any manner that will make it traceable to the individual respondent. However, participants were informed that absolute confidentiality cannot be guaranteed in instances where this might be required under laws of the country or required by the University for Quality Assurance in the assessment of the data reported and analysed. It is acknowledged that participants might provide sensitive, private or secret information – this information can be used in the research as long as the participant is protected by being treated as anonymous.

3.7.3 Anonymity

Anonymity means that the participants identification is not revealed and that no information pertaining to their individual responses can be traced and identified by other to belong to a certain participant (Walford, 2005). This conduct is a norm and standard practice in research and participants have the right to protect their identities. The research is conducted through survey responses using online platforms such as email attachments, direct online survey response and manual, hardcopy format. None of the responses in the analysis are linked or reported in a manner where information can be traced to a specific participant.

3.7.4 Bias

Bias undermines the internal validity of research, and to avoid this, three experts assessed the questionnaire for any ambiguities that might lead to respondents not understanding the questions or answering in a manner that will lead to errors when analyzing the data (Grimes and Schulz, 2002). The questionnaires were assessed for any blurring effects. To further ensure clarity, statistical analysis tools were also used to analyse data, where any inferences and correlation made, do not depend on the researcher's judgement of the outcome, but rather, statistical equations and reasoning.

3.8 Chapter Summary

This chapter discussed the philosophical approach shaping the study and the research approach. The population of the study was identified and sampling techniques discussed. The methods of data collected were identified as well as methods of data analysis. Research quality was discussed including internal and external validity, reliability and trustworthiness of the research. Ethical considerations including informed consent, confidentiality, anonymity and bias were discussed.

CHAPTER FOUR

4 DATA PRESENTATION, ANALYSIS AND DISCUSSION OF FINDINGS

Introduction

This chapter reports on data collected, which is presented in the first section. The second section of this chapter analyses the data, using statistical methods that were introduced in Chapter 3. The findings are the then reported and discussed.

4.1 Data Presentation

This section presents the data received from respondents. The general information detailing the background and profile of respondents is presented first.

4.1.1 Questionnaire Survey

The following responses represent the data received from the respondents. Even though the data is collected from individuals, the questionnaire was designed in such a manner that the participant are representative of the firm, by the use of indirect questions, which are analysed to compute reliable results.

4.1.1.1 Background Profile of the Survey Respondents

Table 4-1 represent the background and profile of respondents as well as the demographics of the firms represented. It shows that 59% of the respondents represent the consulting organisations/firms while construction firms were represented by 33% respondents.

Table 4-1 Background profile of respondents

Categories	Classification	Frequency	Percentage
Category of Organisation of Respondents	Contracting	16	33%
	Consulting	29	59%
	Client	4	8%
	Total	**49**	**100%**
Academic Qualification	Unspecified	7	14%
	Diploma	9	18%
	Undergraduate degree	13	27%
	Honours/BTech	14	29%
	Masters/MBA	6	12%
	Total	**49**	**100%**
Gender	Male	38	78%
	Female	11	22%
	Total	**49**	**100%**
Registered with a Professional Council	YES	36	73%
	NO	13	27%
	Total	**49**	100%
Years of Experience	1-4 years	10	20%
	5-9 years	7	14%
	10-14 years	16	33%
	15- 19 years	8	16%
	Above 19 years	8	16%
	Total	**49**	**100%**
	Average	**9,8**	
Age of respondents	18-25 years	6	12%
	26 - 35 years	16	33%
	36 - 55 years	24	49%
	56 - 65 years	3	6%
	Total	49	**100%**

The background and profile of the respondents attest to the adequate knowledge of respondents to answer questions relating to the research. More than 87% of respondents had a qualification beyond the National Qualification Framework (NQF) level five (5). More than 66% of respondents had work experience within the construction industry of above ten (10) years. The percentage of male, 79% - to females 19% attest to the notions that the construction industry continues to be a male dominated industry. While 52% of the respondents are between the ages of 36 – 55, which indicates that the majority of respondents in this study are seasoned and matured experts in their various practices in within the industry.

Table 4-2 shows the respondents/organisational technological infrastructure. More than 85% of respondents had access to a laptop computer.

Table 4-2 Technological infrastructure

Categories	Classification	Frequency	Percentage
Devices available in respondent's organisation	Desktop computer	22	45%
	Laptop	42	85.71%
	Mobile phone	29	59.18%
	Tablet/iPad	12	24.49%
	3D Laser scanner	3	6.12%
	Video Drone	2	4.08%
	HD Camera	12	24.49%
	No. of respondents	**48**	
Devices and platforms used accessible to respondents In their organisations	Cloud based application	24	51%
	Internal network based server	37	79%
	External network based server	6	13%
	Hardcopy format	14	30%
	Portable storage devices	13	28%
	Video Drone	2	4%
	HD Camera	12	26%

Table 4-3 identify the respondent's involvement in project delivery, where 85% of respondents identified to be involved in the physical execution and close out of construction projects.

Table 4-3 Respondents involvement during project

Categories	Classification	Frequency	Percentage
	No. of respondents	**47**	
Project involvement	Concept and Feasibility	22	46%
	Design Development	26	54%
	Execution and Close out	41	85%
	Facility Management	8	17%
	No. of respondents	**48**	

4.1.1.2 Software platforms available for use in firms and the extent of BIM use

The study sought to know the software platforms available for use in firms and the extent of BIM use. The data collected with regards to these enquiry is presented in Figure 4-1.

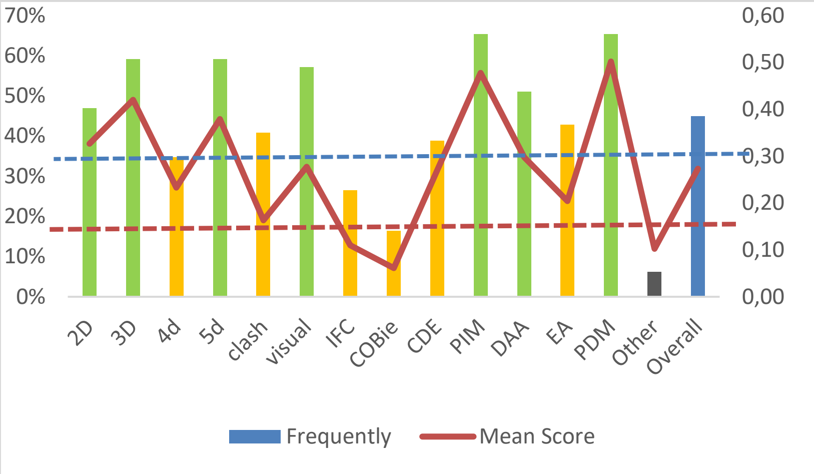

Figure 4-1 Software platforms available and extent of use

4.1.2 Organisation Details and organisational assessment scores

Table 4-4 and Table 4-5 detail the organisational details where:

1. Service – is the participants involvement in project stages, either the participants primarily in design, construction or both (design and construction)
2. Firm – the primary or core business of the organisation the participant is representing
3. Size – the size of the organisation, where consulting firms are scaled from the number of employees and construction firms are scaled using the construction companies cidb grade
4. Platform – the platform is scaled and weighted function of technological software available organisational level and the extent of use of the software within the organisation
5. Software – is the scaled and weighted function of software identified at individual level and extent of use
6. Storage – is the sum of the weighted storage forms available in organisations
7. Device – is the sum of weighted technological hardware
8. Expertise – sum of scaled and weighted qualification and experience
9. Technology – sum of scaled and weighted technological factors (hardware, software, extent of use, networks, etc)
10. BIM_Capability
11. BIM_Adoption
12. Performance
13. BIM_Maturity

Table 4-4 Organisation details and organisational assessment scores: Construction

Participant	Firm	Platform	Software	Share_Storage	Device	Expertise	Technology	Firm_Size	Performance	BIM_Capability	BIM_Adoption	BIM_Maturity	Level_of_BIM_maturity	Level_of_BIM_adoption	Level_of_BIM_Capability
4.00	Construction	2.60	2.80	1.00	1.00	3	7.40	Small	-3	11.40	2	5.20	None	Basic	Basic
9.00	Construction	9.60	.00	1.00	3.00	5	13.60	Large	0	21.60	4	38.40	Advanced	Advanced	Advanced
11.00	Construction	9.80	.00	1.00	1.00	3	11.80	Medium	0	16.80	4	39.20	Advanced	Advanced	Intermediate
18.00	Construction	3.00	2.80	2.00	4.00	4	11.80	Small	3	16.80	2	6.00	None	Basic	Intermediate
20.00	Construction	4.60	1.00	4.00	2.00	4	11.60	Small	3	16.60	2	9.20	None	Basic	Intermediate
26.00	Construction	10.60	.00	.00	2.00	1	12.60	Large	0	16.60	4	42.40	Expert	Advanced	Intermediate
27.00	Construction	4.60	1.00	1.00	2.00	1	8.60	Medium	0	11.60	2	9.20	None	Basic	Basic
36.00	Construction	2.60	1.60	1.00	4.00	7	9.20	Medium	1	18.20	2	5.20	None	Basic	Intermediate
37.00	Construction	.00	.00	3.00	4.00	1	7.00	Small	0	9.00	1	.00	None	None	None
42.00	Construction	4.40	1.20	3.00	1.00	7	9.60	Medium	0	18.60	2	8.80	None	Basic	Intermediate
44.00	Construction	3.60	1.00	2.00	2.00	3	8.60	Large	0	14.60	2	7.20	None	Basic	Basic
45.00	Construction	8.20	2.00	1.00	5.00	4	16.20	Large	3	23.20	4	32.80	Advanced	Advanced	Advanced
62.00	Construction	.40	.40	2.00	2.00	3	4.80	Small	0	8.80	1	.40	None	None	None
63.00	Construction	.40	.20	2.00	3.00	3	5.60	Large	0	11.60	1	.40	None	None	Basic
64.00	Construction	2.00	2.60	2.00	3.00	4	9.60	Medium	0	15.60	1	2.00	None	None	Intermediate
65.00	Construction	1.60	.60	3.00	2.00	4	7.20	Small	-3	12.20	1	1.60	None	None	Basic

Table 4-5 Organisation details and organisational assessment scores: Consulting

Participant	Firm	Platform	Software	Share_Storage	Device	Expertise	Technology	Firm_Size	Performance	BIM_Capability	BIM_Adoption	BIM_Maturity	Level_of_BIM_maturity	Level_of_BIM_adoption	Level_of_BIM_Capability
6.00	Consulting	5.60	3.00	1.00	4.00	7	13.60	Large	0	23.60	3	16.80	Basic	Intermediate	Advanced
10.00	Consulting	4.40	.00	1.00	3.00	5	8.40	Small	-1	14.40	2	8.80	None	Basic	Basic
15.00	Consulting	4.20	2.40	1.00	3.00	1	10.60	Small	-1	12.60	2	8.40	None	Basic	Basic
16.00	Consulting	3.60	.00	.00	2.00	5	5.60	Medium	0	12.60	2	7.20	None	Basic	Basic
22.00	Consulting	1.60	.40	1.00	2.00	4	5.00	Small	-2	10.00	1	1.60	None	None	None
23.00	Consulting	4.00	.00	4.00	2.00	3	10.00	Large	0	16.00	2	8.00	None	Basic	Intermediate
24.00	Consulting	2.60	1.20	3.00	1.00	7	7.80	Small	-1	15.80	2	5.20	None	Basic	Intermediate
25.00	Consulting	1.40	1.60	1.00	4.00	5	8.00	Large	-1	16.00	1	1.40	None	None	Intermediate
31.00	Consulting	1.00	1.00	4.00	2.00	1	8.00	Large	1	12.00	1	1.00	None	None	Basic
32.00	Consulting	2.00	3.00	1.00	3.00	5	9.00	Large	1	17.00	1	2.00	None	None	Intermediate
34.00	Consulting	5.00	.20	4.00	3.00	4	12.20	Large	0	19.20	2	10.00	None	Basic	Intermediate
35.00	Consulting	4.60	.00	1.00	2.00	1	7.60	Large	0	11.60	2	9.20	None	Basic	Basic
38.00	Consulting	4.40	1.80	2.00	4.00	4	12.20	Small	3	17.20	2	8.80	None	Basic	Intermediate
39.00	Consulting	9.00	2.80	3.00	1.00	3	15.80	Small	0	19.80	4	36.00	Advanced	Advanced	Intermediate
41.00	Consulting	8.40	.80	1.00	2.00	5	12.20	Medium	-1	19.20	4	33.60	Advanced	Advanced	Intermediate
46.00	Consulting	2.60	.40	1.00	2.00	5	6.00	Large	3	14.00	2	5.20	None	Basic	Basic
47.00	Consulting	4.40	3.20	2.00	3.00	4	12.60	Medium	0	18.60	2	8.80	None	Basic	Intermediate
49.00	Consulting	2.20	1.00	1.00	3.00	4	7.20	Large	0	14.20	1	2.20	None	None	Basic
51.00	Consulting	4.20	2.00	1.00	3.00	5	10.20	Medium	1	17.20	2	8.40	None	Basic	Intermediate
52.00	Consulting	3.80	2.40	4.00	3.00	5	13.20	Large	3	21.20	2	7.60	None	Basic	Advanced
53.00	Consulting	2.80	.60	3.00	1.00	4	7.40	Small	0	12.40	2	5.60	None	Basic	Basic
55.00	Consulting	6.80	3.00	2.00	1.00	3	12.80	Small	0	16.80	3	20.40	Intermediate	Intermediate	Intermediate
56.00	Consulting	3.40	3.00	1.00	1.00	3	8.40	Small	0	12.40	2	6.80	None	Basic	Basic
57.00	Consulting	2.60	.60	1.00	2.00	5	6.20	Large	0	14.20	2	5.20	None	Basic	Basic
59.00	Consulting	4.40	2.00	4.00	6.00	5	16.40	Medium	3	23.40	2	8.80	None	Basic	Advanced
60.00	Consulting	2.00	.00	1.00	2.00	4	5.00	Medium	1	11.00	1	2.00	None	None	Basic
66.00	Consulting	1.20	1.20	1.00	2.00	4	5.40	Large	-1	12.40	1	1.20	None	None	Basic

Participant	Firm	Platform	Software	Share_Storage	Device	Expertise	Technology	Firm_Size	Performance	BIM_Capability	BIM_Adoption	BIM_Maturity	Level_of_BIM_maturity	Level_of_BIM_adoption	Level_of_BIM_Capability
67.00	Consulting	2.00	1.20	3.00	3.00	7	9.20	Large	3	19.20	1	2.00	None	None	Intermediate
68.00	Consulting	.60	.80	3.00	1.00	5	5.40	Large	-1	13.40	1	.60	None	None	Basic
69.00	Consulting	3.60	1.00	3.00	1.00	7	8.60	Large	0	18.60	2	7.20	None	Basic	Intermediate
70.00	Consulting	.80	1.00	2.00	3.00	5	6.80	Large	3	14.80	1	.80	None	None	Basic
71.00	Consulting	3.40	3.20	2.00	5.00	5	13.60	Large	0	21.60	2	6.80	None	Basic	Advanced
72.00	Consulting	6.80	1.20	2.00	1.00	1	11.00	Large	0	15.00	3	20.40	Intermediate	Intermediate	Basic

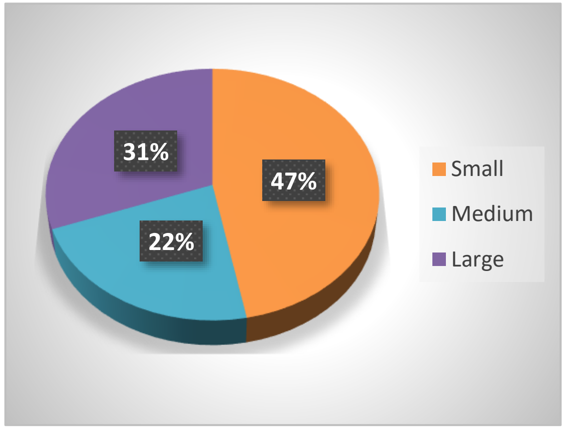

Figure 4-2 Range of firms based on their size

Figure 4-2 above shows the size of the consulting and construction organisations.

4.1.3 Level of BIM adoption in consulting and construction firms

The level of BIM adoption has been categorised into the following: none, basic, intermediate and expert adopters. The results obtained from the levels of BIM adoption by consulting and construction firms are represented in Table 4.6, where 30.6% of consulting and construction firms are none adopters, meaning no use of BIM related technologies in their organisations and 51% are Basic adopters, 6% are Intermediate adopters and 12% advance adopters with zero or no Expert adopters.

Table 4-6 Level of BIM adoption

Level of BIM adoption

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	None	15	30.6	30.6	30.6
	Basic	25	51.0	51.0	81.6
	Intermediate	3	6.1	6.1	87.8
	Advanced	6	12.2	12.2	100.0
	Total	49	100.0	100.0	

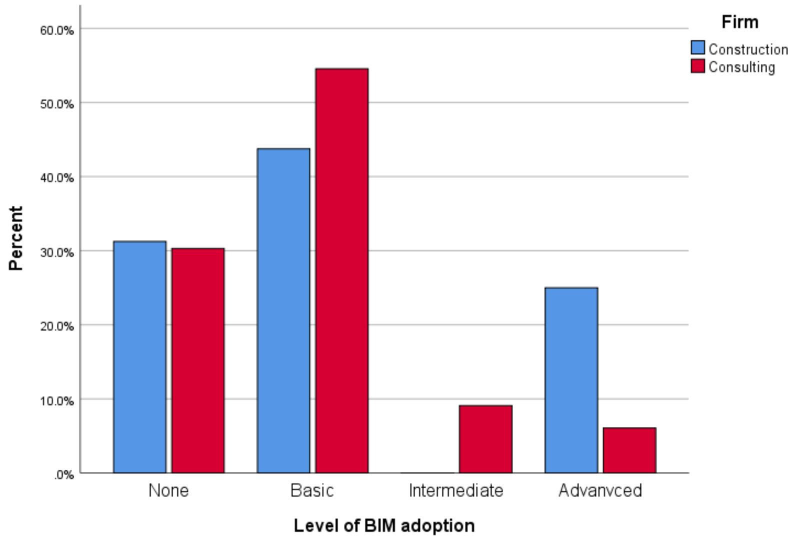

Figure 4-3 Level of BIM adoption

Figure 4-3 shows a split in levels of adoption within each category between the consulting and construction companies.

4.1.4 Level of BIM capability in consulting and construction firms

The level of BIM capability has been categorised into the following competency levels, none, basic, intermediate and expert. The results obtained of the levels consulting and construction firms are represented in Table 4.7, where 6% of both consulting and construction firms have no BIM capabilities, 40.8% have Basic BIM capabilities, 40.8% have Intermediate BIM capabilities and 12% Advance BIM capabilities with zero or no organisation with Expert BIM capabilities.

Table 4-7 Level of BIM capability

Level of BIM Capability					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	None	3	6.1	6.1	6.1
	Basic	20	40.8	40.8	46.9
	Intermediate	20	40.8	40.8	87.8
	Advanced	6	12.2	12.2	100.0
	Total	49	100.0	100.0	

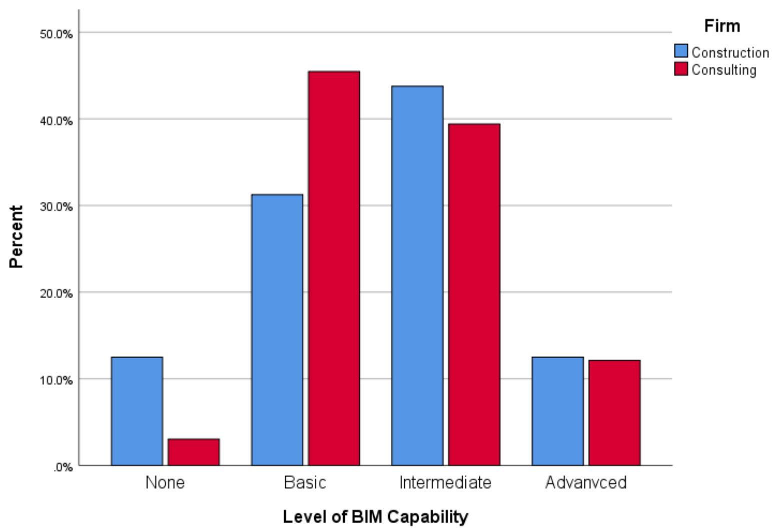

Figure 4-4 Level of BIM capability

Figure 4-4 shows a split in levels of capability within each category between the consulting and construction companies.

4.1.5 Level of BIM maturity in consulting and construction firms

The level of BIM maturity has been categorised into the following competency levels, none, basic, intermediate and expert. The results obtained of the levels consulting and construction firms are represented in Table 4.8, where 81% of both consulting and construction firms have no BIM maturity, 2% have the basic level of BIM maturity, 4% have the intermediate level BIM of maturity and 10% the advanced level of BIM maturity, with 2% having the expert level of BIM maturity.

Table 4-8 Level of BIM Maturity

Level of BIM Maturity

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	None	40	81.6	81.6	81.6
	Basic	1	2.0	2.0	83.7
	Intermediate	2	4.1	4.1	87.8
	Advanced	5	10.2	10.2	98.0
	Expert	1	2.0	2.0	100.0
	Total	49	100.0	100.0	

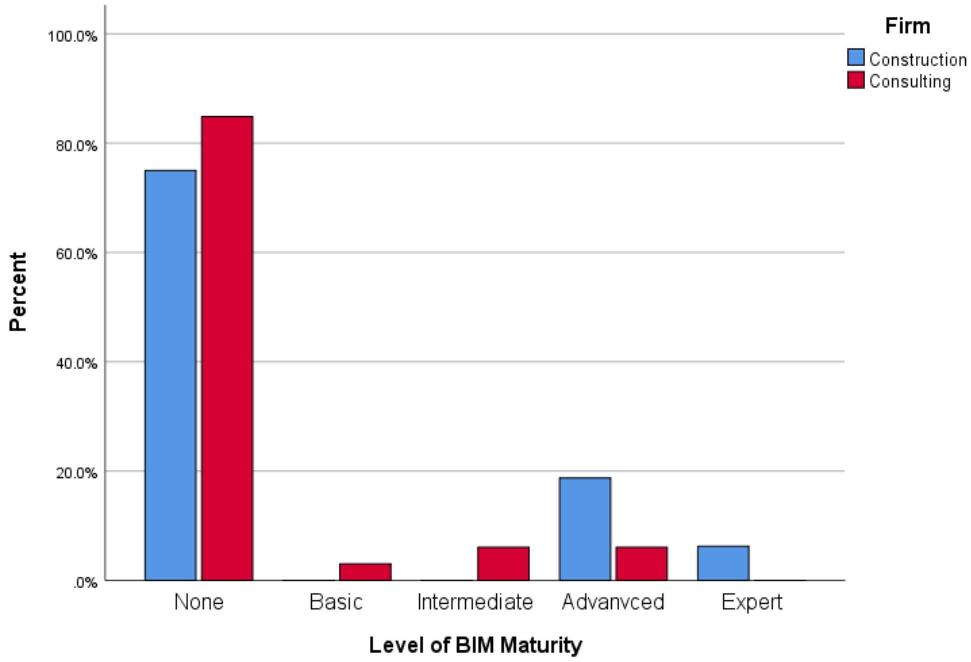

Figure 4-5 Level of BIM Maturity

Figure 4-5 shows a split in levels of capability within each category between the consulting and construction companies.

4.1.6 Perceived benefits of BIM adoption

Figure 4-6 shows respondents' perception of BIM benefits, where 72% of respondents strongly agreeing that BIM allows for better collaborative environments, 57% respondents strongly agree that BIM improves overall project delivery, 43% respondents strongly agree BIM improves project cost performance and enhances project scheduling. The perceived BIM Benefits of BIM are also populated and presented in Table 4-9.

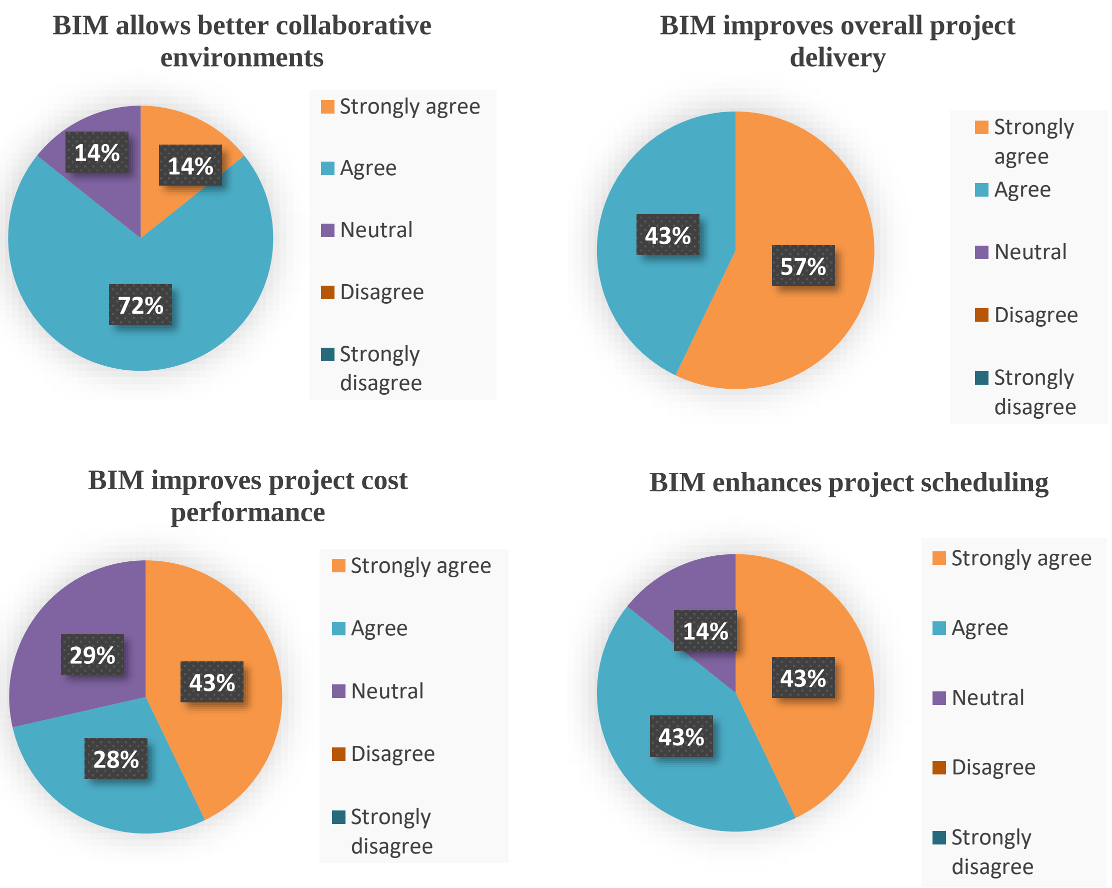

Figure 4-6 Perceived benefits of BIM on project performance

Table 4-9 Perceived BIM Benefits

Item	Performance area	Mean Item Score	Ranking
1	BIM improves overall project delivery	0,91	1
2	BIM enhances project scheduling	0,86	2
3	BIM improves project cost performance	0,83	3
4	BIM allows better collaborative environments	0,80	4

Table 4-10 Perceived drivers of BIM use

Item	Performance area	Mean Item Score	Ranking
1	To improve project delivery	0,86	1
2	To stay competitive in the market	0,71	2
3	Top management request	0,43	3
	To reduce operating costs	0,14	4
4	It was a design and build contract	0,14	5

Table 4-9 and Table 4-10 show the perceived benefits and perceived drivers of BIM adoption respectively. BIM is perceived to improve project delivery and the main driver of BIM adoption is to improve project delivery.

4.2 Interviews

The purpose of the interviews in this research are to observe and document the environment within which consulting and construction firms operate in. The data served as a reference tool in guiding the analysed findings with the observations made in the various firms. Table 4-11 and summarises the number of firms visited and the total respondents who agreed to a short interview. Fourteen construction firm practitioners and twenty three consulting firm practitioners were interviewed.

Table 4-11 Interviews distribution by site or office

Category of primary or core service provided by the firm	Number of sites/offices visited	Total number of personnel interviewed from the site/office visits
Construction	9	14
Consulting	6	23
Total	**15**	

4.2.1 Background profile of respondents

The following section provides a background of the respondents. Table 4-12 starts off with a gender based comparison between the firms. Table 4-13 details the age categories of respondents. Table 4-14 list the qualification groups in the various firms. Table 4-15 list the occupational titles held by the participants in their current projects or firms as at the time of the interviews.

Table 4-12 Background profile of respondents - gender

		Female	Male	
Firm_Type	Consulting	11	12	23
	Construction	6	8	14
Total		17	20	37

Table 4-13 Background profile of respondents - age

		18 - 25	26 -35	36 - 55	56 -65	
Firm_Type	Consulting	5	13	4	1	23
	Construction	2	9	2	1	14
Total		7	22	6	2	37

Table 4-14 Background profile of respondents - qualification

		Masters/MBA	Honours/Btech	Degree	Diploma	
Firm_Type	Consulting	3	10	8	2	23
	Construction	1	5	5	3	14
Total		4	15	13	5	37

Table 4-15 Background profile of respondents – occupation

Occupation/Title	Total participants
Contracts Manager	1
Project Manager	1
Architect	10
Quantity Surveyor	4
Health and Safety Officer	1
Site Manager	1
Operations Manager	1
Electrical Engineer	3
Civil Engineer	5
Site agent	1
Mechanical Engineer	3
Town Planner	1
Legal advisor	1
Environmentalist	1
Property Developer	1
Process facilitator	1
	37

4.2.2 Technological infrastructure

Table 4-16 Technological infrastructure

	firm	N	Mean
Technological Infrastructure	Construction	14	1.5000
	Consulting	23	3.3043

Table 4-16 represents the average level of the technological infrastructure observed from consulting and construction offices. Figure 4.7 depicts the picture, where construction sites had poor technical infrastructure compared to consulting offices.

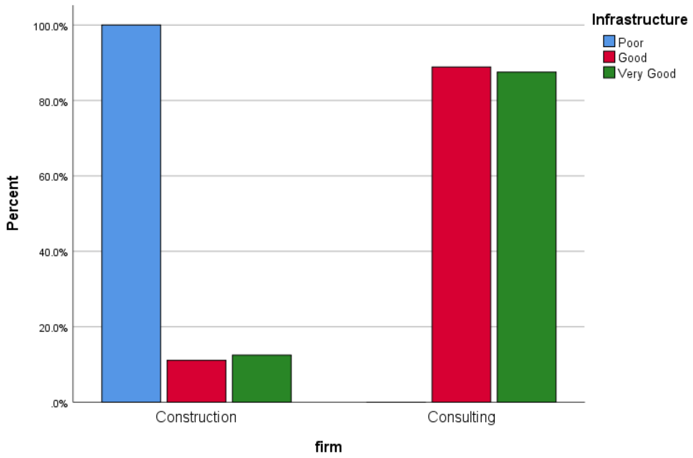

Figure 4-7 Technical infrastructure

Table 4-17 Participants understanding of BIM

	BIM is a:	Frequency	Percent	Valid Percent	Cumulative Percent
Valid	0.No answer	5	13.5	13.9	13.9
	1.technology	11	29.7	30.6	44.4
	2.a process	1	2.7	2.8	47.2
	3.a software	1	2.7	2.8	50.0
	4.policies	7	18.9	19.4	69.4
	5.is a project delivery method	2	5.4	5.6	75.0
	6.is technology, process, software	5	13.5	13.9	88.9
	7.no knowledge of BIM	4	10.8	11.1	100.0
	Total	36	97.3	100.0	
Missing	System	1	2.7		
Total		37	100.0		

Table 4-17 shows the responses of the participants understanding of BIM with the highest 30% showing that the respondents understand BIM to be only a from technology.

4.3 Data analysis

4.3.1 Test of Hypothesis

This section of the study uses the data presented and applies statistical analysis in order to test the research hypothesis. The general Research hypothesis is restated as follows:

> ***There is a significant difference in the level of adoption, capability and maturity of BIM, between consulting and construction firms.***

The first set of sub-hypotheses derived from the general hypothesis, tests the difference in levels of BIM assessment measures and the type of service a firm provides (consulting or construction service), the sub-hypotheses are:

H_1: *There is a significant difference in the BIM Capability levels between consulting and construction firms*

H_2: *There is a significant difference in the BIM Adoption levels between consulting and construction firms*

H_3: *There is a significant difference in the BIM Maturity levels and project performance*

The second set of hypothesis tests if there is any relationship, between the level of BIM adoption and project performance in consulting and construction firms. The hypothesis is restated as follows:

H_4: *There is a significant relationship between the level of BIM maturity and project performance of consulting and construction firms*

All the above stated hypotheses have a null hypothesis version that states that there is no significance in the difference of means of the variables tested for each, these null hypothesis are stated in detail, in the relevant section with the test result.

4.3.1.1 H1: BIM capability

The study sought to test the following hypothesis:

H_0: *There is a significant difference in the BIM Capability levels between consulting and construction firms*

H_1: *There is no significant difference in the BIM Capability levels between consulting and construction firms*

Results of the T-test of the data is presented in Table 4-18; the difference between the means of different firms based on the analysis of the BIM Capability levels.

Table 4-18 T-Test for BIM capability levels

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Level of BIM Capability	Equal variances assumed	.626	.433	-.180	47	.858	-.04356	.24264	-.53169	.44456
	Equal variances not assumed			-.169	25.561	.867	-.04356	.25821	-.57475	.48763

H_1 states that there is a significant difference in the BIM Capability levels between consulting and construction firms. The results of the Levene's Test for Equality of Variances show that:

The ρ-value of 0.858 is not significant at the 0.05 significance level.

Based on these findings, the null hypothesis one that states that there is no statistically significant difference between the level of BIM capability in consulting and construction firm is accepted. It can therefore be deduced from these findings that there is no significant difference in the level of BIM capability between consulting and construction firms.

4.3.1.2 H1: BIM adoption

The study sought to test the following hypothesis:

H_2: *There is a significant difference in the BIM Adoption levels between consulting and construction firms*

H_2 null: *There is no significant difference in the BIM Adoption levels between consulting and construction firms*

Results of the T-test of the data is presented in Table 4-19 T-Test for BIM adoption levels; the difference between the means of different firms based on the analysis of the BIM adoption levels.

Table 4-19 T-Test for BIM adoption levels

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Level of BIM adoption	Equal variances assumed	3.550	.066	.977	47	.334	.27841	.28510	-.29514	.85195
	Equal variances not assumed			.860	22.160	.399	.27841	.32370	-.39263	.94945

H_2 states that there is a significant difference in the BIM adoption levels between consulting and construction firms. The results of the Levene's Test for Equality of Variances indicate the assumption of equal variances and therefore:

the ρ-value of 0.334 is not significant at the 0.05 significance level.

Based on these findings, the null hypothesis two that states that there is no statistically significant difference between the level of BIM adoption in consulting and construction firm is accepted. It can therefore be deduced from these findings that there is no significant difference in the level of BIM adoption between consulting and construction firms.

4.3.1.3 H1: BIM maturity

The study sought to test the following hypothesis:

H_3: *There is a significant difference in the BIM Maturity levels between consulting and construction firms*

H_3 null: *There is no significant difference in the BIM Maturity levels between consulting and construction firms*

Results of the T-test of the data is presented in Table 4-20; the difference between the means of different firms based on the analysis of the BIM Maturity levels.

Table 4-20 T-Test for BIM maturity levels

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Level of BIM Maturity	Equal variances assumed	10.072	.003	1.444	47	.155	.47917	.33185	-.18842	1.14675
	Equal variances not assumed			1.208	20.054	.241	.47917	.39655	-.34788	1.30621

H_3 states that there is a significant difference in the BIM maturity levels between consulting and construction firms. The results of the Levene's Test for Equality of Variances indicate equal variances not assumed and therefore:

the ρ-value of 0.241 is not significant at the 0.05 significance level.

Based on these findings, the null hypothesis 3 that states that there is no statistically significant difference between the level of BIM maturity in consulting and construction firm is accepted. It can therefore be deduced from these findings that there is no significant difference in the level of BIM maturity between consulting and construction firms.

4.3.1.4 BIM maturity and project performance

The second set of hypothesis tests if there is any relationship, between the level of BIM maturity and project performance in consulting and construction firms. The hypothesis is restated as follows:

H_4: *There is a significant relationship between the level of BIM maturity and project performance*

H_4 null: *There is no significant relationship between the level of BIM maturity and project performance*

To test this hypothesis, the Pearson correlation is used and Table 4-21 and Table 4-22details the result of this analysis.

Table 4-21 Standard deviation: BIM maturity and performance

	Mean	Std. Deviation	N
Level of BIM Maturity	1.4898	1.10156	49
Performance	.35	1.508	49

Table 4-22 Relationship between BIM maturity levels and project performance

Correlations

		Level of BIM Maturity	Performance
Level of BIM Maturity	Pearson Correlation	1	-.029
	Sig. (2-tailed)		.842
	N	49	49
Performance	Pearson Correlation	-.029	1
	Sig. (2-tailed)	.842	
	N	49	49

H_4 states that there is a relationship between BIM maturity levels and project performance. The results of Pearson correlation of -0.029 (a weak negative relationship between the two variables)

the ρ-value of 0.842 is not significant at the 0.05 significance level.

Based on these findings, the null hypothesis four that states that there is no statistically significant difference between the level of BIM maturity and project performance is accepted. It can therefore be deduced from these findings that there is no significant difference between the level of BIM maturity and project performance.

4.3.1.5 BIM capability and project performance

The second set of hypothesis tests if there is any relationship, between the level of BIM capability and project performance in consulting and construction firms. The hypothesis is restated as follows:

H_5: *There is a significant relationship between the level of BIM capability and project performance*

H_5 null: *There is no significant relationship between the level of BIM capability and project performance*

To test this hypothesis, the Pearson correlation is used. Table 4-23 and Table 4-24 details the result of this analysis.

Table 4-23 Standard deviation: BIM capability and performance

	Mean	Std. Deviation	N
Performance	.35	1.508	49
BIM_Capability	15.7265	3.77816	49

Table 4-24 Relationship between BIM capability levels and project performance

Correlations

		Performance	BIM_Capability
Performance	Pearson Correlation	1	.412**
	Sig. (2-tailed)		.003
	N	49	49
BIM_Capability	Pearson Correlation	.412**	1
	Sig. (2-tailed)	.003	
	N	49	49

**. Correlation is significant at the 0.01 level (2-tailed).

H_4 states that there is a relationship between BIM capability levels and project performance. The results of Pearson correlation of 0.412 (a positive relationship between the two variables)

the ρ-value of 0.003 is significant

Based on these findings, the hypothesis that states that there is a statistically significant difference between the level of BIM capability and project performance is accepted. It can therefore be deduced from these findings that there is a significant difference between the level of BIM capability and project performance.

4.3.2 Testing the conceptual framework of the study

In chapter 2, while developing the conceptual framework of the study, literature showed a correlation in BIM adoption, BIM capability and BIM maturity, wherein, the levels of BIM capability affect the levels of BIM Maturity and Adoption. This section presents the statistical analysis to verify and or support this framework as presented in Table 4-25.

Table 4-25 Relationship between BIM adoption, capability and maturity

Correlations

		BIM_Capability	BIM_Adoption	BIM_Maturity
BIM_Capability	Pearson Correlation	1	.546**	.492**
	Sig. (2-tailed)		.000	.000
	N	49	49	49
BIM_Adoption	Pearson Correlation	.546**	1	.955**
	Sig. (2-tailed)	.000		.000
	N	49	49	49
BIM_Maturity	Pearson Correlation	.492**	.955**	1
	Sig. (2-tailed)	.000	.000	
	N	49	49	49

**. Correlation is significant at the 0.01 level (2-tailed).

The results of Pearson correlation show a significant correlation between the levels of BIM capability, adoption and maturity. The stronger relationship is found between BIM maturity and BIM adoption, at a Pearson correlation value of 0.955.

4.4 Research findings

This section presents the research findings in relation to the research objectives. In doing this, the findings are first presented in relation to research objectives of the study. The findings are also discussed in relation to the literature reviewed in Chapter two of this study to check if whether the findings of this study are in line with the findings from literature or they differ. General discussions from observations in an interview also presented in this section.

4.4.1 Levels of adoption, capability and maturity

Research objective 1: Assess the level of BIM adoption, capability and maturity in consulting and construction firms.

The level of BIM adoption, rated from none adopter to expert adopter, the study found 30.6% of consulting and construction firms to be none adopters, 6% intermediate adopters and 12% advanced adopters with zero or no expert adopter.

The level of BIM capability, rated from no capability to expert capabilities, the study found 6% of consulting and construction firms to have no BIM capabilities, 40.8% with basic BIM capabilities, 40.8% with advanced BIM capabilities, with zero or no expert capabilities in both consulting and construction firms.

The level of maturity, rated from no maturity to the expert level of maturity: 81% of both consulting and construction firms have zero or no BIM maturity, 2% have the basic level of BIM maturity, 4% have the intermediate level BIM of maturity and 10% the advanced level of BIM maturity, with 2% having the expert level of BIM maturity.

4.4.2 Comparison of levels between consulting and construction

Research objective 4: Assess if there is any difference in the level of adoption, capability and maturity of BIM between consulting and construction firms

- The study found that that there is no significant difference in the level of BIM capability between consulting and construction firms.
- The study found that that there is no significant difference in the level of BIM adoption between consulting and construction firms.
- The study found no significant difference in the level of maturity in BIM between consulting and construction firms.

4.4.3 Relationship between BIM maturity, capability and project performance

Research objective 5: Evaluate if there is any relationship between level of BIM maturity and project performance

- The study found no significant difference between the level of BIM maturity and project performance.
- The study found that there is a statistically significant relationship between the level of BIM capability and project performance

4.4.4 Perceived benefits and drivers BIM adoption

Research objective 6: Establish perceived benefits of BIM in the South African construction industry. The perceived benefits of BIM adoption are found to be that (i) BIM improves project delivery, with a mean item score of 0,91, (ii) BIM enhances project scheduling, with a mean item score of 0,86, (iii) BIM improves project cost performance, with a mean item score of 0,83

4.5 Discussion of findings

Findings from the observations and responses during the interviews and are discussed, thereafter, general discussions on findings.

4.5.1 Relationship between the levels of BIM adoption, capability and adoption

The conceptual framework of the study discussed how the three components, BIM adoption, BIM capability and BIM performance are related and affect each other. The results of Pearson correlation show a significant correlation between the levels of BIM capability, adoption and maturity. The stronger relationship is found between BIM maturity and BIM adoption, at a Pearson correlation value of 0.955.

To study BIM adoption, capability and maturity, literature reviewed shows that BIM competency assessments are a mix of internal organisation factors, external factors and technological factors. Recapping on the conceptual framework of the study, it was shown that:

- BIM capability is a function of BIM fields, technology, processes and policies
- BIM adoption is affected by internal organisation factors, external factors and technological factors
- BIM maturity is the advancement in BIM capability and BIM adoption

As illustrated in the conceptual framework of this study in section 2.7.1 (and recapped below), BIM adoption, capability and maturity are interrelated, in that:

- BIM capability (competency) affects BIM adoption (actual use), where, if organisations have the minimum BIM requirements, they can adopt BIM and vice versa, when firms adopt BIM, the competency levels are increased through learning and use of BIM related tools and workflows
- BIM adoption affects BIM maturity, where, as firms adopt BIM, the levels of BIM maturity increase (or decrease) due to the achievement (or not) of the perceived benefits and usefulness of using BIM (derived for the Technology Acceptance model). This relationship is also vice versa, where the levels of BIM Maturity influence BIM adoption, as firms mature and realised the full benefits of using BIM, their adoption levels can increase.

The organisational factors (which include processes and policies) presented in the findings include the expertise of the individuals within firms, where variables such as qualifications and years of experience within the construction industry contributed the analysis of competencies. The background profile of the respondents reported that 87% of respondents have a tertiary qualification. More than 66% of the respondents had work experience within the construction industry of above ten years. More than 73% of respondents identified registration with at least one Professional Council. As an organisational factor, registration with professional councils is important as it allows for the platform for continuous professional development to keep individuals abreast with developments in their fields, such as BIM.

The technological factors presented in the findings include hardware, software, networks and the sum of extent of use of these items by individuals within organisations, thus representing organisational extent of use. The adoption of technology within organisations is a factor of availability, the external environment and the organisational context. The findings revealed that more than 85% of respondents had access to laptops provided by their organisations and 59% with mobile phones. These devices are essential as they form the basis of software application usage. More than 79% of respondents identified an organisational, internal network based server for the sharing and storing of project and company information. Literature reviewed states that digital storage is the current dominant form of data storage and digital data management and organisation is becoming an important for the industry. Literature also attest in that: BIM in practice suggest that in the present state there are indeed technologies available, which can potentially improve the work process. However, the lack of tools supporting the integration of different project phases has been a major concern

When testing the levels of BIM maturity, the study's statistical analysis found not significant difference between the consulting and construction firms. However, complementing the results obtained in Level of BIM maturity in consulting and construction firms, the study with the observations from the interviews

The construction firms' practitioner's competency scores exceed those from consulting firms when using the same platform, even though not statistically significant. The observation is that, construction firm based professionals are more expert users of their relevant technological applications. In that, a quantity surveyor (for an example) based in a construction firms uses in-depth, detailed data and explores the capabilities of software than those in consulting firms, who uses the same software to generate estimations and high-level financial reporting based on summarised data. The consulting firms might have a larger representation of software usage but, the extent of use within the software capabilities, differs between consultant based and construction based practitioners. This difference in extent of use of BIM technologies (higher in construction firms) might have been offset by the higher level of use of BIM technologies in consulting firms, hence the statistical analysis showed no significant difference in the levels of BIM maturity.

4.5.2 BIM adoption, capability and maturity

The findings revealed that the levels of BIM adoption in consulting and construction firms to be is mainly "None" to "Basic", with a larger number firms construction firms in the "Advance" level than consulting firms. However, the statistical analysis showed that there is no significant difference in the mean adoption level of these two groups. Literature states that BIM adoption as per the development conceptual framework, is influenced or driven by technology. Firms that have professional users who know how to use discipline specific software and application were found to have greater adoption motivation than firms with no-expert users who have limited to no availability of technological resources.

The organisational make up of consulting firms is found to be different than that of a construction firm. Consulting firms on the one hand are found to have fewer expert employees who are capable and comfortable with using computer software to improve efficiency to the level of detail and interrogation that Contractor based Professionals do. Construction firms on the other hand have a larger number of employees with a vast and diverse backgrounds, from foremen with no educational background to senior management with specialist degrees. Most of the consulting firms that indicated to be using BIM were mostly referring to the use of the basic modelling software and mainly for architectural visualisation purposes and the designed models did not necessarily feed into other discipline packages. The survey data revealed that there is an increasing take-up of BIM technologies in the South African construction industry. However, the current processes that architects use for producing information still replicate those that are typical of CAD use, the survey indicates that South Africa is still behind leading BIM-using countries, although the trend lines indicate that this is a relatively short period.

Through literature review, the performance assessment measures used for BIM adoption, capability and maturity were identified. Literature reviewed listed the available BIM assessment measures used within the construction industry around the world, with the commonly used BIM assessment framework developed in the United States. The Interactive Capability Maturity Model (ICMM) - National Building Information Modelling Standard (NBIMS), (NIBS 2007) is an elaborate assessment tool with 11 topics (A – K) assessed against ten maturity levels (1 – 10). It is the most commonly used BIM maturity assessment tool followed by the BIM QuickScan (Sebastian and van Berlo, 2010). Literature review showed that several tools to evaluate the BIM maturity levels have been developed around the globe, over the past years (Månsson and Lindahl, 2016). These frameworks are intended to measure the performance of organisations and teams but are not applicable across all organisational scales (Succar, 2010) and or countries.

4.5.3 Summary

Practitioners within the South African Construction Industry do not fully understand the concepts of Building Information Modelling, both in academia and in practice. This affects the reports on the adoption of BIM. This study has shown and emphasised that, BIM is not a type of software but rather, a digital project delivery method that uses innovative technologies, processes and policies. Some of the practitioners who were interviewed in this study, and reported themselves to be expert users of BIM, were found to refer to the 3D model visualisation of software such as Revit, Tekla, Bentley and Autodesk or similar and related software. Some participants would indicate that they have never worked on BIM before, but when probed further about the platforms and applications they use, you would find that they work on a network-based server, receiving and sending project files in various formats and using software with 4D and 5D capabilities, but because 4D planning and 5D construction schedules are not the same with BIM in terms of the participants understanding , the practitioners would indicate that they have never used BIM tools. This misconception and misunderstanding of what BIM is has resulted in inconsistent reporting of BIM requirements and performance planning in previous studies. Hence this study designed the questionnaires to have indirect functional questions rather than direct and straightforward questions.

CHAPTER FIVE

5 CONCLUSIONS AND RECOMMENDATIONS

Introduction

This study assessed the level of BIM adoption, capability and maturity in consulting and construction firms and evaluated if there were differences in the level of adoption, capability and maturity of BIM between consulting and construction firms. The study also evaluated if there is any relationship between level of BIM maturity and project performance of consulting and construction firms. Lastly, the study reports on the perceived benefits of BIM in the South African construction industry.

To achieve the study objectives, the study began with a literature review process, both local and international, to identify relevant and related themes to this study. The reviewed literature provided a basis for the study, identifying the collective, prominent and key concepts to this study, where the theoretical model was presented and the conceptual model of the study was formulated. The formulation on the conceptual model and reference to the study objectives, assisted in designing and developing the appropriate research method and tools for the study. The study followed a sequential mixed method research approach of quantitative and qualitative methods, where data collection methods included: online survey questionnaires; face-to-face interviews and general observations. The research data was analysed using descriptive and inferential statistics. Thereafter, the results presented and were used to answer the research objectives of the study. This sections offers the summary of the study, the key findings, conclusion, recommendations and areas for further research.

5.1 Summary of findings

The summary of the research findings are presented below, in order of the research objectives, however, there key finding is presented first.

Key finding

When assessing the relationship between the different levels of BIM adoption, capability and maturity, it is found that:

- There is a statistically significant relationship between the level of BIM capability and project performance

Research findings: aim and objectives re-visited

From the research aim of the study, which is to evaluate the extent to which BIM adoption, capability and maturity levels differ between consulting and construction firms. This has been achieved and the following conclusions can be made. 30.6% Of consulting and construction firms are none adopters, meaning no use of BIM related technologies in their organisations and 51% are Basic adopters, 6% are Intermediate adopters and 12% advance adopters with zero or no Expert adopters. 6% of both consulting and construction firms had none BIM capabilities, 40.8% had Basic BIM capabilities, 40.8% had Intermediate BIM capabilities and 12% Advance BIM capabilities with zero or no organisation with Expert BIM capabilities. The majority of the of both consulting and construction firms (81%) have none BIM maturity, 2% had the basic level of BIM maturity, 4% had the intermediate level BIM of maturity and 10% the advanced level of BIM maturity, with 2% having the expert level of BIM maturity. This study has treated BIM not as a specific software but rather as a collection of project delivery approaches that are driven by computable, data rich methods (which can be the use of various software) to generate building information, in digital accessible formats.

The research objectives of this study have been achieved as revisited in this section. The levels of BIM adoption, capability and maturity, as presented and analysed using statistical tools, are in line with existing literature which states that there is gradual adoption of BIM in South Africa. Further research is however necessary as BIM adoption continues to grow and until sufficient participants can be found in order to improve sample sizes and make better inferences about the populations represented. The larger the quality and reliability of data to the populations represented, the better the quality of research towards the compilation of BIM policies and implementation guides. The summary of the research findings are presented next, in the order of the research objectives.

Research objective one is to assess the level of BIM adoption, capability and maturity in consulting and construction firms

- The level of BIM adoption, rated from none adopter to expert adopter, the study found 30.6% of consulting and construction firms to be none adopters, 6% intermediate adopters and 12% advanced adopters with zero or no expert adopter.
- The level of BIM capability, rated from no capability to expert capabilities, the study found 6% of consulting and construction firms to have no BIM capabilities, 40.8% with basic BIM capabilities, 40.8% with advanced BIM capabilities, with zero or no expert capabilities in both consulting and construction firms.
- The level of maturity, rated from no maturity to the expert level of maturity: 81% of both consulting and construction firms have zero or no BIM maturity, 2% have the basic level of BIM maturity, 4% have the intermediate level BIM of maturity and 10% the advanced level of BIM maturity, with 2% having the expert level of BIM maturity.

Research objective two is to assess if there is any difference in the level of adoption, capability and maturity of BIM between consulting and construction firms

- The study found that that there is no significant difference in the level of BIM capability between consulting and construction firms.
- The study found that that there is no significant difference in the level of BIM adoption between consulting and construction firms.
- The study found no significant difference in the level of maturity in BIM between consulting and construction firms.

Research objective three is to evaluate if there is any relationship between level of BIM maturity and project performance

- The study found no significant difference between the level of BIM maturity and project performance but
- This research found that there is a relationship between BIM capability levels and project performance. The results of Pearson correlation of 0.412 (a positive relationship between the two variables) where the *ρ-value of 0.003 is significant.*

Research objective four is to establish perceived benefits of BIM in the South African construction industry

- The perceived benefits of BIM adoption are found to be that (i) BIM improves project delivery, with a mean item score of 0,91, (ii) BIM enhances project scheduling, with a mean item score of 0,86, (iii) BIM improves project cost performance, with a mean item score of 0,83

Findings from the interviews

From the interviews and conversations with participants, it is found that practitioners within the South African Construction Industry do not fully understand the concepts of Building Information Modelling. This study has shown and emphasised that, BIM is not a type of software but rather, a digital project delivery method that uses innovative technologies, processes and policies. The organisational make up of consulting firms is found to be different than that of a construction firm. Consulting firms are found to have fewer expert employees who are capable and comfortable with using computer software to improve efficiency to the level of detail and interrogation that Contractor based Professionals do. The consulting firms might have a larger representation of software usage but, the extent of use within the software capabilities, differs between consultant based and construction based practitioners. This difference in extent of use of BIM technologies (higher in construction firms) might have been offset by the higher level of use of BIM technologies in consulting firms, hence the statistical analysis showed no significant difference in the levels of BIM maturity.

5.2 Conclusions

This study has been formulated using the Technology, Organisation and Environment (TOE) framework as the theoretical point of departure. The environment within which organisation organisations operate and the organisational context and technology, are determinants of the organisations readiness to adopt BIM. The conceptual model stated that

- BIM capability (competency) affects BIM adoption (actual use), where, if organisations have the minimum BIM requirements, they can adopt BIM and vice versa, when firms adopt BIM, the competency levels are increased through learning and use of BIM related tools and workflows

- BIM adoption affects BIM maturity, where, as firms adopt BIM, the levels of BIM maturity increase (or decrease) due to the achievement (or not) of the perceived benefits and usefulness of using BIM (derived from the Technology Acceptance model). This relationship is also vice versa, where the levels of BIM Maturity influence BIM adoption, as firms mature and realised the full benefits of using BIM, their adoption levels can increase.

The results of Pearson correlation show a significant correlation between the levels of BIM capability, adoption and maturity. The stronger relationship is found between BIM maturity and BIM adoption, at a Pearson correlation value of 0.955. This finding validates the conceptual model, as BIM capability impacts and affects BIM adoption and BIM adoption affects BIM maturity.

From the aim of the study, which is to establish measures of performance for assessing BIM adoption, capability and maturity levels between design and construction firms and evaluate whether the level and extent of BIM usage differs between consulting and construction firms, this has been achieved and the following conclusions can be made. BIM adoption is gradually increasing in South Africa but the understanding of what BIM really is, is still a matter of concern. This study has treated BIM not as a specific software but rather as a collection of project delivery approaches that are driven by computable, data rich methods (which can be the use of various software) to generate building information, in digital accessible formats.

The research objectives of this study have been achieved and BIM performance assessment measures established from literature. The levels of BIM adoption, capability and maturity presented and analysed using statistical tools are in line with existing literature which states there is gradual adoption of BIM in South Africa. Further research is however necessary as BIM to continue until sufficient participants can be found in order to improve sample sizes and make better inferences about the populations represented. The larger the quality and reliability of data to the populations represented, the better the quality of research towards the compilation of BIM policies and implementation guides.

5.3 Recommendations

The following recommendations are made:

To increase BIM adoption, capability and maturity within the country –

- BIM related technologies and methodologies should be incorporated in the curricula of all tertiary institutions offering built environment related programs
- BIM related technologies should have smaller packages and or licencing targeting small to medium construction enterprises. Construction industry is fragmented and majority of the work is subcontracted to smaller entities with no financial capacity to purchase or rent large licences
- A formation of BIM advisory board in essential, made up of influential government representatives, academia, professional councils, voluntary associations and all stakeholders representing the construction industry and the built environment at large.
- Technical advisory board which will report to the BIM advisory board, to be made up of BIM related technologies experts and built environment professionals, who are leaders in their respective fields.
- Creation of a South African based BIM Library and Glossary with BIM implementation guidelines and compilation of best practice specific to the South African context
- Supporting local software developers and students to develop indigenous software that also meets international standards at local affordable costs.

5.4 Limitations of the study

In the course of conduction this research, the following limitations were encountered:

5.5 Recommendations for future research

The following research areas could be explored further.

- A study on the implications of BIM implementation to organisational workflows is required; most focus is currently given to technological factors and not much focus to the developing of policies and processes to assist in the regulation of BIM projects
- BIM adoption studies need to continue but rather than indicating the level of BIM adoption only, they can be case study driven to share in depth, how BIM has been adopted by the various organisations or project teams.
- A study on BIM implementation strategies at macro level.
- Development of South African BIM project performance matrix
- Business value of BIM – propositions and development of BIM return on investment matrix
- Macro BIM adoption – industry performance matrix and impact models

5.6 Critical reflections

This study was based on the premise that there are differences in the organisational competencies of consulting and construction organisations and these differences affect the adoption of BIM technologies. A growing number of consulting and construction firms have made attempts to adopt BIM to enhance their services and products across the globe, but in South Africa there remains a limited use of BIM tools and workflows. The uncertainties in the implementation strategies and actual performance of BIM tools remain a concern. The transition to BIM has requires the need for organisations to assess their performance such as evaluating benefits and impact of BIM, measuring capability and maturity and evaluating return on investment. Consulting and construction firms in the South African construction industry continue using traditional methods to deliver construction projects even though these methods continue to yield poor results. The shift to the BIM project delivery method requires changes in the manner construction businesses function within the project delivery process. Currently, there are no industry adopted measures of BIM assessment and performance for BIM adoption, capability and maturity within the South African construction industry and as such, there is no collection of best practice or guidelines for effective strategies of implementing BIM successfully

This study found that there is a statistically significant relationship between the level of BIM capability and project performance. However, BIM adoption, capability and maturity with the Architecture, Engineering and Construction Industry is still primary seen as a design solution used by consulting firms, rather than an industry wide project delivery method that integrates the design, construction and maintenance supply chain. BIM as a project delivery method embraced by all project participants across the project delivery cycle is still at an infancy in the South African construction industry.

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APPENDICES

APPENDIX A - SURVEY QUESTIONNAIRE

APPENDIX A: SURVEY QUESTIONNAIRE

Research Information

Construction Economics and Management Department, Engineering and the Built Environment, University of Cape Town

The following questions relate to a study on Building Information Modelling adoption, capability and maturity amongst South African consulting and construction firms.
Please answer based on your past experience. You are encouraged to complete the questionnaire as far as you can, even if you have not been involved in BIM projects.

PLEASE NOTE THAT ALL ANSWERS TO QUESTIONNAIRE ARE CONFIDENTIAL.
The questionnaire has been ethically approved and cleared by the Ethics In Research Committee.

Your participation in the study is voluntary and can be withdrawn at any point during the study and will not result in any penalty, legal action or loss of any nature.

Any personal information provided during the study will be kept confidential and will not be included in the reporting of the results. Absolute confidentiality cannot be however guaranteed in instances where this might be required under the laws of the country or required by the University for quality assurance in the assessment of the data reported and analyzed.

For further information, or any querries related to the study, you may contact the researcher on the details below.

Contact: 0216505358
E-mail: fltama002@myuct.ac.za

Thank you for your participation in this research.

1. Please indicate if you would like to proceed with the survey and contribute to the study as indicated above

- ◯ Yes [please continue to the next page]
- ◯ No [thank you for you time, end of survey]

General information

2. What is your gender?

- ◯ Female
- ◯ Male
- ◯ Please self-identify if non of the above are applicable

3. Please indicate your age group

- ◯ Below 18
- ◯ 18 - 25
- ◯ 26 -35
- ◯ 36 - 55
- ◯ 56 -65
- ◯ Above 65

4. What is your highest qualification?

- ◯ PhD
- ◯ Masters/MBA
- ◯ Honours/Btech
- ◯ Degree
- ◯ Diploma
- ◯ Matric
- ◯ Other (please specify)

5. Please indicate your years of experience in the Construction Industry

0 Years 80

6. Please rank the distribution of your clientele according to contribution to turnover where - 1 is the highest contributor; and 4 is the lowest contributor

- [ ] Public Sector
- [ ] Private sector - Foreign investors
- [ ] Private sector - Individuals and organisations
- [ ] Private sector - Property developers

7. Please select all the provinces where you have offices?

- [ ] Western Cape
- [ ] KwaZulu Natal
- [ ] Gauteng
- [ ] Eastern Cape
- [ ] North West
- [ ] Limpopo
- [ ] Free State
- [ ] Mpumalanga
- [ ] Northen Cape

Elsewhere? (please specify by country)

8. Please indicate which of the following services or software platforms are available within your organisation. Indicate by rating the level of use on the given scale. *(Select all the platforms are aware of, it can be more than 1 if necessary)*

	Not used at all	0 - 20%	21 - 40%	41 - 60%	61 - 80%	Above 80%
2D Drafting						
3D Modelling						
4D - Time (Scheduling)						
5D - Cost Analysis and management						
Clash detection						
Visualisation						
IFC Generation						
COBie						
Common data environment						
Project Information Management						
Design Analysis and Appraisal						
Energy Assessment						
Project Delivery Management						

Other (please specify or comment)

9. Please identify the modelling software applications used in your company's day-to-day operations (whether for design or extracting information for costing/scheduling/fabrication/construction). Please list them according to the extentof use:

above 80%

61 - 80%

41 - 60%

21 -40%

0 - 20%

10. How would you rate your ability to make use of all the capabilities of the software identified in Q9 above?

- ○ None
- ○ Beginner
- ○ Intermediate
- ○ Advanced
- ○ Expert

Any comment?

11. Which, if any, of the following platforms do you use to share and/or store project files?*(Please select all that is applicable)*

- ☐ Cloud based application (e.g. iCould, myCloud, GoogleDrive, etc)
- ☐ Internal network based server
- ☐ External network based server
- ☐ Hardcopy format
- ☐ Portable storage devices
- ☐ Other (please specify)

12. Are you registered with any of the professional bodies under the Council of the Built Environment

- ○ Yes
- ○ No

If YES, please specify (e.g. Pr CM - SACPCMP)

13. At what stage of project development are you commonly involved in*(please select all that apply)*

- ☐ Concept and Feasibility
- ☐ Design Development
- ☐ Construction
- ☐ Facility management

14. Please indicate which devices your organisation has made available to you. (Select more than 1 if necessary)

- [ ] Desktop computer
- [ ] Laptop
- [ ] Mobile phone
- [ ] Tablet/iPad
- [ ] 3D Laser scanner
- [ ] Video Drone
- [ ] HD Camera

Other (please specify any other gadget you use for your day-to-day operations)

15. Which of the organisations below, best describes the core function of the firm you work for?

- ○ Contractor (includes specialist trade contractors).
  [If you work for a construction firm, please skip Questions 16 - 18 and proceed to Question 19]
- ○ Consulting firm (includes: Design, Cost, Project & Property Management firms).
  [If you work for a consulting firm, please skip Questions 19 - 21 and proceed to Question 22]
- ○ Public sector (government)
  [If you work for public sector, please skip Questions 16 - 21 and proceed to Question 22]
- ○ Private client (includes individuals and organisations)
  [If you are a client in the industry, please skip Questions 16 - 21 and proceed to Question 22
- ○ Other (please specify)

Questions applicable to consultants (design/cost/project management)

16. Please indicate the size of the firm by indicating the number of employees.

- 1 - 5
- 6 - 20
- 21 - 50
- 51 - 200
- More than 200

17. Please rank the procurement methods below by order of how most project are procured within your organisation (in the past 5 years): where 1 is most common and 4 is least common method

- [ ] Traditional procurement (Design-Bid-Build)
- [ ] Design and Build
- [ ] Construction Management
- [ ] Project Management
- [ ] Other

18. Please indicate all the services offered by the firm

- [ ] Architecture
- [ ] Urban Design
- [ ] Structural Engineering
- [ ] Civil Engineering
- [ ] Project Management
- [ ] Construction Management
- [ ] Property Development/Real Estate
- [ ] Electrical Engineering
- [ ] Master Planning
- [ ] Mechanical Engineering
- [ ] Cost Management/Value Engineering
- [ ] Industrial Engineering
- [ ] Geotechnical services
- [ ] Other (please specify)

Questions applicable to construction firm based individuals

19. Kindly indicate your grade and class of works on the Construction Industry Board (cidb) Register of Works.

	Grade
GB	
CE	
EB	
EP	
ME	
SB	
SC	
SD	
SE	
SE	
SF	
SG	
SHI	
SI	
SJ	
SK	
SL	
SM	
SN	
SO	
SQ	

20. Please rank the manner in which you procure most of your projects where - 1 is highest number of projects procured in this method and 4 is the least number of projects procured in the method

- [ ] Traditional procurement (Bid-Build)
- [ ] Design and Build
- [ ] Construction Management
- [ ] Other

21. Please select all the sectors that you serve with the construction services (more than 1 if necessary)

- [ ] Commercial
- [ ] Rail
- [ ] Retail
- [ ] Leisure
- [ ] Education
- [ ] Health
- [ ] Residential
- [ ] Transportation
- [ ] Dams
- [ ] Mixed use
- [ ] Agricultural
- [ ] Aviation
- [ ] Mining
- [ ] Energy
- [ ] Other (please specify)

Past Project information

22. Please identify your recent well understood completed project then answer the following questions:

Project Name

Project type (Commercial/Residential/Industrial/etc)

Client (Private/Public)

Project budgeted value

Project planned duration

Please identify (if any) set of quality standards were used for the delivery of project or by the organisation (e.g. ISO)

Was the project completed on time? (If not, please state by how long the project was delayed)

Was the project completed within budgeted cost? (If not, please state by how much the actual cost differed from budgeted)

Did the project meet the client/design specifications and quality standards? (If no, then please identify the main areas where the project failed)

23. Was the project identified in Q22 above a BIM project?

- ○ Yes
- ○ No
- ○ Not sure

If YES, please indicate/comment on how BIM impacted project perfomance

24. Have you worked on other BIM project(s)?

- ◯ Yes [please continue with survey]
- ◯ No and I do not plan to be part of a BIM project [end of survey]
- ◯ No but I plan to be part of a BIM project in the future [end of survey]
- ◯ I do not know anything about BIM [end of survey]

BIM based questions

25. Please identify your recent well understood BIM project then answer the following questions:

Project Name	
Project type (Commercial/Residential/Industrial/etc)	
Client (Private/Public)	
Project budgeted value	
Project planned duration	
Please identify (if any) set of quality standards were used for the delivery of project or by the organisation (e.g. ISO)	
Was the project completed on time? (If not, please state by how long the project was delayed)	
Was the project completed within budgeted cost? (If not, please state by how much the actual cost differed from budgeted)	
Did the project meet the client/design specifications and quality standards? (If no, then please identify the main areas where the project failed)	

26. For how many years have you been working with BIM?

- ◯ Less than 1 year
- ◯ 1 year
- ◯ 2 years
- ◯ 3 years
- ◯ 4 years
- ◯ More than 5 years

27. On what percentage of projects do you make use of BIM?

- ◯ Less than 20%
- ◯ 20% to 40%
- ◯ 40% to 60%
- ◯ 60% to 80%
- ◯ More than 80%

28. Based on your experience, please rate the level of agreement to the following BIM performance factors as benefits of BIM in the delivery of projects

	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
BIM improves overall project delivery	◯	◯	◯	◯	◯
BIM improves project cost performance	◯	◯	◯	◯	◯
BIM enhances project scheduling	◯	◯	◯	◯	◯
BIM allows better collaborative environments	◯	◯	◯	◯	◯
I do not want to use BIM again because of data exchange issues	◯	◯	◯	◯	◯

29. Based on your experience and understanding, please indicate what BIM means (select all that applies)

- ☐ BIM is technology
- ☐ BIM is processes
- ☐ BIM is policies
- ☐ BIM is a software
- ☐ BIM is all of the above

30. Please indicate which enablers do you use for each of the below metrics for your BIM Value benchmarking as a control measure for your BIM performance?

Contract sum variation	
Duration variation	
Cost per unit quantity	
RFI's per Rand value	
Clashes per Rand value	
Lost time to injuries	
Sustainability	
Client satisfaction	

31. How did you come about to use BIM in your projects? Please select all that apply

- [ ] Client request
- [ ] Top managements request
- [ ] To stay competitive in the market
- [ ] To improve project delivery
- [ ] The contract allowed for BIM
- [ ] It was a design and build contract
- [ ] Other (please specify any other reasons you have used BIM)

32. Which of the below listed models have been used by your organisation to measure BIM capability and maturity at an individual, project or organisation level

	Individual	Project	Organisation
BIM QuickScan	☐	☐	☐
BIM Maturity Matrix	☐	☐	☐
BIM excellence	☐	☐	☐
bimSCORE	☐	☐	☐
Interactive Capability Maturity Model	☐	☐	☐
No assessment is performed	☐	☐	☐

Other (please specify)

33. Will you be willing to participate in an interview?

- ◯ Yes (Please fill the section below)
- ◯ No (thank you for your time and responses - END OF SURVEY)

34. Please provide your contact details:

Name

Email address

Contact number

APPENDIX B – CONSENT TO INTERVIEWS

APPENDIX B: CONSENT TO INTERVIEWS

CONSENT TO PARTICIPATE IN RESEARCH

Participant number:…………...

Dear Sir/madam.

Thank you for your willingness to participate in this research. The aim of this research is to assess the level of adoption, capability and maturity in the use Building Information Modelling (BIM) by design and construction firms in South Africa.

Please answer the following questions relating to Building Information Modelling based on your past experience. You are encouraged to answer the questions as far as you can, even if you have not been involved in BIM projects

PLEASE NOTE THAT ALL ANSWERS TO QUESTIONNAIRE ARE CONFIDENTIAL.

Your participation in the study is voluntary and can be withdrawn at any point during the study and will not result in any penalty, legal action or loss of any nature.

Any personal information provided during the study will be kept confidential and will not be included in the reporting of the results. Absolute confidentiality cannot be however guaranteed in instances where this might be required under the laws of the country or required by the University for quality assurance in the assessment of the data reported and analysed.

For further information, or any queries related to the study, you may contact the researcher on the details below.

Contact: Amanda Mtya
Tell: 0216505358
E-mail: fltama002@myuct.ac.za

1. Please sign below if you agree to proceed to participate in this research and answer the research questions.

………………………………………………….. ……………………………………

Participant signature Date

APPENDIX C – SCHEDULE OF INTERVIEW QUESTIONS

General information: ice breaker questions – participant given the page to select options

Participant no……

2. What is your gender?

- Female
- Male
- Please self-identify if non of the above are applicable

3. Please indicate your age group

- Below 18
- 18 - 25
- 26 -35
- 36 - 55
- 56 -65
- Above 65

4. What is your highest qualification?

- PhD
- Masters/MBA
- Honours/Btech
- Degree
- Diploma
- Matric
- Other (please specify)

5. Please indicate your years of experience in the Construction Industry

FOLLOW UP SCHEDULE OF INTERVIEW QUESTIONS AND OBSERVATIONS
Participant no:_____

6. Current project information

7. Your role in the project:___________________________________

8. Which technologies(devices/sharing platforms/software packages etc) do you use?

    a. Devices – laptops, mobile, etc
    b. Sharing platforms
    c. Software packages used and extent of use – participants probed to offer as much insight into what tasks they use on each platform and how long they estimate to use the applications in their day-to-day
    d. Storage formats and platforms
    e. Information management
    f. Perception of the impact to project performance

9. Which communication platforms do you use to communicate with:
    a. Design team consultants______________________________
    b. Client____
    c. Subcontractors_____________________________________
    d. Internal workforce__________________________________

10. Which coordination platform do you use to share project information (drawings, goals, general team alignment):____

11. BIM SPECIFIC QUESTIONS

    a. Participants asked what their understanding of BIM is?
    b. Has the participant worked on a BIM project?

12. General observations
    a. Communication around the site/office
    b. Work atmosphere and environment
    c. Visible infrastrucure

APPENDIX D – COVER LETTER FOR GENERAL OBSERVATIONS

Department of Construction Economics and Management

Engineering and the Built Environment

University of Cape Town, Private Bag X3, Rondebosch 7701
5th Level, Snape Building Upper Campus
Tel: +27 (0) 21 650 3443 Fax: +27 (0) 21 689 2746

Internet: http://www.cons.uct.ac.za
Email: CON-cem@uct.ac.za

Dear Sir/Madam,

I write to you as a research student at the University of Cape Town.
This is to ask for your assistance regarding the following research project:

Evaluation of Building Information Modelling (BIM) adoption, capability & maturity within South African consulting and construction firms Survey (https://www.surveymonkey.com/r/BIMadoptionSA)

The research survey in in the above link has been cleared by the Ethics committee. Briefly, the general questions are about:

- the type of software/hardware packages they use to deliver projects
- Information Technology Infrastructure
- Any smart technologies used to aid delivery of projects
- If none of these are used/available – reasons/barriers

Your assistance is required in the following manner:

- Access to construction firms/projects of any type above the value of R40million rand, completed in the past 4 years OR in progress.
- The firm/project participants of interest in the projects are:
    - Consultants contacts
    - Construction team contacts (especially Main contractor/Construction Management)
- The firm/project can be based anywhere in the following provinces:
    - Western Cape
    - Eastern Cape
    - Gauteng
    - KwaZulu Natal

Thanking you for your assistance,

Amanda Mtya
MPhil Candidate |Department of Construction Economics & Management
Research Area: Building Information Modelling
T: +27 21 650 5358 **E**: fltama002@myuct.ac.za

APPENDIX E – APPROVED ETHICS CLEARANCE

APPENDIX E: APPROVED ETHICS CLEARANCE FORM

Faculty of Engineering and the Built Environment, University of Cape Town

APPLICATION FORM

Please Note:

Any person planning to undertake research in the Faculty of Engineering and the Built Environment (EBE) at the University of Cape Town is required to complete this form **before** collecting or analysing data. The objective of submitting this application *prior* to embarking on research is to ensure that the highest ethical standards in research, conducted under the auspices of the EBE Faculty, are met. Please ensure that you have read, and understood the **EBE Ethics in Research Handbook** (available from the UCT EBE, Research Ethics website) prior to completing this application form: http://www.ebe.uct.ac.za/ebe/research/ethics1

APPLICANT'S DETAILS

Name of principal researcher, student or external applicant		AMANDA MTYA
Department		CONSTRUCTION ECONOMICS AND MANAGEMENT
Preferred email address of applicant:		FLTAMA002@myuct.ac.za
If Student	Your Degree: e.g., MSc, PhD, etc.	Mphil
	Credit Value of Research: e.g., 60/120/180/360 etc.	180
	Name of Supervisor (if supervised):	A/Prof A. Windapo
If this is a researchcontract, indicate the source of funding/sponsorship		N/A
Project Title		Evaluation of Building Information Modelling (BIM) adoption, capability and maturity within South African design and construction firms

I hereby undertake to carry out my research in such a way that:

- there is no apparent legal objection to the nature or the method of research; and
- the research will not compromise staff or students or the other responsibilities of the University;
- the stated objective will be achieved, and the findings will have a high degree of validity;
- limitations and alternative interpretations will be considered;
- the findings could be subject to peer review and publicly available; and
- I will comply with the conventions of copyright and avoid any practice that would constitute plagiarism.

SIGNED BY	Full name	Signature	Date
Principal Researcher/ Student/External applicant	AMANDA ALICIA MTYA		**12 Jan 2018**
APPLICATION APPROVED BY	Full name	Signature	Date
Supervisor (where applicable)	ABIMBOLA WINDAPO		12 JAN 2018
HOD (or delegated nominee) Final authority for all applicants who have answered NO to all questions in Section1; and for all Undergraduate research (Including Honours).	KATHY MICHELL		
Chair : Faculty EIR Committee For applicants other than undergraduate students who have answered YES to any of the above questions.	R Behrens		12 Jan 2018