BUQS 7009 Research Report

A FRAMEWORK TO IMPROVE BIM IMPLEMENTATION AMONG SOUTH AFRICAN CONSTRUCTION COMPANIES

Student's Name: Hlengiwe Masuku

Student Number: 390955

Supervisor: Ehsan Saghatforoush

The School of Construction Economics and Management

University of Witwatersrand

Johannesburg

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Declaration

I declare that this Research Report is my own, unaided work. It is submitted in partial fulfilment of the degree of Master of Science (MSc) in the field of Project Management in Construction at the University of the Witwatersrand, Johannesburg.

It has not been submitted before for any degree or examination in any other university.

Signature of Candidate:

Name of Student Hlengiwe Masuku (390955)

Signature of Candidate:

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Abstract

The construction industry is key in the economic growth of many countries as it supports economic factors such as employment creation, gross domestic product growth and production just to mention a few. Therefore, the efficiency and effectiveness of this sector cannot be overemphasized. Building information modelling has proved to be the cornerstone of collaboration and efficiency within the construction industry to an extent that implementation and application is now mandatory in some of the more economically developed countries for all public sector projects. The implementation of building information modelling in the South African construction industry is still in the infancy stage. This research seeks to provide a framework for improving BIM implementation among South African construction companies based on their existing maturity. To achieve the research objectives and to answer the research questions, the online survey, literature review and case study research methods are adopted. The data collection methods include online questionnaire, Metasynthesis and interviews. Quantitative data analysis is done through Microsoft excel spreadsheets while qualitative data is analysed through the MAXQDA qualitative analysis software. Findings suggest that very few construction companies in South Africa have adopted the use of BIM but should work with all stakeholders during the implementation process to achieve success. Furthermore, the government of South Africa which is the largest client in the industry should lead the process of BIM implementation. The research presents a framework which can be adopted and or adapted by construction companies in the implementation of BIM. In summary, the South African construction industry stands to benefit from the implementation of BIM. However, the successful implementation requires a collective effort from all the involved stakeholders.

List of Abbreviations

Abbreviation	Description
2D	Two dimensional
3D	Three Dimensional
4D	Four Dimensional
5D	Five Dimensional
6D	Six Dimensional
ASAQS	The Association of South African Quantity Surveyors
BEE	Black Economic Empowerment
BIM	Building Information Modelling
CAD	Computer Aided Design
CASP	Critical Appraisal Skills Programme
CBE	Council for the Built Environment
CC’s	Construction Companies
CETA	Construction Education and Training Authority
CIDB	Construction Industry Development Board
ECFs	Engineering Consulting Firms
ECSA	Engineering Council of South Africa
FIFA	Federation Internationale de Football Association
GDP	Gross Domestic Product

ICT	Information Communication Technology
IFC	Industry Foundation Classes
IPD	Integrated Project Delivery
MEP	Mechanical, Electrical and Plumbing
MS	Mean Score
NHBRC	National Home Builders Registration Council
PEP	Project Execution Plan
PMI	Project Management Institute
PWC	Price Waterhouse Coopers
RICS	Royal Institution of Chartered Surveyors
SACAP	South African Council for the Architectural Profession
SACPCMP	The South African Council for the Project and Construction Management Professions
SACQSP	The South African Council for the Quantity Surveying Profession
SAICE	The South African Institution of Civil Engineering
SD	Standard Deviation
UK	United Kingdom
USA	United States of America

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INTRODUCTION

1.1 Background to the study

Major construction projects are always faced with several challenges all over the world and this is because construction projects are complex in their nature. These challenges either occur during contract signing, implementation and when the project has been completed (Fatemeh & Saghatforoush, 2017). Other reasons for these challenges are co-existence of multiple contracts as this results in a lack of integration and co-ordination between the project team, leading to project duration extension, financial costs, and compromised quality (Froise & Shakantu, 2014). Construction projects are generally multi-disciplinary, and this requires clear and effective communication among the project team members to allow effective coordination among team members (Noghli, Saghatforoush & Forghani, 2017).

A new approach introduced for implementing integrated project delivery (IPD) in the United States of America (USA) requires all project members to be present from initiation (Talkhabi, Jalal, & Golabchi, 2014). During contract negotiations, possible detection of clashes and challenges are discussed in the presence of team members, thus decreasing possible claims and improving project quality (Noghli, Saghatforoush & Forghani, 2017). Despite the known advantages of the approach, South Africa is still lagging in implementing the approach. Without any doubt, information communication technology (ICT) can play a significant role in eliminating challenges experienced by contractors thus, the construction industry should make fundamental changes in current traditional processes by adopting and implementing ICT (McAuley, Johnson, and Duberley, 2013). Advantages of ICT include but are not limited to reduction of shortcomings of available contracts and achieving project success.

Building Information Modelling (BIM) is a new information technology concept that can be used by construction companies for producing and managing building information throughout its life cycle (Noghli, Saghatforoush & Forghani, 2017). Moreover, BIM is a digital representation of physical and functional features of a structure before the actual physical construction. In addition, BIM functions as a common source of information among the project team and includes construction companies and the design team (Talkhabi *et al*., 2014). Seventy-five (75%) percent of companies all over the world have agreed that they

have improved coordination between the design and construction members, increased quality of the projects and reduce costs and duplications (Noghli, Saghatforoush & Forghani, 2017).

However, to take full advantage of this technology, construction companies should properly implement BIM into their organisations as a competitive and strategic advantage by identifying their maturity levels and organising the development process towards improving implementation (Fatemeh & Saghatforoush, 2017). The aim of the study is to improve implementation of BIM in South African construction companies based on their maturity levels. The study addresses the importance of understanding maturity levels of a company and how each level affects the implementation. Moreover, the study also evaluate how maturity levels are related to company challenges which helps to provide foundations for proper implementation of BIM in construction companies.

According to McAuley, Johnson and Duberley (2013) and Talebi and Saghatforoush, (2017), BIM has been around since early millennium (early 2000s) and has managed to spread worldwide since it was introduced by countries such as the United Kingdom (UK), Finland, and Australia which are the leaders in BIM implementation. Moreover, Succar, Sher and Williams (2012) developed a framework for describing BIM implementation maturity levels as well as various factors affecting BIM implementation. One of the main factors for slow BIM implementation in engineering consulting firms (ECFs) in South Africa is low performance of human capital and company maturity (Fatemeh & Saghatforoush, 2017).

BIM was introduced in South Africa around 2004 and the South African design and construction industry is currently adopting BIM, although the adaptation rate is behind in South Africa compared to other countries (Froise & Shakantu, 2014; Odubiyi, Aigbavboa, Thwala & Netshidane, 2019). In South Africa, BIM is slowly being implemented by ECFs (Chimhundu, 2015). Chimhundu (2015) found that one of the implementation strategies would be for the government to prioritise the introduction of BIM maturity level two (2) as this would fast track the implementation country wide. Moreover, suggestions made also included that statutory bodies such as the Council for the Built Environment (CBE), Construction Education and Training Authority (CETA) and Construction Industry

Development Board (CIDB) should consider assisting in BIM trainings as this would increase the awareness and influence all stakeholders to implement BIM (Chimhundu, 2015).

This section provided a background of the study, the following section substantiates the problem of the study.

1.2 Substantiation of the Problem

Plenty of studies have been conducted on BIM maturity measurement tools and some of these studies focus on identifying features of these tools, while previous studies would develop tools, including creation of measurements of frameworks, design, and selection of measures (Giel & Issa, 2014 & Wu, Xu, Mao & Li 2017). Limited information focuses on improving the implementation of BIM based on the maturity levels of a company while identifying associated challenges to achieve successful project delivery. Talebi and Saghatforoush (2017) stated that, the process of measuring maturity levels is an evaluative process and as such, construction companies can make use of the results to measure their level and determine their status.

Due to the nature of BIM, the implementation of new technologies is key in the realisation of the full BIM potential. To allow for production of acceptable models of BIM, process management and meeting of growing expectations, it is important for current technologies to be mastered. Moreover, there are various BIM levels (see Figure 2.2) and as such, stakeholders should at least meet the same agreed level for the successful delivery of a project.

BIM technology adoption and implementation should have a socio-technical view as it is as much about people and processes as it is about technology (Arayici & Aouad, 2010). To succeed in BIM technology implementation, the complexity of BIM requirements, customers, social aspects, organisation of a company, information and communication technologies must be taken into consideration. Without understanding and suitable tools, successful implementation is difficult to realise although partial success stories can be achieved. Due to fact that some of the stakeholders are doing the implementation, the utmost importance is to have the support from all organisational levels of the company.

Without a doubt, competent and innovative development organisation with in-real-life connection to business and experienced leadership forms the basis of a successful implementation team.

Benefits of using BIM include project success, reduction of imposed costs, reduction of mistakes and duplications in a project (Latiffi, Mohd, Kasim & Fathi, 2013). Moreover, for one to maximise on the benefits of this technology, they should first be able to implement it in the organisation(s). Presently, modern technologies are considered as a valuable resource (Talebi & Saghatforoush, 2017).

One of the factors responsible for slow adaptation of BIM in South African construction companies can be described in a framework developed by Succar *et al*., (2012). In his framework he describes various factors affecting BIM maturity levels of construction companies. One of the main factors responsible for slow BIM implementation is low performance of human capital and company maturity (Talebi & Saghatforoush, 2017). According to a study by Kestle (2009), lack of project pre-planning, and collaboration of the different professionals involved in a project often leaves room for omission and errors causing cost overruns, delays, compromised quality and sometimes can lead to lawsuits between different professionals in a project. This is also true for construction companies in Gauteng, South Africa (Love, Simpson, Hill & Standing, 2013).

Proper implementation of BIM in South Africa depends largely on the willingness of construction companies, as co-operation and investment of time and money into the attaining the skills required to successfully implement BIM is an investment that will not go to waste as BIM implementation will bring a positive outcome for all parties involved (Kekana, Aigbavboa & Thwala, 2014)

1.3 Problem Statement

Due to failure and or lack of coordination between the design and construction teams, construction companies are faced with a problem of declining productivity which can be enhanced through improvement of BIM implementation based on maturity levels.

1.4 Principal Research Question

1. How can BIM implementation be improved among South African construction companies based on their maturity level?

1.4.1 Research Sub-Questions

1. What is the current maturity level of construction companies to apply BIM in South Africa?
2. What are the challenges for proper implementation of BIM in construction companies?
3. What are foundations for proper implementation of BIM in construction companies based on their maturity levels?

1.5 Research Aim

The aim of the study is to develop a framework for improving BIM implementation among South African construction companies based on their existing maturity.

1.6 Research Objectives

1. To measure current maturity level of construction companies in South Africa to apply BIM.
2. To identify challenges for proper implementation of BIM in construction companies
3. To provide foundations for proper implementation of BIM in construction companies based on their maturity level.

1.7 Scope and limitations

Scope: The study surveyed professionals in the construction industry in Gauteng, South Africa, particularly the infrastructure sector.

Limitations:

- Limited projects that use BIM in construction companies.
- Professionals in construction companies may be too busy to assist with interviews and questionnaires.

1.8 Assumptions

- International challenges to BIM implementation are assumed to apply to South Africa.

1.9 Chapter Summary

The chapter aimed at introducing the research setting. The first sub-section focused on the background of the study followed by substantiation to the problem, the research problem, then research aim and objectives. The research then introduced the hypothesis, scope, and limitation of the study and finally the assumption. The next chapter focuses on the literature review which is the in-depth evaluation of previous research on maturity levels of South African construction companies and their challenges to proper implementation of BIM. Moreover, the chapter also expands on the reasons behind selection of the research topic as well as comparing international findings on maturity levels of construction companies to those in South Africa. Lastly, the research explains how previous research connects to the current proposed research by critically evaluating previous research findings and finally highlight the research gap.

LITERATURE REVIEW

2.1 Introduction

The previous chapter provided an introductory to the research, focusing on the aim and objectives as well as research questions. This chapter reviews literature associated with assisting the research focus to enable the researcher to gain in-depth knowledge about the research area of study. The chapter also provides a basis upon which findings are compared to the primary data findings in Chapter 4. The following subsection provides a literature background of the study.

2.2 Background

In recent years, productivity of the building industry has declined significantly compared to other industries. One of the main reasons behind this failure of building projects is due to lack of coordination between the design and implementation teams. BIM improves cooperation among architects, engineers, and contractors, reduces duplications, and completion time, development cost, and improves quality (Chimhundu, 2015). BIM was introduced to the world since the beginning of the third millennium, and within a few years, expanded worldwide, including Africa, in South Africa however, BIM is used in few projects only. Among the main reasons of non-realisation of BIM in the construction industry in South Africa, is low performance of human capital and organisational structures, which are considered as the most significant aspects of organisational maturity (Cabinet Office, 2016).

As mentioned before, the success of multi-disciplinary and complex infrastructure projects is dependent upon effective collaboration among all the various professionals involved. Project information is communicated to assist decision making through the life cycle of the project. As mentioned before, information technology applications play a vital role in project collaboration. However, the utilisation of these technologies has always been slow and or partially adopted by construction companies in South Africa. The South African construction industry is currently adopting BIM, although the adaptation rate is behind in South Africa compared to other countries (Froise & Shakantu, 2014). South Africa is starting to increase BIM implementation with more construction companies become aware of their maturity levels to implement BIM. Evidently, BIM will become the key means of information exchange

between various professionals involved in construction projects (Arbabi, Saghatforoush, Nikouravan & Mahoud, 2017).

To enjoy the fruits of BIM, construction companies should take the key step of implementing the concept. Thus, identifying proper foundations on realisation and implementation of BIM methodology can provide preventive measures to avoid project failure and puts construction companies on the path to success (Froise & Shakantu, 2014). Therefore, this study will highlight the significance of measuring maturity level of construction companies in applying BIM technology, through descriptive analysis of literature review, it will establish challenges for proper implementation of BIM in construction companies. Maturity measurement models help organisations to realise their capabilities and compare their projects and organisational programs with a specific and scientific standard. Since most countries of the world turn toward using this technology and making it compulsory, the output of measuring maturity can make the decision-making process of companies easier and faster while preparing the companies to compete globally.

This section provided a literature background for the study. The following section presents an illustration of the structure adopted during the literature review process.

2.3 Literature review structure

Literature review is defined as an objective, critical summary of published literature relevant to the study area. Without any doubt, literature review is key in helping the researcher develop conceptual frameworks of a specific area of study. Moreover, literature review findings also help researchers in motivating the need for conducting the study under consideration. The literature review of this study follows the stages illustrated in Figure 2.1.

Figure 2.1: Literature Review Flow Chart

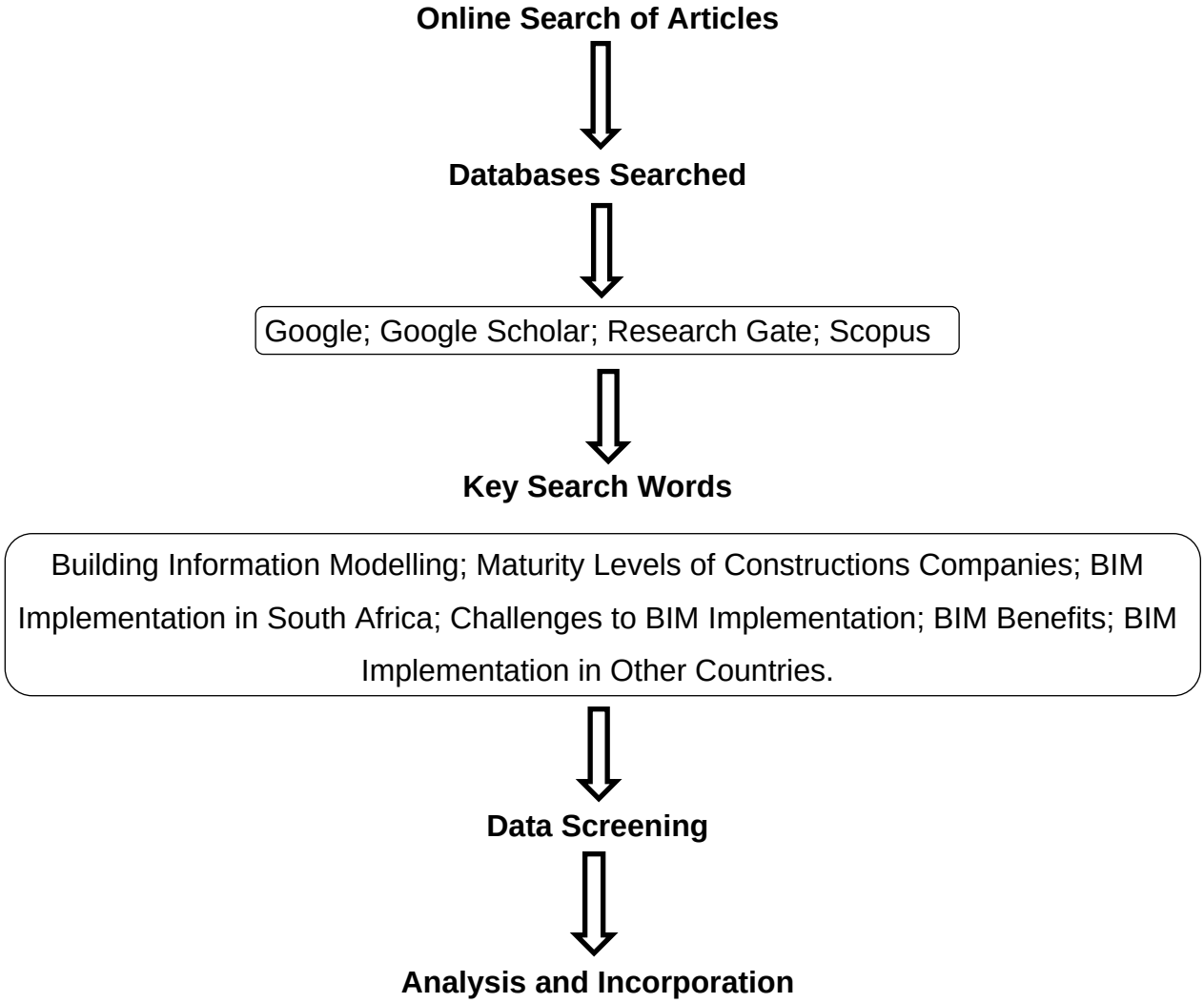


Figure 2.1 illustrates the literature review process adopted in this study. The following section focuses on construction companies.

2.3 Introduction to Construction Companies

The construction industry is generally a good indicator of economic performance. According to Price Waterhouse Coopers (PWC) (2017), the construction industry contributes to employment and economic growth and in 2016 the industry contributed an average of 3.9 % to the gross domestic product (GDP) of South Africa. Considering the nature and complexity of construction processes there is an increased need for reliable information by the time a project goes to construction phase, consultants and contractors can make refined

decisions about projects. Kiprotich (2014) stated that better estimates, clash detections, quality and time controls are more defined. According to PWC (2017), the performance of the construction industry has recently declined, this includes defects, rework, delays, injuries and accidents, all of which are caused by the pervasive nature of the industry. This is unfortunate as the construction industry is labour intensive and can absorb many unemployed youths.

Construction Companies in South African spend a significant amount of time sharing two-dimensional (2D) documents which makes the planning and coordination of construction activities more difficult particularly those on complex projects (Love *et al*., 2013). Better working methods are available via collaboration but are underutilised. One of the major changes is the use of technology to operate and exchange information during complex projects (Kiprotich, 2014). Hardin (2009) realised that workflows produced by BIM aligned to better visualisation, better building metrics and improved analysis are revolutionising the way the industry communicates and designs buildings. Previously, information was exchanged using two dimensional ideas on paper. However, due to the advancements in technologies over time, new concepts and systems have evolved and are helping the construction industry to improve delivery of projects. The following subsection focuses on the implementation of BIM within the construction industry.

2.4 Implementation of BIM in South African Construction Companies

While the previous section focused on construction companies in general, this section discusses the implementation of BIM within construction companies in South Africa. According to Kiprotich (2014) South Africa construction companies have for a long time been utilising BIM in various computer aided design systems however in recent years BIM has had an increased use by the structural and civil engineering professionals. Autodesk BIM and Tekla software packages made an impact in the country especially on the construction of the stadiums for the 2010 Federation Internationale de Football (FIFA) World Cup and the construction of the Medupi Power Station, however the implementation was mainly for the three-dimensional (3D) modelling and interface management for clash detection. However, the full spectrum of BIM implementation was not realised during these projects, this is evident in the price increase from design concept to project execution.

South African is yet to reach the maturity levels of developed nations, Saxon (2013) observed that it is logical that BIM implementation would lead to economic growth (Fouche, Smallwood & Emuze, 2011) argued that innovative technology and management promote industry growth through increased competitiveness. According to Chimhundu (2015) the benefit of promoting BIM to the government, South Africa would result to improved levels of competition and efficiency in construction companies leading to better project delivery in both private and public sector projects.

The South African construction industry is expected to achieve a balanced socio-economic through heavy capital investment in infrastructure with limited resources, in spite of the industry's expectation it is faced with challenges such as cost over runs, project delays, claims to name a few, these challenges can be alleviated by proper implementation of BIM (Akintola, Root & Venkatachalam, 2017). This study seeks to provide foundation for proper implementation of BIM in construction companies.

In South Africa the CBE is responsible for development of construction professionals, maintaining professional standards in the build environment and coordinating other subsidiary professional bodies. The CIDB is responsible for promoting uniformity and efficiency in construction procurement and infrastructure delivery, the department of public works is responsible for the provision and management of government's fixed asset, all three of these institutions together provide guidance and regulation of the construction industry. One of the study's objectives is to provide foundation for proper implementation of BIM in construction companies. For construction companies to apply these foundations for the implementation of BIM they must be accepted by the three institutions. The researcher investigated based on the above-mentioned institutions what they would consider as foundations for proper implementation of BIM in construction companies.

The following section looks at BIM, and provides the definition of BIM, its benefits, tools, challenges, and issues with BIM implementation. It also highlights a review of BIM implementation in other countries.

2.5 Building Information Modelling

The previous section focused on the implementation of BIM in the South African construction industry. This section gives a detailed introduction of the BIM concept starting with the definition followed by a section on the tools for BIM, the benefits of BIM, challenges, and issues of implementing BIM and finally, the implementation of BIM in other countries.

2.5.1 Building Information Modelling definition

Hardin (2009) gives the following definition for building information model: “BIM is a digital representation of the building process to facilitate exchange and interoperability of information in digital format.” Azhar, Hein and Sketo, (2008) further defines BIM as an integrated computer-generated n-th dimensional model that represents a building project and stimulates the coordination planning, building and operation of the project. For this study, BIM will be defined as “A model defining the physical and the functional characteristics of a facility in a digital representation form’’ (Gardezi, Shafiq, Nurudinn and Farhan, 2014). BIM concept is to build a structure in a virtual environment before the actual physical construction so that the problems and their potential impacts that will be encounter during the actual construction can be detected and solved before construction. Gardezi et al., (2014) observed that the use of BIM can by construction companies can results in great benefits and improve in the quality of workmanship and ultimately improve the construction industry.

The n-th of the building model represents the degree in which the building information model has been applied. According to Cerovskek, (2011), in construction, BIM is recognised in terms 3D, 4D, 5D and 6D. 3D BIM this refers to all three dimensions relating to spacing that is, length, width, and depth which allow for 3D visualisation of the structure. 4D BIM refers to 3D with the added dimension of time or project programme, such as time until installation and operation. 5D BIM refers to 4D BIM with the added dimension of cost, such capital cost of purchasing a component. 6D BIM refers to 5D BIM, but with the added dimension of facilities management, sustainability of an asset this may include information from manufacture such as maintenance schedules.

Aouad, Lee and Wu (2017) use the term nD which translate to the multi-dimensional aspect of BIM, it can be utilised during the design analysis, execution, management, maintenance, and operation phase of a project.

2.5.2 Tools for BIM

Table 2.1 below shows five types of BIM tools suggested by PWD namely Revit Architecture, Revit Structural, Revit Mechanical, Electrical and Plumbing (MEP), and Cost-X. The tools play a pivotal role in assisting construction stakeholders including but not limited to architects, engineers, project managers and quantity surveyors in the management of construction project activities. According to Latiffi *et al*., (2013) these tools assist stakeholders with the production of good project documents.

Table 2.1: BIM Tools (Latiffi *et al*., 2013)

Construction Professionals	**BIM Tools**
Architect	Revit Architecture
Structural Engineer	Revit Structural
Mechanical, Electrical and Plumbing	Revit MEP
(MEP) Engineer	Revit MEP
Project Manager	Revit MEP
Quantity Surveyor	Cost-X

2.5.3 Benefits of BIM

According to Azhar, Hein and Sketo (2012) are of the view that, during the design phase, BIM can be used for the detection of conflicts, interference and collision which allows key systems to be physically inspected to determine any technical interferences. An example would be that the process verifies a service such as plumbing to ensure that it will not interfere with say the erection of beams.

According to Monteiro and Martins, (2013), BIM is a very accurate virtual model which manages construction projects in terms of design, estimation of cost, scheduling of projects, construction and operation and maintenance of the facility. BIM tools such as Revit, Bentley, Autodesk, Graphisoft and Exactal are used to assist construction players such as

consultants and contractors in managing construction projects activities (Eastman et al., 2011; Newman, 2013; Zhang, Teizer, Lee, Eastman & Venugopal, 2013). BIM detects design clashes and increase accuracy in cost estimating as well as project scheduling during pre-construction phase (Mohd & Latiffi, 2013).

BIM produces three dimensional virtualised structures that contain immense amount of information. This provides the professional team with insight and control over the structure before the commencement of project. Aouad, Lee and Wu (2017) state that the success of construction undertakings depends on the ability of the professional team to consider and communicate multi-disciplinary concerns, constraints, goals, and perspectives.

2.5.4 Challenges to BIM implementation

There have been many studies with reasons why BIM technology is not utilised. According to Fazli, Fathi, Enferadi, Fazli and Fathi (2014) researchers show that the cost and time needed to train staff to be competent with BIM is much more than what construction companies can afford this than makes them less interested in BIM. They further argued that the execution of BIM is more difficult than what the software engineers have suggested. The South African Construction Industry generally suffer from poor levels of project performance, inadequate documentation, poor knowledge transfer and low collaboration between the design and project teams (Emuze & Smallwood, 2014). The United Kingdom claims that the purposeful steps towards implementation of BIM have managed to deliver efficiency savings of up to 3 billion pounds between 2011 to 2015 (Cabinet Office, 2016). Additional targets have been set for the next 5 years to deliver projects with 33% reduction in costs (Cabinet Office, 2016). It may not be impossible for the South Africa construction companies to achieve the same if foundations for proper implementation of BIM are provided, this is one of the study's objectives.

Fazli et al., (2014) observed that one of the usual problems is getting the different file formats to function well when creating a combined building information model. When data is obtained from the original building information models a certain value is attained, the same cannot be said when data is taken after the model have been converted into IFC file format, different value can be attained

With the widespread and continuous integration of BIM utilisation in construction companies it is likely to cause challenges to traditional project practices, in this BIM collaboration context an area of concern is the copy right and licensing of contributing professionals' intellectual property. According to London, Singh, Taylor, Gu and Brankovic, (2008) the regulations with regards to BIM need to be accepted and implemented by the relevant governing bodies to negate this risk

According to London, et al., (2008) the following challenges have been Identified, cultural and existing work practices; these ties to the fact that construction companies are slow to implement any new technology, this statement is supported by Anderssen, (2000) including that any new innovations are deemed to be risky for construction companies. Weitz, (2016) also stated that profit margins in building are generally small and error could result in the success or failure of a project.

2.5.5 BIM Implementation Issues

Eadie, Odeyinka, Browne, McKeown and Yohanis (2013) stated almost all the companies reported that they did not see the profit or were unaware of any improved or declined profitability due to the implementation of BIM. This could be attributed by the fact that calculating the return on investment of BIM requires long-term records of associated investment and returns to ascertain this benefit. Given most of the interviewed companies had only used BIM for only short period of time, determining the return-on-investment of BIM can be a challenge.

Nonetheless, these firms observed and acknowledged certain benefits of BIM in their operations. With respect to using BIM for visualisation, they reported that they gain benefits in terms of:

- Cost and time savings in creating redundant building models.
- Improved project presentations to clients and for approval process.
- Facilitation of the examination and verification of architectural design concepts.
- Reduced production time; and
- Increased quality of the outputs.

There have been numerous BIM initiatives to facilitate successful BIM implementation throughout the building lifecycle (Atkinson, Amoako-Attah and Bahadori-Jahromi, 2014). The aim is to create collaborative methods preferred for construction companies with the aid of BIM, provide valuable outcomes into collaborative methods of BIM utilised by various countries. Cabinet Office, (2016) has observed that changes required to implement BIM within organisations and on project team level are more likely to result in disruptions as they have to change not only workflows but all construction companies and the whole industry has to be matured enough to apply BIM. The aim of this study is to measure maturity levels of construction companies in South Africa to apply BIM.

The section that follows is on BIM maturity levels and a definition of BIM maturity levels. The researcher also highlights the maturity levels of South African construction companies.

2.6 Maturity Levels of BIM

Successful implementation of BIM requires a thorough understanding of current situation of BIM operations as well as effective, advanced, and performing measurements, in order for construction companies to be able to collaborate effectively they need to be able to operate and exchange information (Zieliński & Wójtowicz, 2019). They are different levels of shared collaboration in a construction project, these are known as BIM maturity levels as we proceed through the BIM maturity levels the collaboration ability between the project team also increases. Currently there are four BIM maturity levels with zero being low collaboration and level three is full integration (Love *et al*., 2013).

The BIM institute (2017) defines the BIM Level 0 is the simplest step of information generation it is essentially the use of computer aided design or CAD tools to create drawings and drawn elements using ICT software. It is the first step up from generating the information by hand. Levels 1 - 3 deals with varying degrees of modelling, collaboration and finally the exchange of fully integrated, interoperating data known as a common data environment. Succar *et al*., (2012) developed a framework for describing BIM implementation maturity levels, the framework describes the various levels as follows:

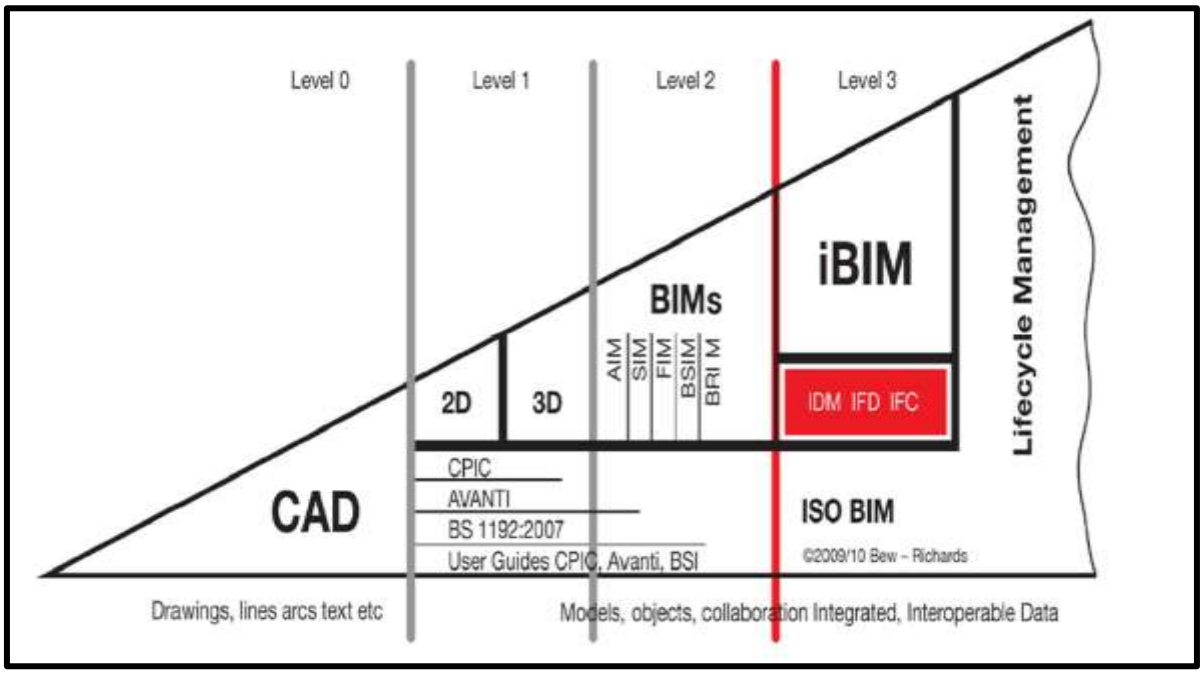


Figure 2.2: BIM Maturity Model (Applecore design, 2014)

BIM Level 1 (Partial collaboration): It is the progression from CAD to generating suites of 2D information, followed by non-federated 3D models. It essentially involves a single professional modelling expertise; an example could be a Quantity Surveying developing and sharing estimates on a WinQS with other professionals.

BIM Level 2 (Full Collaboration): This level focuses on the manner which the information is shared between project team members, multiple professionals collaborate to produce a model with interoperable interchange, and an example of this could be a QS sharing data with a cost engineer.

BIM Level 3 (Full integration): this level is the goal for the construction industry, its main point is the attainment of the full integration of information in a cloud-based environment the development of interdisciplinary models which has rich data fully integrated, interoperating data known as a common data environment. An example of data model at this stage includes intelligent model with design, analysis, lean construction principles, maintenance schedules and the whole life costing of the structure. According to BIM institute (2017) level 3 represents full collaboration between all disciplines by means of using a common data environment ,this model is kept centralised, users can access and modify the same model, removing all conflicting information it is also known as “Open BIM”

Talbot (2018) suggests that there are benefits to obtaining a BIM level 2: it ensures that all processes are being fulfilled on a project work to a top level, it gives you client a piece of mind in your ability to complete projects successfully and efficiently. Talbot (2018) further suggested that the most important benefit for construction companies is that it gives them an impressive advantage over their competitors, making them the first choice for projects.

Chimhundu (2015) added that, the implementation of Level 2 BIM in South African construction companies would result in innovative ways of working in terms of the collaboration of the design teams, construction methodologies, development of BIM tools knowledge management and sharing.

2.6.1 South African Construction Companies and their maturity levels

The South Africa construction companies are still rooted in their traditional methods for procurement and delivery of projects (Akintola, Root & Venkatachalam, 2017). They further argued that this hinders the growth and maturity of construction companies to adopt collaborative methods that might realise the many advantages of BIM implementation. According to Kiprotich (2014) Autodesk BIM and Tekla software's packages have made a big impact in the construction industry especially during the construction of the 2010 FIFA World Cup and Power Stations such as Medupi, however the adaptation was mainly for the 3D modelling and interface and for clash detections, Kiprotich (2014) further states that the full spectrum of BIM usage was not realised during the project, this is evident in the cost escalation and delay of completion of some of these projects. This indicates that the construction companies had low BIM maturity levels.

BIM is the development of integrated, parametric models of buildings, BIM enables better integration, constructability review, and better co-ordination for construction, building performance analysis including facility management (Eastman, Teicholz, Sacks & Liston, 2008). BIM dimensions such as 3D parametric and 6D which also captures facility management information are virtual models capable of representing specific details to facilitate analysis required before, during and after construction (Stephen & Robert, 2007). With proper use of BIM models and dimensions construction companies can improve their BIM maturity level.

According Booysen et al., (2013); Froise and Shakantu (2014), in South Africa where BIM authorising software systems have been used for a least a decade, some progress is being made although its implementation has not shown some growth and they remain at low maturity level. There are several reasons for this regard. This study measures maturity levels of construction companies in South Africa to apply BIM. The following section covers the research gap, this is the missing pieces in the research literature it is the area that has not been explored or under explored.

2.7 Research Gap

Construction companies in South Africa are currently under-utilising maturity Level 2 (Kotze, 2013). The low performance of construction companies together with low maturity levels are the prompters for this study, from the literature review, it is evident that none of the studies focused on improving the implementation of BIM based on the company's maturity levels while identifying its associated challenges to achieve successful project delivery.

According to Talebi and Saghatforoush, (2017) construction companies are always experiencing challenges for completing project on time, within budget and at a desired quality this can be achieved through proper implementation of BIM, and the first step towards achieving this is measuring the construction company's maturity level.

According to Akintola, Root & Venkatachalam, (2017), since South Africa is lagging in BIM implementation it would be efficient for South Africa Construction Industry to adopt and adapt existing standards from Global leaders rather than to recreate their own, as those standards have been tried and tested. Arayici (2018) suggest that in order to properly implement BIM in a sustainable manner it is important to understand the BIM maturity levels, which are sub-dived into three levels based on an analysis by Succar *et al*., (2012). Level one is object-based modelling, level two is the model-based collaboration and level three is the network integration Succar *et al*., (2012). Once a company has knowledge their maturity levels this study will provide them with a framework to improve BIM implementations among South African construction companies based on their maturity levels.

South African construction companies currently has level 1 BIM implementation maturity, BIM Africa (2018) suggest a level 2 which is a more collaborative level. South Africa's

traditional methods of project delivery often results in immense revisions during the design and implementation stages which leads to project delays and cost overruns. Successful BIM implementation generally results in efficiency gains project execution in terms of eliminating waste, speedy decision making, improved communication (Arayici, Coates, Koskela, Kagioglou, Usher & O'Reilly, 2011).

According to CIDB (2019), the South African Construction Industry is currently experiencing recession due to reduction in private and public investment into the sector, lack of business confidence, wasteful expenditure due to corruption. This reduced investment results in power project performance hence the need for proper implementation of BIM in construction companies. The failure by construction companies to embrace innovation at a faster has resulted in poor productivity, this negatively affects the economy of the country (Deloitte 2019). Poor productivity performance by construction companies can be eliminated using BIM (Fatemeh & Saghatforoush, 2017).

South Africa has been utilising been for over a decade now, however it has been neither widespread or used to its optimal (Akintola, Root & Venkatachalam, 2017), based on this it prompted these researcher to identify key constants to optimal and widespread implementation of BIM in South African construction companies, their study focused on the key constrains for BIM implementation widespread and optimal use, this leaves a gap for this study to link maturity levels of South African constructions companies to challenges as well as providing foundations for proper implementations.

This study offers focuses on.

1. Measuring maturity levels of construction companies in South Africa
2. Identifying challenges for proper implementation of BIM in construction companies
3. Providing foundations for proper implementation of BIM in construction companies based on their maturity level.

2.8 Chapter Summary

The literature reviewed shows that there are three maturity levels of BIM implementation, it suggests that the steps within each of the stages need to be critically observed for a successful implementation of BIM. It was also realised that South African construction

companies are not matured to implement BIM compared to UK, USA, Canada and other Western countries. This is evident from the higher levels of collaboration and more advanced systems and tools including well defined BIM policies that are in use in their construction industry in countries like UK, USA, Canada and Finland.

Although BIM has many benefits for construction companies and clients, there still exists many challenges to successful implementation more so in South Africa. Literature suggest that one of the implementation strategies would be for the government to priorities the introduction of BIM maturity level 2 as this would fast track the implementation country wide. It further suggested that statutory bodies such as the CBE, CETA and CIDB should consider assisting in BIM trainings as this would increase the awareness and influence of BIM to all stakeholders.

The next chapter is the research design, this chapter will uncover the mythological choices, research strategy and the time horizon selected by the researcher. Research design is a plan on how the researcher will go about answering the research questions it will also consist of clear objectives which were derived from research questions (Saunders, Lewis and Thornhill, 2016). They further state that a research design should specify the sources from which the researcher intends to collect data from and how they propose to analyse and discuss it.

RESEARCH METHODOLOGY

3.1 Introduction

The previous section provided a discussion of existing literature on BIM implementation. This section comprises of the research philosophy, research methods, research design, and data analysis. A description of the methods and design applied is provided under research design while the technique with which the data was analysed in addition to an account of the process is described under data analysis. A justification for the research methodology adopted and the relationship between the research methods and objectives will reinstate the credibility of this research.

3.2 Research philosophy and approach

According to Gemma (2018:2), “a research philosophy is what the researcher perceives to be truth, reality and knowledge.” This is since the philosophy summarises views and standards that guide data design, collection, and analysis to complement philosophical principles. This research adopts the positivism philosophy which according to Gill and Johnson (2010) and Saunders, Lewis, and Thornhill (2016:135), “is related to the philosophical stance of a natural scientist involving working with an observable social reality to produce law-like generalisations.”

Positivism researchers are of the view that, if facts can be proven or disproven, then, the result is true, reality is uniform and observation and measuring provides in-depth information of the reality (Gemma, 2018; Tombs & Pugsley, 2020). Johnson (2014) and Kivunja and Kuyini (2017) are of the view that, the research findings from a positivist theory may be reliable and support scientific assumptions. However, Hammersley, (2013), argues that it might be impossible in social research projects to measure phenomena related to intention, attitudes and thoughts of a human which makes it difficult to further explore abstract conceptualisation. Without a doubt, it is worth to conclude that, research validity of the results is one of the significant strengths of this approach (Pham, 2018).

3.3 Research Methods

Saunders et al., (2016:4) are of the view that methodology focuses on theory of how research should be undertaken. This research is of an explanatory nature, which can be defined as the initial research into a hypothetical or theoretical idea (List, 2018). Due to BIM being a relatively new concept in South Africa, this study is based on international literature. The researcher has an idea on the current maturity levels of construction companies in Gauteng and seeks to understand them more. List (2018) further explains that explanatory studies help review existing knowledge and provide insights about topics of interest, in this case, BIM.

An inductive approach is the most suitable for this study. According to Levin-Rozalis (2010), inductive approach is concerned with the generation of new theory emerging from data. As previously stated, BIM is a new concept in South Africa and the objective of the study is to provide the foundation for proper implementation of BIM in construction companies. The inductive approach is therefore used to meet the research objectives. The method is sub-divided into research methods, data collection method, data analysis method and software. To choose the most suitable research method, the researcher addresses each objective separately.

3.3.1 Survey

According to Denscombe (2010), surveys measure some facets of a social fact or trend as well as gathering facts to test a theory. There are different types of surveys, but this research adopts the internet survey. As emphasised by Denscombe (2010), internet surveys are faster and relatively cheap when compared to other surveys such as postal and does not affect the quality of data if implemented correctly. Therefore, a researcher working under a tight financial and time budget, internet survey proves to be the best. It should also be noted that due to the impacts of Covid-19, the internet survey proves to be the best form of collecting quantitative data without breaking any regulations.

The first objective is to assess the maturity levels of construction companies in Gauteng. The research method adopted is survey since the maturity levels, they are associated with a deductive research approach. According to Saunders *et al*., (2016) surveys are used to

answer ‘who’, ‘what’, ‘where, ‘how much’, and ‘how many’ questions this makes the method suitable as the research question is what are the maturity levels of construction companies. Saunders *et al*., (2016) further explains that surveys are perceived as authoritative by people and is comparatively easier to explain and to understand.

3.3.2 Literature Review

Literature review involves searching for, reading, evaluating, and summarising as much as possible of the available literature that relates both directly and indirectly to your research topic (Du Plooy-Cilliers et al., 2014). The second objective is to establish challenges of proper implementation of BIM in construction companies. Gathered literature will test that the challenges found from literature apply in South Africa through a case study. Due to the information age, literature review is now a popular research method since many if not all research is available online mostly free of charge (Saunders, 2016). However, Denscombe (2010) stresses the need for careful screening of online sources since some of the information is not peer reviewed and or is published on websites that are not authentic.

3.3.3 Case Study

According to Atkinson (2002), case studies are one of the various qualitative and quantitative data collection methods available to a researcher. A case study is an in-depth inquiry into a topic within a real-life (Yin, 2014). Rahim and David (2015), emphasise that, case studies are useful in understanding complex social processes in organisational and environmental context as it is specially made for exploring new processes or behaviours that are little known.

The case study allows for a holistic, in-depth investigation is required. An advantage of case study is that the examination of the data is most often conducted within the context of its use (Yin, 1984). For this research, construction companies that have different maturity levels will be studied as case study to assess their challenges and establish whether they experience the same or different challenges for BIM implementation. This allows the researcher the capacity to generate insights from intense and in-depth research into the study in its real-life context (Saunders *et al*., 2016)

The third objective is to establish proper foundation for implementation of BIM the research method is case study, it allows for a holistic, in-depth investigation (Saunders *et al*., 2016). An advantage of case study is that the examination of the data is most often conducted within the context of its use (Yin, 1984). In additional some positivist researchers have advocated the use of case studies to build theory and develop theoretical hypothesis which can be subsequently tested (Saunders *et al*., 2016). This makes the method chosen suitable as the study is also an inductive study which at the end will generate a hypothesis.

3.4 Data Collection Method

To choose the most suitable data collection method the researcher will address each objective separately.

3.4.1 Questionnaire

The first objective is to assess the maturity levels of construction companies in Gauteng: The data collection method will be questionnaire, according to Saunders *et al*., (2016) questionnaires are mostly utilised as they allow the collection of standardised data from a sizable population in a highly economical way. An effective questionnaire is one that enables the transmission of useful and accurate information or data from the respondent to the researcher. This requires the researcher to ensure that questions presented to respondents are clear and unambiguous it allows the respondent to interpret them articulate his or her response and transmit it effectively back to the researcher (Wilkinson & Birmingham, 2003). The questionnaire used in this study is divided into three sections, section A which deals with demographic data, section B which deals with empirical findings while section C deals with general questions meant to engage with the respondents (see Appendix A).

3.4.2 Meta-Synthesis

As mentioned before, the meta-synthesis approach will be used to synthesise the data collected. The process of meta-synthesis will be carried out with the main objective of integrating past results from various qualitative researches that are interrelated (Walsh & Downe, 2005) and from those researches, select and appraise, summarise and categorise the evidence to address the research questions and objectives (Chenail, Thomas-Purcell,

George and Wulff, 2018). Subsequently, meta-synthesis will be carried out through a systematic statistical analysis of previous studies on the topic under review. In qualitative research, adopting a meta-synthesis approach is reliable for systematic search of resources as this process follows an intentional, logical, and consistent approach to analysing data across different qualitative studies, and then compare the results of the different studies. One of the benefits of conducting a meta-synthesis is that at the end of it, data collected for specific research is collectively viewed and then the research findings are integrated into a form that is easily accessible and understandable even by the layman.

According to Erwin, Brotherson, and Summers (2011), meta-synthesis is an analytical technique that builds on the qualitative results of the previous studies to gain a deeper understanding of the study area. The Metasynthesis technique involves rigorously going through qualitative data to synthesise the results of previous studies to generate a comprehensive meaning of the data through an interpretative process of the analysed data (Erwin *et al.*, 2011). In digging deeper to generate new knowledge about the phenomenon under study, the findings of the previous research are considered considering the sociocultural and disciplinary context in which the primary research was originally conducted (Peterson, 2009).

While conducting meta-synthesis for this research, the following sources of information will be analysed; interpreted data, unanalysed quotes, field notes and documents (Finfgeld, 2003). Finfgeld, (2003) went on to describe the three types of meta-synthesis.

- Theory building which pushes the levels of theorising beyond that which can be achieved in a single study
- Theory explication which reconceptualises abstract phenomena
- Descriptive which comprehensively analyses a phenomenon

The second objective is to establish challenges of proper implementation of BIM in construction companies. The data collection method is Meta-synthesis and interviews. Meta-synthesis is reliable for systematic search of resources and is conducted like a meta-analysis approach this approach is for integrating several studies to create a comprehensive and interpretative finding (Ezy, Saghatforoush & Abbasianjahromi, 2018). In this instant this study is conducted with the aim to establish challenges for proper

implementation of BIM in construction companies, with the use of challenges gathered from literature and then tested in construction companies.

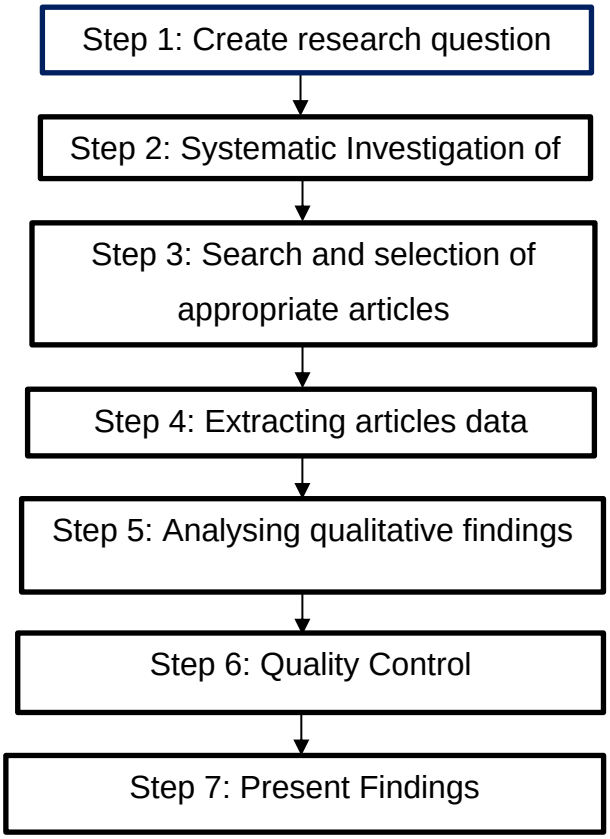


Figure 3.1: Steps for Meta-synthesis Approach (Adapted from Arbabi *et al*, 2017)

3.4.3 Interviews

An interview is a purposeful conversation between two or more people, requiring that the interviewer to establish understanding and ask concise and unambiguous questions to which the interviewee is willing to respond (Saunders *et al*., 2016). Apart from literature review they recommended the use of in-depth interviews as a way of collaborating data collected. Yin, (2003), divided interviews into three; open ended, focused, and structured. According to Griffiths, (2008), the other reason for carrying out the interviews is to avoid relying on the researcher's pre-determined assumptions.

Since the research is analytical, descriptive, and explanatory in nature, interviews are deemed appropriate for the exploratory part with the respondents afforded a chance to clarify statements and this allowed a greater opportunity to probe these responses to

achieve a better understanding of the interview questions. Participates for the interview will be chosen and selected via snowballing.

The third objective makes use of interviews. The third and final objective is to establish proper foundation for implementation of BIM the data collection method is Interviews, interviews is used to obtain detailed information about a topic, they give the researcher more meaning to the significance of what is happening. This study seeks to obtain information for the proper implementation of BIM to provide proper foundations for the implementation of BIM.

3.5 Data Analysis and software

To choose the most suitable data analysis method the researcher will address each objective separately.

3.5.1 Quantitative

The first objective is to assess the maturity levels of construction companies in Gauteng. The data analysis method is quantitative. It allows the researcher to suggest possible relationships between variables and to produce models between these relationships, understand, describe, and develop a phenomenon or setting (Saunders *et al*., 2016). Quantitative data analysis is characterised by graphical and chart illustrations, cross tabulation, and calculation of measures of central tendency (mean, mode and standard deviation) (Lacey and Luff, 2009).

The analysis involves the use of descriptive statistics to address the research question(s). In this study the researcher is to understand the maturity levels of construction companies by defining the maturity level and companies will choose which level they fall in. Quantitative data seeks to explore the phenomena and answers (Wilkinson & Birmingham, 2003). The researcher makes use of the Microsoft excel spreadsheets to analyse and present findings.

3.5.2 Qualitative

Qualitative research meaning is derived from words or images not numbers, words and numbers may have multiple meanings and interpretations it is important that the researcher take the time to explore and explore and clarify these meanings with great care (Saunders

et al., 2016). Lacey and Luff (2009), pointed to the fact that, research questions involving why, what, or how are suitably answered through qualitative research. Qualitative data analysis involves the determination of themes based on the information collected through observation and or interviews. The second objective is to establish challenges of proper implementation of BIM in construction companies. Data analysis method is quantitative, qualitative method will be applied for this objective and the software will be MAXQDA (see Appendix E). The third objective is to establish proper foundation for implementation of BIM the data analysis method is a qualitative method, MAXQDA software is so useful and plays a basic role in the analysis of texts in the qualitative studies and can easily organise and classify data by using its coding system.

The study will follow a qualitative approach, information will be interview transcripts, researcher notes, audio recordings and text documents gathered during the interviews. This data will be analysed as follows:

- The content will be categorised, summarised and tabulate
- Create a narrative analysis by formulating stories presented by respondents
- Framework analysis such as familiarising, identifying a thematic framework this involves charting, mapping, and interpretations.
- Grounded theory, this involves analysis of a single case to formulate a theory and then additional cases to evaluate if they contribute to the theory.
- Identify themes, patterns and relations that can be applied to generate findings
  Summarising the data, at this stage the researcher will link the findings to hypothesis, aim, and objectives, noteworthy quotations from transcripts will be utilised to make emphases of major themes within findings and possible contradictions.

Table 3.1 provides a summary of the research methods adopted in this research. For each research objective and sub question, the Table, states the research method, data collection method, data analysis method and software used to achieve the objective.

Table 3.1: Methods Summary

Objective	Sub-questions	Research Method	Data Collection method	Data Analysis	Software
To measure current maturity level of construction companies in South Africa to apply BIM.	What is the current maturity level of construction companies in South Africa to apply BIM?	Survey	Questionnaire	Quantitative	Excel Spreadsheet
To identify challenges for proper implementation of BIM in construction companies	What are the challenges for proper implementation of BIM in construction companies?	Literature Review	Meta Synthesis	Qualitative	MAXQDA
To provide foundation for proper implementation of BIM in construction companies based on their maturity levels.	What are foundations for proper implementation of BIM in construction companies?	Case Study	Interview	Qualitative	MAXQDA

3.6 Population and Sampling

A population includes all elements that meet certain criteria for inclusion in a study (Burns & Grove 2003:43). For this study the population will consist of professionals working for construction companies in South Africa Gauteng: this includes Architects, Engineers,

Quantity surveyors and Project Management consultants. The sample will be determined by Construction Industry Development Board (CIDB).

For this study the researcher will focus on active, civil engineering construction companies in South Africa, Gauteng. This is to create a more comparative analyses and to avoid generalising across all construction companies that have different works. CIDB defines Civil Engineering companies as construction works primarily concerned with materials such as steel, concrete, earth and rock and their application in the development, extension, installation, maintenance, removal, renovation, alteration, or dismantling of building and engineering infrastructure. The basic work types are water, sewerage, roads, railways harbours, and transport, urban development, and municipal services. According to the CIDB there are only 531 registered and active Civil Engineering construction companies in South Africa, Gauteng, this is what determined the size of the sample for the study.

The researcher did not refine the sample further into grades because of the need to look at companies of different sizes to give the different maturity levels, giving space for the researcher to provide companies with different maturity levels proper foundations for BIM implementation based on their maturity levels. Construction companies will have the desire for a competitive advantage that BIM can provide. The aim of the study to improve implementation of BIM among South African construction companies based on their maturity level and experienced challenges. The participants must meet the eligibility criteria. Eligibility criteria are the reasons or conditions for including the sample in the study (Polit & Hungler, 2004:290). Eligibility criteria of this study requires the professionals to:

- Have at least worked for a year in the construction companies
- Have access to project information
- Must be aware of the communication methods in the construction companies
- Be trained and qualified in their respective field

Below is the Figure that illustrates the sampling technique.

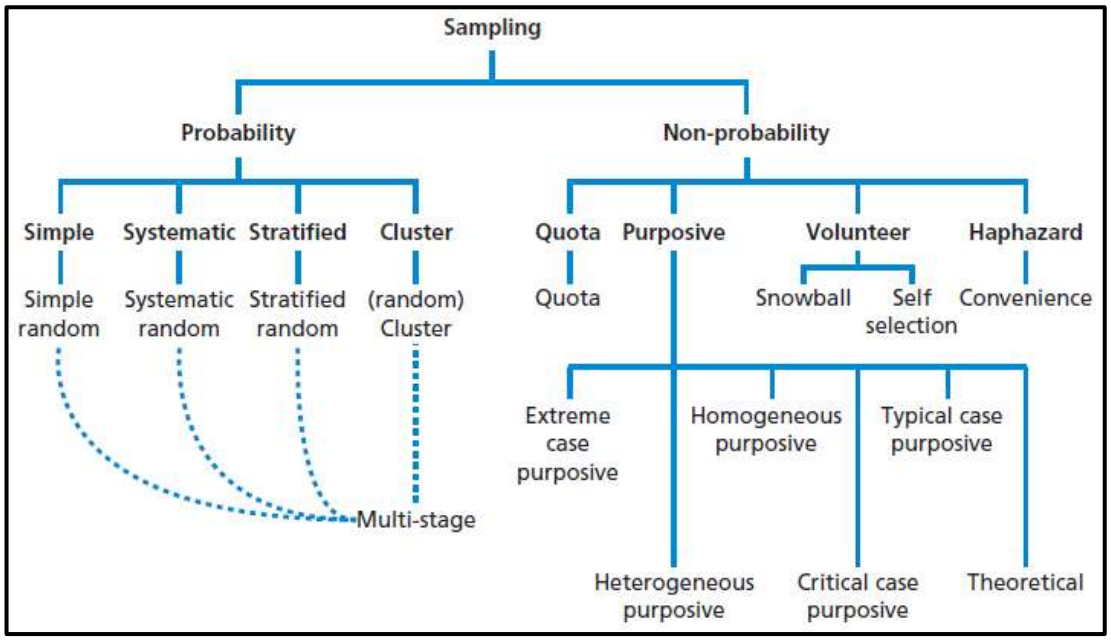


Figure 3.2. Categorisation of sampling techniques (Saunders et al, 2016)

A non-probability purposive sampling design will be used for the study, the researcher chose the non-probability sampling because for the need of their knowledgeable use of BIM in construction companies and their experience of collaboration and co-ordination methods in their respective companies. The study will follow a homogenous sampling. According to Saunders *et al*., (2016) homogenous sampling focuses on one subgroup in which all the sample groups are similar such as particular occupation or level in an organisation's hierarchy. This will allow the researcher to explore the sample in greater depth and minor differences to be more apparent. The sampling method is used for the survey only.

3.7 Data collection Protocol

The research approach will be a primary data collection in the form of qualitative nature. Qualitative studies allow for a greater level of depth understanding. Interviews will be conducted with the various professionals in construction companies accompanied by a questionnaire that is prepared. The researcher will ensure that leading questions are not asked during the interview. A short introduction to BIM will be given to the interviewees before the interview starts to familiarise them with the concept of BIM as well as its benefits.

3.8 Ethical Risks and Mitigation Strategy

The construction companies would have concerns on confidentially, and anonymity when intrusting you with their information. To maintain the integrity of all participants, strict confidentiality and anonymity in all collection and gathering of data will be followed. The study will adhere to the University of the Witwatersrand's ethics code with regards to research, all respondents will participate voluntary with informed consent for understanding the risk should there be any, and procedure of the research

3.9 Validity and Reliability

Validity can either be construct, internal or external. Construct validity is the determination of the correct measuring instrument for the concepts being studied (Polit & Beck, 2012). Reliability is a measure of regularity and should a separate study be carried out, it should arrive at the same results (Somekh & Lewin, 2006). To ensure reliability in a qualitative study it is important to examine the truth worthiness of the information. According to Scale (1999) a good quality research reports lies at the heart of the issues. For questionnaires emphasise is places on the fact that questions must be understood by the respondent in the manner that the researcher intended it to be, and the answer by the respondent must be understood by the researcher the way the respondent intend it to be Saunders *et al*., (2016).

According to Saunders *et al*., (2016), for a questionnaire to be valid and reliable the following four stages must occur.

- Stage 1: The researcher must be clear of the data requirements and designs the questions.
- Stage 2: Respondent decodes the questions as the researcher intended.
- Stage 3: Respondent answers the question.
- Stage 4: Researcher decodes the answer in the way the respondent intended.

Mitchell (1996) outlined three common approaches to assist in assessing reliability, he added that the researcher is to compare the data collected with other data from a variety of sources. Reliability refers to consistency, the approaches are:

- Test re-test obtained by relating data collected with those from the same questionnaire collected under similar or near equivalent conditions as possible.
- Internal Consistency: This involves relating the responses to the questions in the questionnaire with each other, this allows the researcher to measure the consistency of responses across a subgroup of questions.
- Alternative forms: this offers some sort of reliability by comparing responses to alternative forms of the same question or groups of questions.

In addition, to validate the questionnaires from respondents a follow up interview will be arranged. At the end of the prepared questionnaire respondents will be asked to indicate if they may have additional time for a follow up semi-structured interview with the researcher.

3.10 Chapter Summary

This chapter was on research design the philosophical approach for this paper is epistemology, as defined in the chapter it concerns assumption about knowledge, what constitutes acceptable, valid and legitimate knowledge and how we can communicate knowledge to others. The aim of the study is to provide a framework for improving BIM implementation among South African construction companies based on their existing maturity. This will be done by investing maturity levels of construction companies, test challenges found through literature to see whether they apply in South African construction companies and finally provide foundation for proper implementation of BIM in construction companies based on their maturity level, this is the knowledge that will be communicated to the construction companies.

The chapter that follows is the research execution plan, this is the researchers how-to-guide from ethical clearance application through to write-up and final submission. It is the tool the researcher will use to review milestone to complete the research. The execution plan will also consist of required resources and research constraints.

DATA PRESENTATION AND ANALYSIS

4.1 Introduction

The previous chapter focused on the research methodology adopted in this research. This chapter discusses issues relating to data presentation and analysis thereof. There are three kinds of data collection techniques employed in this research as alluded to in the previous chapter. Sections 4.2 and 4.3 deal with the presentation of online survey findings aimed at answering questions from the distributed questionnaire. The presentation of data is aided by graphs and charts developed using Microsoft excel. Section 4.4 presents literature review findings from the Metasynthesis process aimed at answering and achieving the second question respectively. Section 4.5 presents case study findings from the interview process and analysis conducted using the MAXQDA software. Lastly, section analyses the research findings linking them with findings from the literature review section.

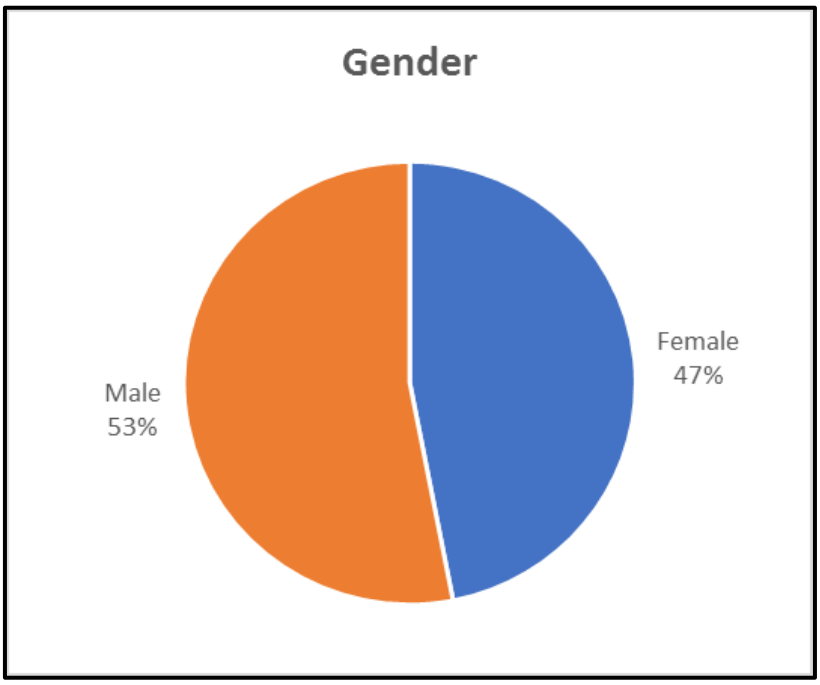
4.2 Demographic Data

As mentioned under section 3.4.1, the questionnaire is divided into three sections (see Appendix A). This section covers the presentation of data aimed at answering section A of the questionnaire with questions A01, A02, A03, A04 and A05. Since the research adopted the non-probability sampling technique due to insufficient information on the research population with BIM knowledge and experience. A total of 55 questionnaires were distributed and 49 responded over a period of two weeks giving a more than 89% response rate. The demographic information of the respondents is summarised in the Figures 4.1, 4.2, 4.3, 4.4 and Table 4.1 in the following subsections.

4.2.1 Respondents Gender Profile

This subsection presents findings for question A01 which sought to determine the gender profile of respondents. 53% of the respondents are male while females constituted 47% as shown in Figure 4.1. The 47% female respondents give the impression that, the once male dominated built environment industry is evolving to address gender inequality. However, one may argue that, having a more balanced response from male and female respondents necessarily mean that the industry has involved in gender equality as this could merely be based on the number of male and female respondents that received the questionnaire.

Figure 4.1: Respondents Gender Profile

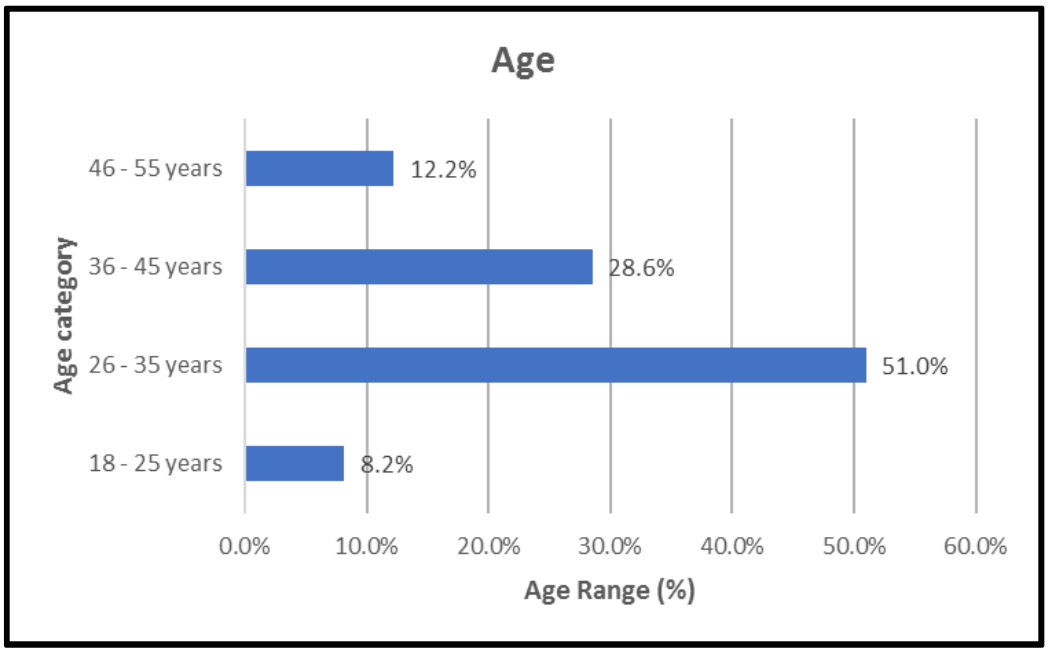


4.2.2 Respondents Age Profile

This subsection presents findings targeted at answering question A02 which sought to establish the age profile of respondents. Findings show that a majority (51%) of the respondents were aged between 26 and 35 years, followed by the age category of 36 to 45 years (28.6%), and then 46 – 55 years (12.2%), lastly, the age category of 18 to 25 years (8.2%). The findings suggest that most of the respondents have gained more experience in their respective professions as shown in Figure 4.2.

However, age does not necessarily relate to experience especially in an economy where the construction industry activity has been hit hard by the lack of infrastructure investment spending and pandemics such as Covid 19 which has resulted in unemployment of many professionals. Most graduates have also struggled to be absorbed by the system which from a critical point of view, raises concern as to why the majority (51%) of respondents fall under the 26 – 35 years age bracket.

Figure 4.2: Respondents Age Profile

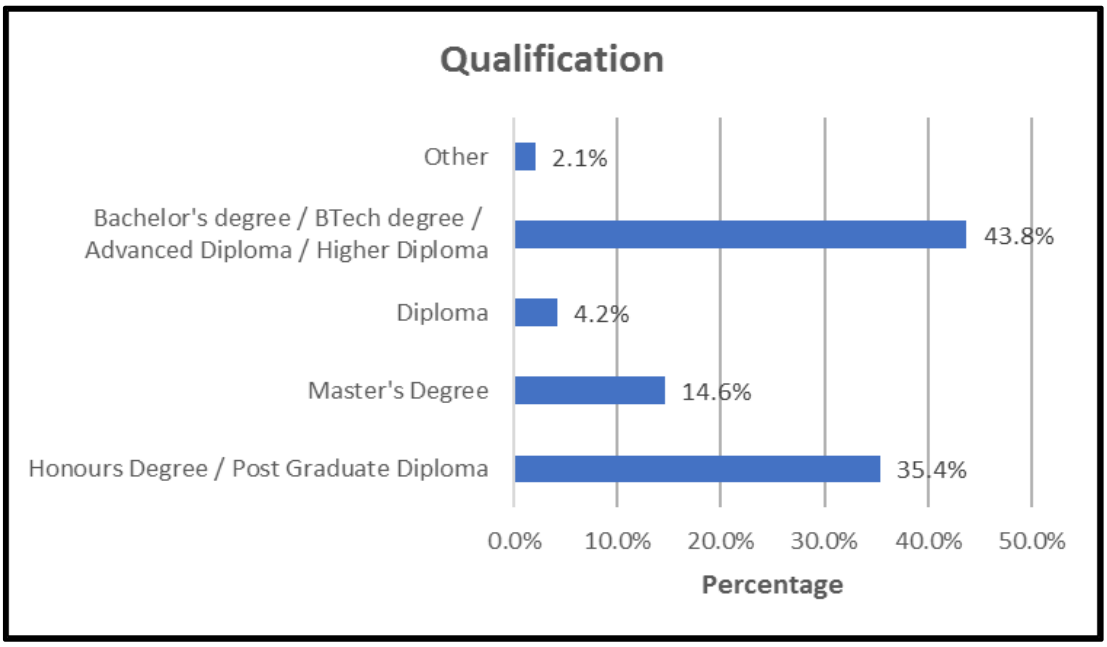


4.2.3 Respondents Qualifications

The aim of this subsection is to present findings for question A03 which sought to determine the academic qualifications of respondents. Equally important is the need to determine the levels of academic achievements for the respondents to determine whether there is any form of relationship between academic achievement and level of BIM understanding. 43.8% of the respondents hold either a bachelor's degree, advanced diploma, or higher diploma, 35.4% hold an honours degree / post graduate diploma, 14.6% have a master's degree while 4.2% hold a diploma and 2.1% hold other qualifications such as certificates and PhDs.

The findings are summarised in Figure 4.3 and clearly reveal that most of the respondents are highly qualified from an academic perspective thereby providing a motivation of the quality of data collected. However, it also key to note that, qualifications alone do not necessarily guarantee quality of responses. Views from respondents who have more practical experience and little or no qualifications can be very key in the generation of quality responses.

Figure 4.3: Respondents Qualifications



4.2.4 Respondents Work Experience

Without a doubt, work experience is key in the sense that respondents can provide key information. As a result, this subsection focuses on findings aimed at determining the level of experience of respondents. The respondents' industry experience ranges from less than five years to more than fifteen years, and most (65.63% public and 100% private) of the respondents have more than five years' experience as presented in Table 4.1. The colour density exhibited in Table 4.1 is merely for illustration purposes and is dependent on the number of respondents that is, the more the response the denser the colour becomes. As shown in Table 4.1, 32 of the respondents have experience working in the private sector. 34.38% of the private sector respondents have less than 5 years' experience, working mainly as engineer (6.25%), quantity surveyor (21.88%), construction project manager (3.13%) and other (3.13%).

Of the 53.13% of respondents working in the private sector with experience ranging between 5 and 10 years, 9.38% work as architects, 12.50% as engineers, 12.50% as quantity surveyors, 9.38 as construction managers, 3.13% as construction project managers and 6.25% as other. Furthermore, of the 6.25% respondents with private experience ranging between 11 and 15 years, 3.13% work as architects and 3.13% other.

6.25% of the respondents with experience above 15 years working as quantity surveyors (3.13%) and construction managers (3.13%).

In terms of public sector, there are no respondents with less than 5 years' experience. Of the 63.64% public sector respondents with experience of between 5 and 10 years, 36.36% work as engineers, 18.18% as quantity surveyors and 9.09% as construction project managers. Those respondents with public sector experience ranging between 11 and 15 years, represented 18.18% and mainly work as engineers (9.09%), and construction project managers (9.09%). Those respondents with public sector experience above 15 years represented 18.18% and were mainly working as quantity surveyors (9.09%) and construction project managers (9.09%).

Table 4.1: Respondents Work Experience

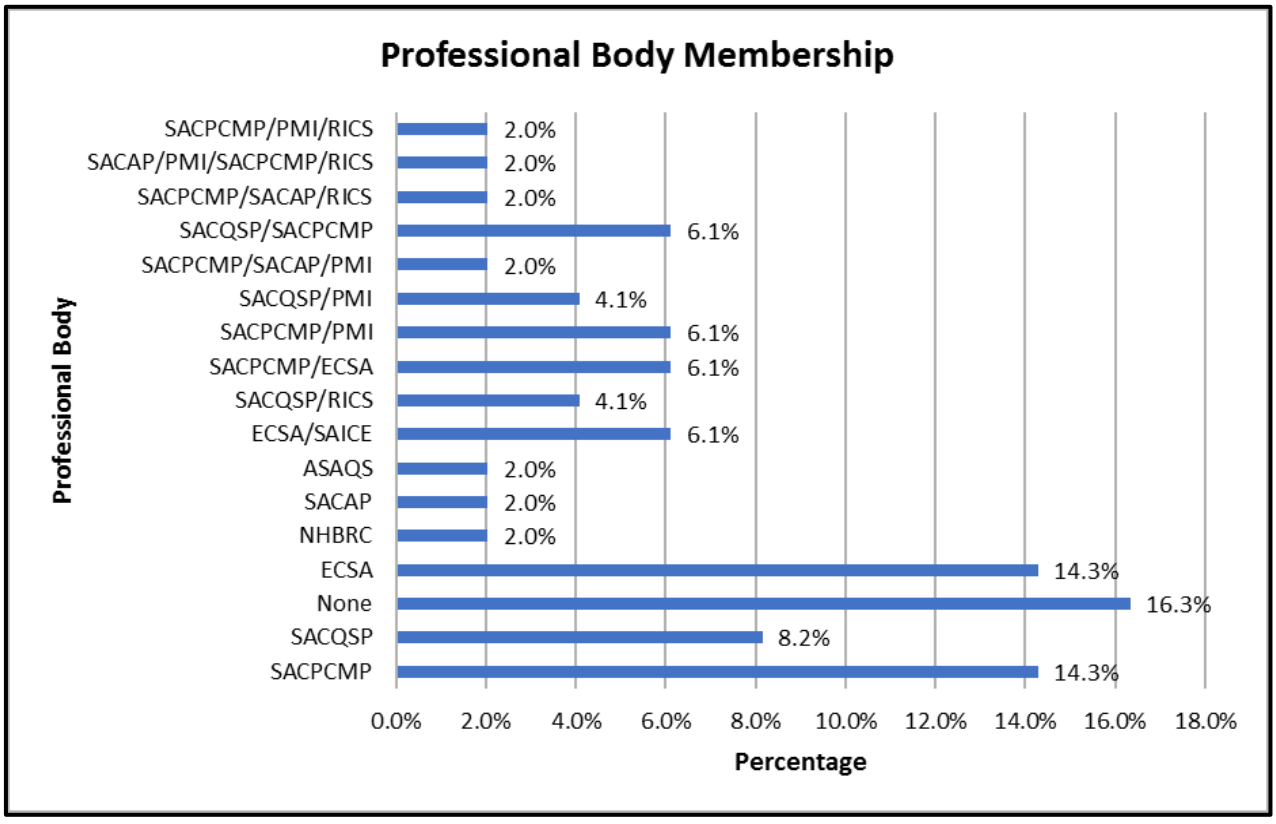
Period	Total	Architect	Engineer	Quantity Surveyor	Construction Manager	Construction Project Manager	Other
	Private Sector % (n=32)						
Under 5 years	34.38	0.00	6.25	21.88	0.00	3.13	3.13
5 - 10 years	53.13	9.38	12.50	12.50	9.38	3.13	6.25
11 - 15 years	6.25	3.13	0.00	0.00	0.00	0.00	3.13
Above 15 years	6.25	0.00	0.00	3.13	3.13	0.00	0.00
	Public Sector % (n=11)						
Under 5 years	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5 - 10 years	63.64	0.00	36.36	18.18	0.00	9.09	0.00
11 -15 years	18.18	0.00	9.09	0.00	0.00	9.09	0.00
Above 15 years	18.18	0.00	0.00	9.09	0.00	9.09	0.00

4.2.5 Respondents Professional Body Membership

Professional bodies are key in ensuring that their members uphold maximum ethical and or professional standards to achieve project quality within the stipulated timeframe. This subsection presents findings on the professional membership of respondents. Most (83.7%) of the respondents are affiliated with at least one of the recognised professional bodies within the South African built environment and internationally while 16.3% of the respondents do not have any professional affiliation.

As shown in Figure 4.4, majority of the respondents are registered with ECSA (14.3%) and SACPCMP (14.3%). 8.2% of the respondents are registered with SACQSP while 6.1% are registered with both SACQSP and SACPCMP, followed by another 6.1% registered with both SACPCMP and PMI, again 6.1% is registered with both SACPCMP and ECSA with the other 6.1% also registered with both ECSA and SAICE. Furthermore, 4.1% of the respondents are registered with both SACQSP and PMI while the other 4.1% is registered with both SACQSP and RICS.

Figure 4.4: Professional Body Membership



Demographic information is key in helping researchers understand the respondents and act as a check point for the quality of collected data. The next section presents findings from Section B of the questionnaire which aim to answer the question stated in Chapter 1.

4.3 Current maturity level of construction companies in South Africa to apply BIM

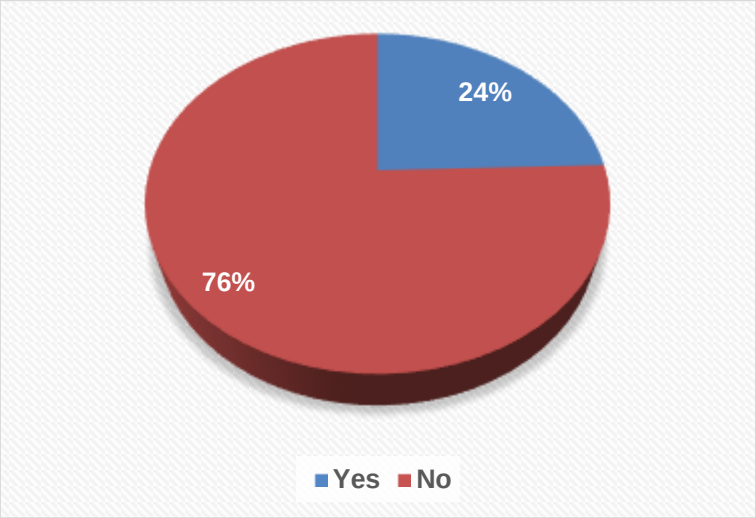
The previous section focused on presentation of demographic information. This section presents findings that assist with answering research questions and to achieve the objectives mentioned in the Chapter 1. The first question sought to determine maturity level of Building Information Modelling. According to the findings tabulated in Table 4.2, majority of the respondents are familiar with BIM.

Table 4.2: BIM Maturity Level

Criteria	MS	SD	Response (%) Not at all Familiar (1)…….Extremely Familiar(5)					n
To what extent do clients make provision for contractor failure on projects?	3.16	1.16	14.29	8.16	32.65	36.73	8.16	49

Following this, the researcher sought to determine the total number of respondents who had a chance to work with BIM on a project. As shown in Figure 4.5, only 24% of the respondents have had a chance to work with BIM on projects. This is a clear indication that BIM implementation is still in infancy stage in South Africa. This is also supported by the literature findings (see Chapter 2) which suggest that the implementation of BIM in South Africa still lags from the more advanced economies of the world.

Figure 4.5: Level of BIM Experience



Thereafter, the researcher sought to determine the extent to which the implementation of BIM enhance productivity within the construction companies, relative to the criteria shown Table 4.3. According to the findings, most of the respondents agree that the introduction of BIM will most likely improve productivity.

Table 4.3: Effect of BIM on Productivity

Criteria	Rank	MS	SD	Response (%) Extremely Unlikely (1)....Extremely Likely (5)					n
Cost and time savings in creating redundant building models	4	3.96	1.06	6.38	4.26	6.38	53.19	29.79	47
Improved project presentations to clients and for approval process	5	3.94	1.01	4.26	6.38	8.51	53.19	27.66	47
Facilitation of the examination and verification of architectural design concepts	3	3.96	0.98	2.13	6.38	17.02	42.55	31.91	47
Reduced production time	2	3.98	0.94	2.13	4.26	19.15	42.55	31.91	47
Increased quality of the outputs	1	4.15	0.91	2.13	2.13	14.89	40.43	40.43	47

Furthermore, the researcher sought to determine the impact of the criteria shown in Table 4.4 on the implementation of BIM. The results show that the respondents agree that all the listed criteria highly affect the implementation of BIM. By adding column 4 and 5 (agree and strongly agree) under Table 4.4, the findings suggest that software learning curves (61.71%), lack of support from company leadership (72.34%), lack of support from operational staff (59.58%) and initial investment costs (65.22%) have a combined majority of respondents who agree and strongly agree that the factors impact the implementation of BIM. 72.73% of the respondents are undecided on the impact of other unknown effects of BIM implementation.

Table 4.4: Impacts of BIM Implementation

Criteria	Rank	MS	SD	Response (%) Strongly Disagree (1)…….....Strongly Agree (5)					n
Software learning curves	4	3.40	1.17	8.51	17.02	12.77	48.94	12.77	47
Lack of support from company leadership	1	3.85	1.04	4.26	6.38	17.02	44.68	27.66	47
Lack of support from operational staff	3	3.60	0.88	0.00	12.77	27.66	46.81	12.77	47
Initial investment costs	2	3.78	1.03	0.00	15.22	19.57	36.96	28.26	46
Other	5	3.09	0.75	4.55	4.55	72.73	13.64	4.55	22

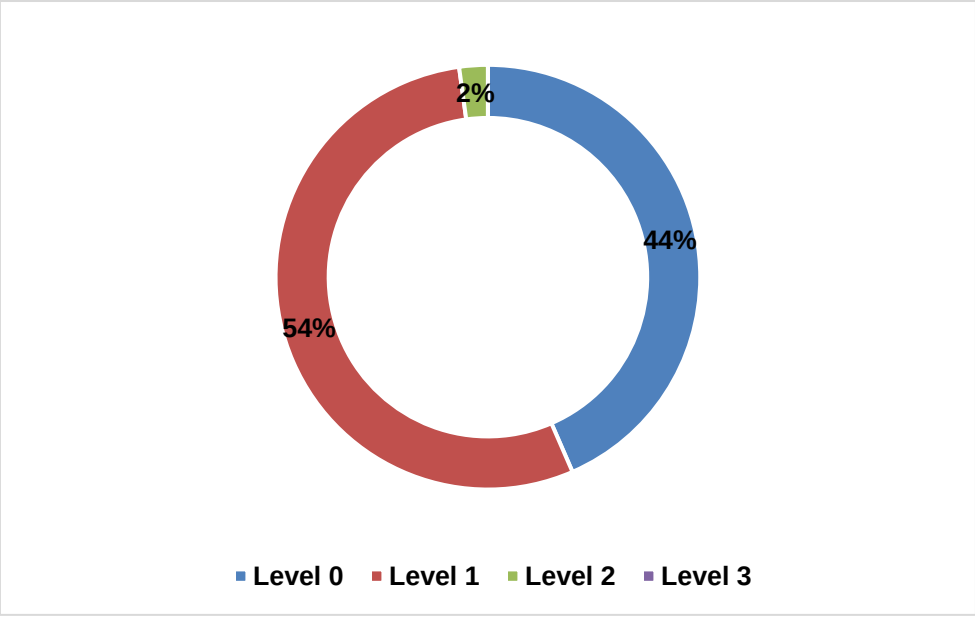
Following this, the researcher sought to determine the state of BIM within the South African construction industry based on the BIM maturity levels as shown in Figure 4.6. Based on the findings illustrated in Figure 4.6, 44% of the respondents are of the view that, BIM implementation in South Africa is still on level 0. As defined in section 2.6, this is the simplest

step of information generation which essentially makes use of computer aided design or CAD tools to create drawings and drawn elements using IT software

Moreover, 54% of the respondents are of the view that BIM adoption and implementation in South Africa is now on Level 1. According to Section 2.6, this level involves the progression from CAD to generating suites of 2D information, followed by non-federated 3D models. A mere 2% of the respondents are of the view that BIM adoption and implementation is now on Level 2 in South Africa. As mentioned earlier, this level focuses on the manner which the information is shared between project team members (see section 2.6).

Lastly, none of the respondents believes that BIM adoption and implementation has reached level 3 in South Africa, which is a full integration level as shown in Figure 4.6. These findings support the need for carrying out this research to come up with a framework supporting the implementation of BIM in South Africa.

Figure 4.6: State of BIM in South Africa



Next, the researcher sought to determine how construction companies exchange information with the design team in a project. Evidently, a majority (26 out of 48) of the respondents agree that the most common way of information exchange is through a mixture of 3D CAD for concept work, and 2D for drafting of statutory approval documentation and

production information and electronic sharing of data is carried out from a common data environment, this is often managed by the contractor. These findings also support literature findings which show that the rate of BIM implementation within South Africa is lagging when compared to other advanced economies. The rest of the findings are summarised in Table 4.5.

Table 4.5: Information Exchange

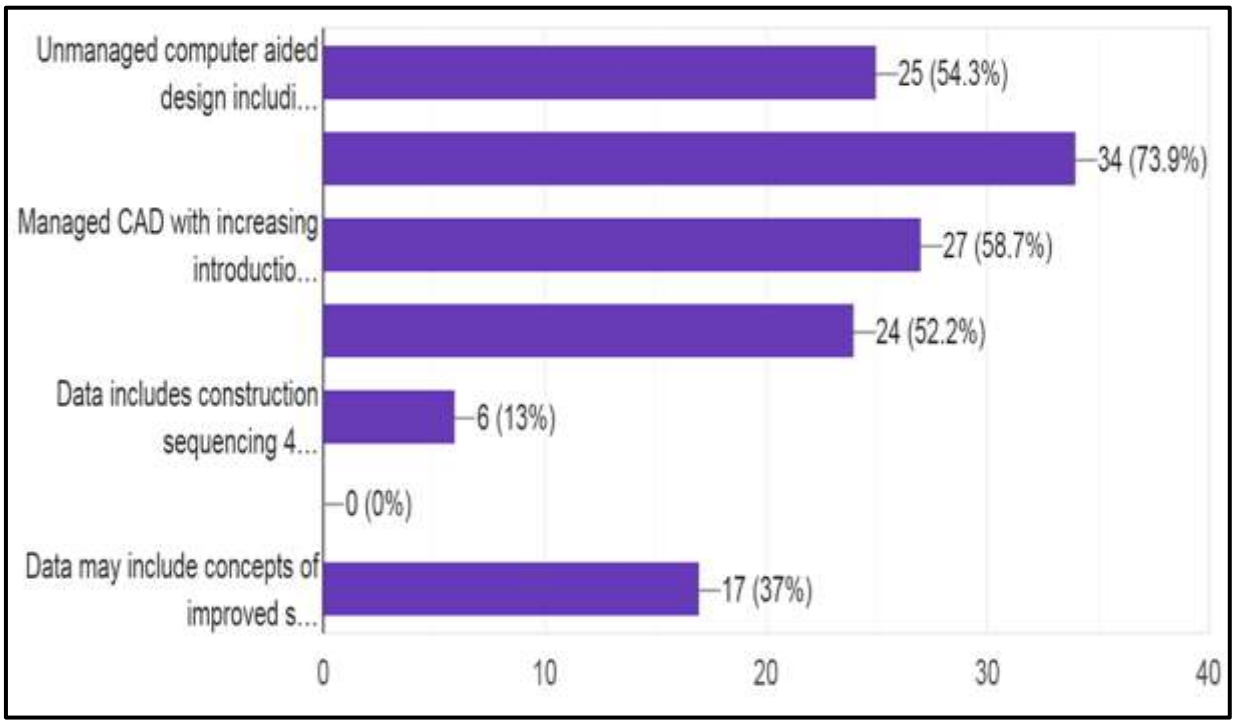
Criteria	n
Mixture of 3D CAD for concept work, and 2D for drafting of statutory approval documentation and production information. Electronic sharing of data is carried out from a common data environment, this is often managed by the contractor.	26
2D CAD drafting only is utilised, mainly for production information, Output and distribution is via paper or electronic prints, or a mixture of both.	11
CAD software that construction and project team is capable of exporting to one of the common format Construction Operation Building Information Exchange	7
Interdisciplinary models which have rich data fully integrated, interoperating data known as a common data environment. An Example of data model at this stage includes intelligent model with design, analysis, lean construction principles, maintenance schedules and the whole life costing of the structure.	4

Lastly, the researcher sought to determine methods of information exchange used by the respondents in their respective organisations when sharing information with the design team. 54.3% of the respondents agreed to the use of, unmanaged computer aided design including 2D drawings, 73.9% confirmed using text with paper based or electronic exchange information without a common standard process between the contractor and design team, managed CAD with increasing introduction of spatial coordination, 58.7% also confirmed the use of standardised structures and format.

52.2% confirmed that the method of information exchange includes 2D and 3D information such as virtualisations or concept development models, 13% of the respondents confirmed that information exchange data includes construction sequencing 4D, and cost information 5D, while none (0%) of the respondents agreed to the use of a single collaborative online

project model with construction sequencing 4D, cost 5D and the whole life cycle information 6d. Lastly, 37% of the respondents are of the view that, data may include concepts of improved social outcome and wellbeing. Figure 4.7 summarises the findings.

Figure 4.7: Methods of information exchange



This section aimed at answering the first question and achieving the first objective. As evidenced by the findings, majority of the respondents are of the view that, despite the benefits associated with the implementation of BIM within the construction industry, the adoption is still minimal. The following section seeks to answer the second question and achieve the second objective through the Metasynthesis process.

4.4 Challenges for proper implementation of BIM in construction companies

Section 4.3 answered the first research question and achieved the first objective. To identify challenges for proper implementation of BIM in construction companies, the Metasynthesis approach is used to answer the second question of this research. Many researchers are seemingly becoming interested in the Metasynthesis method around the globe due to its efficiency in qualitative research (Arbabi *et al*, 2017). As mentioned in chapter three, a careful search and review of existing literature, both academic and professional is done.

This comprises a search, identification and retrieval of literature followed by reading, analysis and pattern recognition. The following steps present the implementation process of qualitative data analysis applied in this research to answer the first question and achieve the first objective.

Step one: **Create research question**

All research begins with a careful consideration of a problem which a study will focus on. During problem formulation the researcher decides whether they are interested in simply describing the variables of interest or whether they are interested investigating the relationship between two or more variables and investigating whether the relationship is associated or occasional. In this study, the research problem is productivity of construction companies has declined significantly over the years compared to other industries, leading to project extension in time and costs and reduction of quality (Froise & Shakantu, 2014). Research has shown that, BIM can significantly improve coordination, reduce duplication, and decrease costs. The existence of these challenges indicates low maturity level in construction companies to apply BIM. This step involves the creation of a research question through the answering of what, who, when and how questions. Thus, the research question is.

What are the challenges for proper implementation of BIM in construction companies?

Step two**: Systematic investigation of texts**

This step involves the researcher selecting the literature that will focus on the study and for the purpose of this study meta-synthesis will be used for one of the objectives which is to establish challenges for proper implementation of BIM in construction companies. In keeping with ethical standards, this research is limited to authentic search engines including those shown in the Table 4.6.

Table 4.6: Data Search Engines

Google Scholar
Google Books
Research Gate
Scopus
Elsevier
Science Direct
Bielefeld Academic Search Engine (BASE)

The keywords and or phrases used in searching for information on the challenges for proper implementation of BIM in construction companies are shown in the Table 4.7 below.

Table 4.7: Key Search Words/Phrases

BIM
BIM Implementation Challenges
BIM Implementation Barriers
BIM Implementation Obstacles

Step three: **Search and selection of appropriate articles**

There is need for a criterion to determine whether a study is weak or not and whether the weak studies can be included or excluded from analysis. Furthermore, the selection criteria to be used in compiling the articles used in Metasynthesis is summarised in the Table 4.8 below. The researcher focused on recent articles to enable a better understanding of current BIM related issues. Most articles selected are published between 2015 to date. Older articles are also considered should they provide key information.

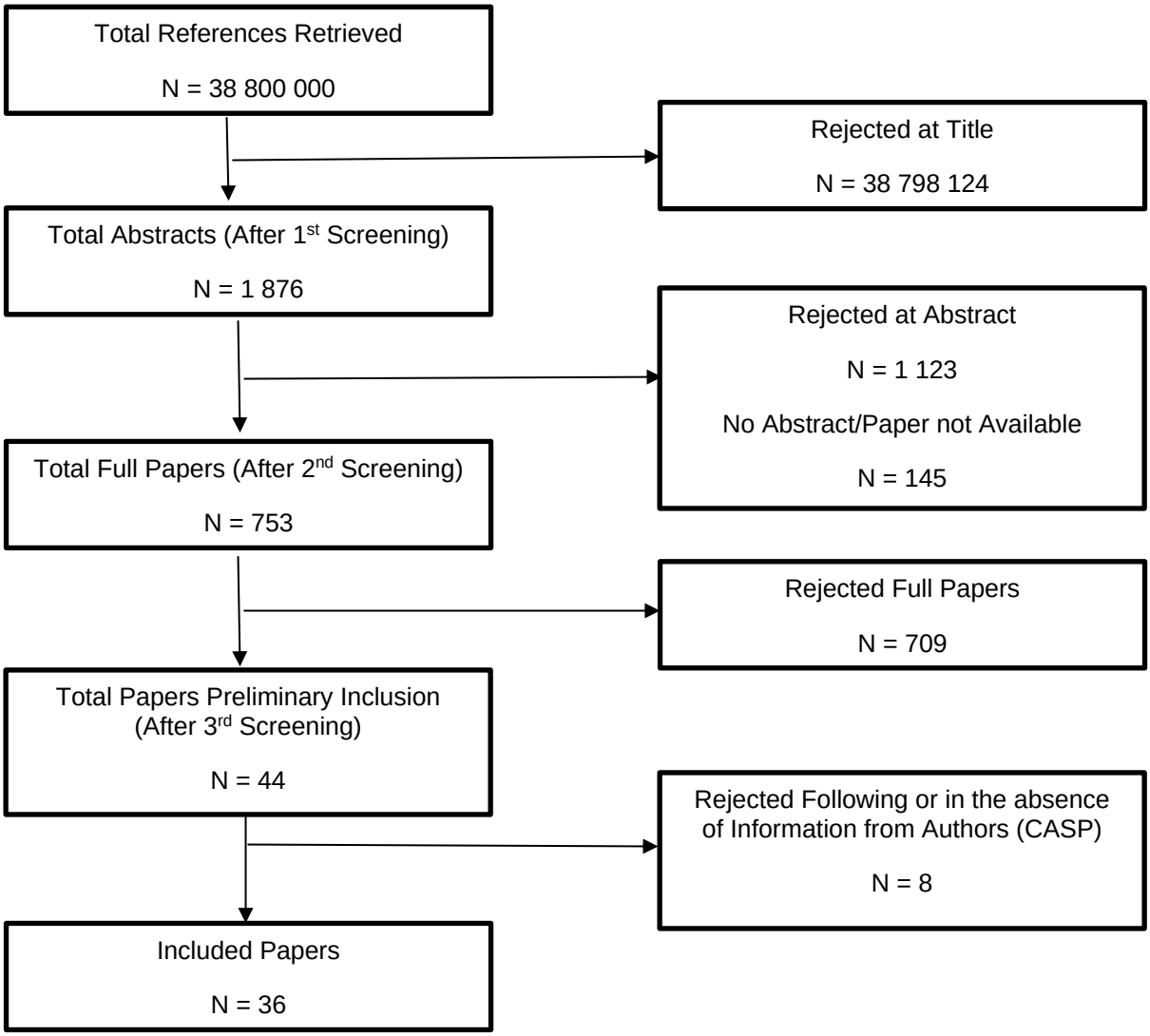
Table 4.8: Metasynthesis Selection Criteria

Preferred Language – English
Publication Timeline – 2015 – to date (but older articles will also be considered)
Research Type – Qualitative

Resource Type – Conference Proceedings, Company Reports, Government Publications, Books, Journals

The resources used to answer the first question are qualitative in nature as shown by the type of resources and texts in the Table 4.9. The results of the review process are illustrated in the Figure 4.8.

Figure 4.8: Data Review Process



A total of almost 38 800 000 references are initially retrieved and after the review process, 36 relevant references remained. These remaining articles are incorporated into the research to identify challenges for proper implementation of BIM in construction companies.

The CASP method, analyses each of all the remaining papers after the 3rd screening through a ten (10) question process with the aim of removing or deselecting articles that do not have adequate content to assist with the answering of the question asked in the first step. The articles are assessed on a scale of 0% – 100% with all those articles scoring over 80% being selected for the study. Therefore, of the 44 articles that remained after the 3rd screening, a total of 36 articles were further screened using the CASP criteria as shown in the Table 4.9.

Table 4.9: CASP Analysis

	Study is qualitative	Qualitative research is clearly justified	Research questions clearly stated	Study context is described	Sampling method is described and appropriate to the research question	Data collection method is described and appropriate to the research question	Ethical considerations considered	Data analysis is described and appropriate for the research question	Claims are supported by enough evidence	How valuable is the research	**Total Score**
Azhar, Khalfan, and Maqsood (2012)	9	10	9	9	9	10	10	10	9	10	**95%**
Rokooei (2015)	10	8	10	9	9	10	10	10	7	10	**93%**
Ghaffarianhoseini, Tookey, Naismith, Azhar, Efimova, and Raahemifar (2015)	8	8	9	9	10	10	10	10	8	10	**92%**
Eadie et al (2014)	10	9	9	9	9	9	9	9	9	9	**91%**
Chien, Wu, and Huang (2014)	9	9	9	9	10	8	9	8	9	9	**89%**
Harris, Che-Ani, and Tarmizi-Haron (2014)	8	9	10	8	9	8	9	8	10	9	**88%**

Tulenheimo (2015)	8	9	9	9	8	8	9	9	9	9	**87%**
Arayici et al (2017)	9	7	9	9	9	9	8	9	8	9	**86%**
Araszkiewicz (2015)	8	9	7	9	8	9	8	8	9	8	**83%**
Volk et al (2014)	8	9	8	7	7	8	9	7	9	10	**82%**
Memon, Rahman, Memon, and Azmon, (2014)	9	8	9	9	7	8	8	7	8	7	**80%**
Alizadeh, Bajgiran, and Nik (2016)	8	6	9	8	8	7	8	8	8	9	**79%**
Kuiper and Dominik (2013)	9	7	6	8	9	8	7	7	9	7	**77%**
Cubitt and Coldwell (2014)	7	9	9	8	6	8	8	7	6	8	**76%**
Thomson and Miner (2010)	6	8	8	6	8	9	7	7	8	8	**75%**
Pinsent Masons (2013)	9	7	7	8	6	7	8	7	8	7	**74%**
Cao, Li, Wang and Huang (2017)	7	6	7	8	6	9	8	9	6	7	**73%**
Singh, Gu, and Wang (2011)	9	8	7	5	7	8	6	9	8	5	**72%**
Miettinen and Paavola (2014)	6	5	8	7	8	7	8	6	7	8	**70%**
Zakaria, Mohamed Ali, Tarmizi Horan, Marshall-Ponting, and Abd Hamid (2013)	7	5	8	5	7	8	7	9	6	7	**69%**
Jin, Hancock, Tang, and Wanatowski (2017)	5	8	7	6	7	8	6	7	6	7	**67%**
Lawrence, Watson, Boudreau, Johnsen, Perry, and Ding (2012)	6	5	6	6	6	6	7	8	7	8	**65%**
Elmualim and Gilder (2014)	6	5	6	8	5	8	7	7	7	5	**64%**
Ham and Gilparvar-Fard (2014)	6	6	5	6	8	6	6	5	7	8	**63%**
Owen, Amor, Palmer, Dickinson, J., Tatum, Kazi,	7	6	6	5	6	6	7	6	7	6	**62%**

Prins, Kiviniemi, and East (2010)											
Hancock et al 2017	5	7	8	6	6	5	7	6	5	5	**60%**
Jiang, Man, Shen, Skibniewski, and Sun (2017)	6	5	5	5	8	5	7	5	7	6	**59%**
Olantunji (2015)	5	7	6	6	6	6	6	6	5	5	**58%**
Chong, Fan, Hsieh, Sutrisna, and Tsai (2017)	6	5	6	5	5	6	8	5	5	6	**57%**
Kiptrotich (2014)	5	8	5	6	6	5	5	5	6	5	**56%**
Efimova, Ghaffarianhoseini, Ghaffarianhoseini, Naismith, Raahemifar, and Tookey (2017)	5	5	5	5	6	5	6	5	8	6	**56%**
Alwash, Love and Olatunji (2017)	5	6	5	6	5	6	5	5	5	7	55%
Brewer, Jefferies and Manderson (2015)	6	5	5	5	5	6	5	5	7	5	54%
McArthur (2015)	5	6	5	5	6	5	5	6	5	6	54%
Porwal and Hewage (2013)	6	5	5	5	6	5	5	6	5	5	53%
Zakaria et al (2013)	5	5	5	5	6	5	5	6	5	5	52%
Alreshidi, Mourshed and Rezgui (2017)	4	5	4	3	4	5	4	3	4	4	40%
Eadie, Browne, Odeyinka, McKeown, and McNiff (2013)	3	4	4	3	4	4	3	4	4	3	36%
Migilinkas, Popov, Juocevicius and Ustinovichius (2013)	4	3	4	3	4	4	3	4	3	3	35%
Kelly et al (2013)	3	2	3	4	4	3	2	3	4	4	32%
Arensman and Mehmet (2012)	3	3	4	2	3	4	3	3	3	2	30%

Rekola, Kojima, and Makelainen (2010)	3	2	3	3	3	2	3	2	2	4	27%
Gu and London (2010)	4	2	3	2	3	2	2	3	2	2	25%
Khosrowshahi and Arayici (2012)	3	2	3	2	3	2	3	2	2	2	24%

Step four: **Extraction articles data**

Without a doubt, data relevance is key during this stage. As such, a total of 36 articles remained after the scrutinizing and screening process. These articles are analysed during this stage to extract challenges for proper implementation of BIM in construction companies to answer the research question asked during the first step.

Step five: **Analysing qualitative findings**

During this stage, a thematic review of BIM implementation challenges is performed. This involves the classification and coding of common sources as well as analysis using the MAXQDA qualitative research software.

Step six: **Quality control**

The researcher selects reliable articles after the screening process shown in the Figure above. The following final section presents findings of the study.

Step seven: **Present findings**

The goal of this stage is to answer the question asked during step one. From the Metasynthesis process, various challenges to the adoption of BIM have been identified. Table 4.10 summarises the findings.

Table 4.10: Metasynthesis Findings

List of Challenges	Category	References
Lack of Senior Management Support	Management	Jung and JOO (2011), Arayici & Aouad (2010)
Doubts about return on investment/ Lack of vision of benefits	Financial/Economic	Arayici et al., (2011); Lee et al., (2012); Coates et al., (2010)
Cost of training	Financial/Economic	Yan and Damian, (2008); Coates et al., (2010); Azhar, (2011); Crotty, (2016); Efficiency and Reform Group, (2011)
Cost of Software	Financial/Economic	Thompson and Miner, (2010); Azhar, (2011); Crotty, (2016); Efficiency and Reform Group, (2011)
Scale of culture required/ Lack of flexibility	Management	Yan and Damian, (2008); Rowlinson et al., (2010); Jordani (2008); Mihindu and Arayici, (2008); Watson, (2010)
Lack supply chain buy-in	Industry Specific	Cabinet Office, (2016)
Staff Resistance	Management	Arayici et al., (2011); Yan and Damian, (2008)
ICT Literacy of stuff/Lack of technical experience	Management	Arayici et al., (2011); Yan and Damian, (2008); Aouad et al., (2017)
Legal Uncertainties	Legal	Udom, (2012); Oluwole, (2011); Christensen et al., (2007); Race, (2012); UK BIM Industry Working Group, (2011); Chao-Duivis, (2011)
Lack of standards	Industry Specific	Abubakar et al., (2014); Aibinu and Venkatesh (2014); Smith (2014),
Lack of government support and drive	Socio Political	Abubakar et al., (2014); Aibinu and Venkatesh (2014); Smith (2014),

List of Challenges	Category	References
Lack of clarity of stakeholder roles and responsibility	Industry Specific	Elmualim and Gilder (2014); Rekola et al., (2010),
Stakeholder perception of the effectiveness and efficiency of BIM.	Management and Industry specific	Ibrahim, Abanda, Vidalakis and Wood (2017); Aziz, Nawawi and Ariff (2016); Becerik – Gerber, Jazizadeh, Li, and Calis (2012); Kelly et al., (2013)
Interoperability	Industry specific	Ibrahim *et al*., (2017) Alizadeh et al., (2016); Salleh and Fung, (2014)
Uncertainty over project life cycle management	Industry specific	Ibrahim *et al*., (2017); Fitzemeyer and Tocci Associates (2017); Mohanta and Das, (2016)

This section focused on answering the second objective to identify challenges for proper implementation of BIM in construction companies. The following section deals with the last question of the research which seeks to provide foundations for proper implementation of BIM in construction companies based on their maturity levels.

4.5 Foundations for proper implementation of BIM in construction companies based on their maturity levels

The previous section focused on achieving the second objective which sought to identify challenges for proper implementation of BIM in construction companies. The objective of this section is to provide foundations for proper implementation of BIM in construction companies based on their maturity level. As mentioned in Chapter 3, the research method adopted to achieve this objective is a case study and for the purposes of this study, 1 case study was done in a company that has had ‘some’ experience working with BIM in projects. However, it is key to mention upfront that, most of the stakeholders engaged with, including the interviewees, agree that BIM implementation in South Africa is still in the infancy stage.

Without any doubt, BIM is the future of the construction industry as emphasised by the Royal Institution of Chartered Surveyors (RICS) (2020). As mentioned earlier, more economically advanced economies such as the United Kingdom have already made BIM mandatory on public projects which has resulted in the increased adoption of BIM (Paul, 2018). Although the implementation of BIM comes with various challenges, project stakeholders should have futuristic mind-sets to allow for the successful implementation of the concept. Scholarly articles presented in chapter 2, section 2.5.3, stress the importance of implementing BIM in the construction industry.

Moreover, data collection was done through interviews and a total of 4 interviews were carried out before the saturation point was reached. As mentioned in Chapter 3 under section 3.4.3, the interviewees were selected through snowballing since the researcher was targeting respondents with knowledge and practical experience working with BIM. Two of the interviewees work as Engineers while the other two work as Project Manager and Quantity Surveyor respectively. The analysis of qualitative interview data findings was done through the MAXQDA software (also see Appendix E).

One of the respondents was of the view that, to improve BIM implementation.

"There needs to be a push for this type of software to be implemented but my main thing of not saying that BIM specific because there might come another software that is different from BIM but sells the same function. So, I do agree that this type of software needs to be pushed and I believe that the best type of people to push it first and foremost is the government since they are the construction industry's biggest client."

RICS (2020) suggests that the first important step in the implementation of BIM is for an organisation determine the current BIM level of maturity stage through carrying out a business audit which helps to identify current capacity and capability of the organisational protocols and technologies. This research focused on the foundations for better implementation of BIM depending on the maturity level. In accordance with the research findings, it is important for organisation seeking to implement BIM to have a plan of action on how factors such as recruitment of staff, in-house training and client relationship management policies will be aligned to the organisational goals.

Another interviewee was of the view that.

"Obviously, for proper implementation of BIM, there must be a standard. If the standard is national or international, everyone will have to work on that standard. If there is no standard, it is going to be difficult but if there is a standard, everyone will be working on one standard."

Furthermore, another interviewee was of the view that.

"Workshops with government would help contractors to include BIM in their policy so that it can be implemented in their projects and once the benefits are realised then other sectors like the private sector can also be motivated to implement BIM."

Based on the 2014 Applecore design of the BIM maturity model illustrated in Chapter 2, Figure 2.2, and the interview findings suggest that BIM in South Africa is still in the infancy stage which is Level 1. There is a consensus among the interviewees as shown in Table 4.11 that the government needs to play a leading role in the implementation of BIM since it is by large the greatest client for the infrastructure and construction industry in South Africa.

Table 4.11 provides a summary adapted from the MAXQDA analysis software on the respondents' feedback with regards to suggestions that can assist construction companies with proper BIM implementation in South Africa. The Table (4.11) summarises all suggestions made by the interviewees to improve implementation which are then linked with the BIM implementation challenges identified through the Metasynthesis.

Table 4.11: Interview Findings for Better Implementation of BIM

Document name	Suggestions for better BIM Implementation (Interviews)	BIM implementation Challenges (Metasynthesis)
Interviewee 1	More BIM education at institutions of higher learning will help in dealing with the challenges.	ICT Literacy of stuff/Lack of technical experience
Interviewee 1	More incentives likened to BEE structure where companies are incentivized to be more BEE compliant to have a better chance of winning tenders especially government tenders.	Lack of Senior Management Support Lack of government support and drive
Interviewee 1	It would also help if the Government introduced a BIM type of rating were if a company is more compliant, there is a better chance of getting a project.	Lack of government support and drive
Interviewee 2	Government should be involved since it is the biggest client for the construction industry. If the biggest client makes BIM mandatory on all projects, it becomes easy for the concept to trickle down to other contractors and subcontractors.	Scale of culture required/ Lack of flexibility Lack supply chain buy-in Staff Resistance
Interviewee 2	Once the stakeholders see the value of the system and how it helps them to fast-track their own work, the whole costing of it will sort itself out.	Doubts about return on investment/ Lack of vision of benefits Cost of Software
Interviewee 3	There must be a standard	Lack of standards Lack of clarity of stakeholder roles and responsibility
Interviewee 4	The South African government will need to work as a driver of BIM implementation since it provides more construction contracts.	Legal Uncertainties Interoperability Uncertainty over project life cycle management
Interviewee 4	The older generation of employees generally do not like change and the	Stakeholder perception of the effectiveness and efficiency of BIM.

	use of these new technologies, but to implement BIM successfully, it has to be introduced at academic level to get a good buy in from the younger generation as they are the future of the industry then that would be a good way forward.	

From the Table above, it is evident that the various challenges associated with the implementation of BIM can be averted by applying different solutions as suggested by the interviewees. The findings from the interviews and Metasynthesis helped the researcher in coming up with a proposed framework to be applied in the successful implementation of BIM regardless of the maturity level. In coming up with the proposed framework, findings presented in Table 4.11 were grouped and arranged to generate key concepts that were incorporated into the framework.

4.6 Framework for improving BIM implementation

Figure 4.9 presents the framework aimed at improving the implementation process of BIM throughout the four (4) maturity levels that is Level 0, Level 1, Level 2, and Level 3. As shown in Figure 4.9, the process commences with the need for stakeholder involvement in the conceptualisation stage leading to the execution process by the contractor(s). Once the stakeholders have conceptualised the need for BIM implementation, an execution plan should be drafted. The project execution plan (PEP) is the central document which creates the ways to execute, monitor, and control projects. The PEP serves as the main communication vehicle to ensure that all stakeholders are aware and well-informed about project objectives and how they will be achieved, the roles and responsibilities of BIM, quality management and agreement on all available technicalities.

Moreover, the execution plan results in the deliverables which are tangible or intangible goods and or services produced because of a project that is intended to be delivered to a customer or client. The BIM execution plan leads to deliverables that improve the project delivery processes. It is key for the South African construction industry to implement frameworks such as the one illustrated in Figure 4.9 to improve and ensure the successful implementation of BIM within the construction industry.

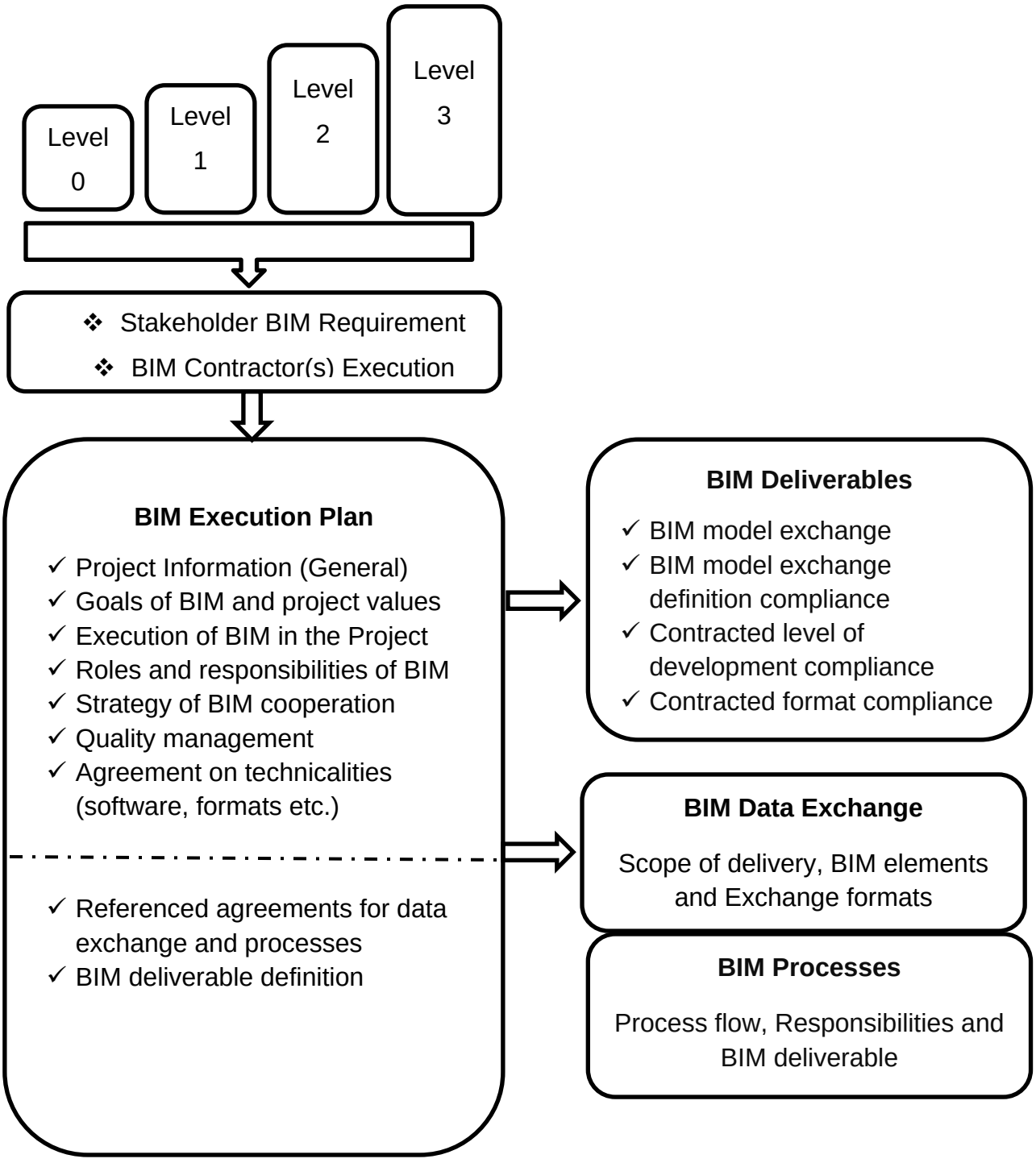


Figure 4.9: Framework for Improving BIM Implementation

This section presented foundations for proper implementation of BIM in South Africa. The next section summarises Chapter findings and provides a link with the final chapter.

4.7 Summary

In brief, this chapter answered and achieved the research questions and objectives respectively. Data collected from questionnaires, Metasynthesis and interviews was presented and analysed to create insightful meaning. A link to reach the research conclusion and suggestions has also been created in this chapter. The next chapter deals with the conclusion of the study, presenting implications for the various stakeholders directly involved or otherwise involved in this research. The chapter will also be dedicated on providing suggestions and recommendations for future research.

.

DISCUSSION, CONCLUSION AND RECOMMENDATIONS

5.1 Introduction

The study provided a framework to improve BIM implementation among South African construction companies based on their maturity level. As was mentioned throughout this research, the BIM implementation in South Africa is still in the infancy stage. Subsequently, research has shown that BIM has significant potential to reduce construction costs through the improvement of collaboration among the stakeholders involved in the construction industry. However, all these potential benefits can accrue to nothing if stakeholders do not work together to ensure the successful implementation of BIM. Providing foundations for proper implementation of BIM in construction companies based on their maturity level is therefore necessary in the success of BIM in South Africa.

5.2 Discussion

The aim of the research was to provide a framework for improving BIM implementation among South African construction companies based on their existing maturity. The suggested framework has been presented under section 4.5. The findings from research suggest that the implementation of BIM within the South African construction industry is still in the infancy stages but there is a strong need for stakeholders to work together in the implementation process to enable the industry to realise the benefits of BIM thus confirming the views of Akintola *et al*., (2017) who were also of the view that BIM implementation in South Africa is lagging. In concluding the research, this section provides a linking bridge between Chapter 2 and 4 findings. Since all the research questions have been answered in Chapter 4, this section discusses the main issues arising from the two Chapters.

Without a doubt, the remark by Salleh and Fung (2014) that, creation of awareness, establishment of rules, regulations, standards, codes of practices and the provision of training are key steps that need to be followed when adopting BIM has been positively confirmed in this study. This is supported by the interview findings as all the respondents supported the need for training and development of stakeholders to encourage them to buy into the idea of implementing BIM. As discussed throughout the research, factors such as lack of established case law, lack of skilled personnel/BIM expertise, unclear specifications,

poor coordination, and lack of knowledge of BIM implementation play a major role in the successful implementation of BIM (Akintola *et al*., 2017 and Atkinson *et al*., 2014).

The findings of Doumbouya et al., (2016) regarding the facilitative benefits of BIM in a building life cycle have been positively validated by the findings of this research. All respondents as presented in Chapter 4, strongly agree that savings or value can be achieved through BIM as it will ensure efficiency and effectiveness within the construction industry. However, all these benefits are dependent on effective implementation of BIM. Aouad *et al*., (2017) emphasised the importance of stakeholder communication in the success of projects. This research aimed to provide a framework for improving BIM implementation among South African construction companies based on their existing maturity. Various suggestions were identified during the collection of primary data which has resulted in the development of the framework in Chapter 4.

Evidently, BIM has various benefits throughout the construction process (Atkinson *et al*., 2014). However, care must be taken to ensure the smooth implementation of BIM in South Africa. The research has provided the challenges encountered in the implementation of BIM and provided means of handling the implementation process through the development of a framework which can be adopted during implementation. The framework presented in Figure 4.9 is key in the successful implementation of BIM within the South African construction industry regardless of level of organisational maturity.

BIM implementation is without shortcomings, but the benefits far outweigh these shortcomings (Fazli *et al*., 2014). As discussed in chapter 2, countries such as the UK that implemented BIM early have realised the benefits leading to the government making BIM compulsory on all public sector construction contracts. Moreover, the findings suggest that there is a need for the South African government to take a leading role in the implementation of BIM like what other governments are doing around the world (Mohd and Latiffi, 2013). The following section provides general conclusions of the research.

5.3 Conclusion

As mentioned under section 1.6, this research sought to

1. To measure current maturity level of construction companies in South Africa to apply BIM.
2. To identify challenges for proper implementation of BIM in construction companies
3. To provide foundations for proper implementation of BIM in construction companies based on their maturity level.

The built environment industry in South Africa has a lot to benefit from the BIM process. Unfortunately, there are very few companies if any in South Africa that are actively utilising this option. Some construction professionals in South Africa do not realise the benefit of BIM due to a lack of education, wrong and misleading information, and the fear of the unknown. There is therefore a need to follow in the footsteps of built environment industries such as the Irish and UK that recognised this shortfall very early and led BIM leaders to focus on targeting the building owners and Facilities Managers and or Asset Managers to be better informed and correctly educated.

5.4 Research Contributions

There are various contributions made by this research both to industry and to the academic field and these categories are explained distinctly in this section.

Contribution to Industry

Firstly, the research emphasises the need to implement BIM in the South African construction industry.

Secondly, the research presents construction professionals with information relating to dealing with challenges associated with implementation of BIM through the creation of a standard checklist.

Contribution to the Academic Field

The research provides a deeper academic understanding of the issues to do with BIM implementation challenges within the South African built environment.

5.5 Research Limitations

The case study method is very effective when respondents have more hence on experience with the subject matter. Indeed, the interview respondents were very much knowledgeable in the various ways of dealing with BIM implementation challenges. However, due to the lack of construction projects fully utilising BIM, the respondents lacked adequate practical experience to provide in-depth responses.

This research entirely relied on sources of data that have been published in English or those that have been translated into English.

5.6 Future Research Recommendations

Currently, BIM is in a conflicted state in South Africa despite all the education work that has been done by organisations such as the BIM Institute. It is still largely unknown in the construction industry. Therefore, the major suggestion for future research is on the readiness of both the public and private sector to implement BIM throughout the building lifecycle.

More research is required on the regulation of BIM in South Africa. An area requiring more focus is the creation of statutory instruments that provide some form of regulation in terms of how BIM is implemented and managed in South Africa.

References

Abubakar, M., Ibrahim, Y. M., Bala, K., and Kado, D. (2014). Contractor's Perception of the Factors Affecting Building Information Modelling (BIM) Adoption in the Nigerian Construction Industry, International Conference on Computing in Civil and Building Engineering

Aibinu, A. A., and Venkatesh, S. (2014). Status of BIM Adoption and the BIM Experience of Cost Consultants in Australia, Journal of Proffesional Issues in Engineering Education and Practice, 140(3)

Akintola, A., Root, D., and Venkatachalam, S. (2017). "Key Constraints to Optimal and Widespread Implementation of BIM in the South African Construction Industry Proceeding of the 33rd Annual ARCOM Conference, Cambridge, UK

Alizadeh, K. M., Bajgiran, J. S., and Nik, E. R. (2016). "Building Information Modeling (BIM): A Study to Prioritize Applications, Risks and Challenges." IEOM Society International, Kuala Lumpur, Malaysia

Alreshidi, E., Mourshed, M., and Rezgui, Y. (2017). "Factors for Effective BIM Governance." Journal of Building Engineering, 10, 89-101

Alwash, A., Love, P., and Olatunji, O. (2017). "Impact and Remedy of Legal Uncertainties in Building Information Modelling." Journal of Legal Affairs and Dispute Resolutions in Engineering and Construction, 9(3)

Andersen, J. L (2000). The Unidentified Value of IT in the Construction Industry. The Hong Kong Polytechnic University, Hong Kong

Aouad, G., Lee, A., and Wu, S. (2017). Constructing the future: nD modelling, Taylor and Francis, London and New york

Applecore Designs, (2014). About BIM, http://www.applecoredesigns.co.uk/bim/

Araszkiewicz, K. (2015). "Building Information Modelling: An Innovative Way to Manage Risk in Construction Projects." International Journal of Contemporary Management, 14(3), 23-40

Arayici, Y., and Aouad, G. (2010), Building Information Modelling (BIM) For Construction Lifecycle Management in: Construction and Building: Design Materials and Techniques, Nova Science Publishers, New York, USA

Arayici, Y., Coates, P., Koskela, L., Kagioglou, M., Usher, C. and O'Reilly, K. (2011) "Technology Adoption in the BIM Implementation for Lean Architectural Practice." Automation in Construction, 20, 189-195

Arayici, Y., Counsell, J., Mahdjoubi, L., Nagy, G. A., Hawas, S., and Dweidar, K. (2017). Heritage Building Information Modelling, 1st Edition, Routledge

Arayici, Y., Fernando, T., Munoz, V., and Bassanino, M. (2018). Interoperability Specification Development For Integrated BIM Use In Perfomance Based Design, Automation In Construction, 85, 167-181

Arbabi, O., Saghatforoush, E., Nikouravan, H. A. and Mahoud, M. (2017). Solutions to Overcome Barriers of Implementing Constructability, Operability and Maintainability (COM) Concepts in Infrastructure Projects: A Meta-Synthesis Approach, Journal of Engineering, Project and Production Management, 7(2), 63-79

Arensman, D., and Mehmet, E. (2012). "Building Information Modelling and Potential Legal Issues." International Journal of Construction Education and Research, 8(2), 146-156

Atkinson, J. (2002). Four Steps To Analyse Data From A Case Study Method, Association For Information Systems

Atkinson, L., Amoako-Attah, J., and Bahadori-Jahromi, A. (2014). Government's Influence On The Implementation Of BIM, Computing In Civil And Building Engineering, 23-25

Azhar, S. (2011). "Building information modelling (BIM) : Trends, Benefits, Risks and Challenges for the AEC industry." Leadership and Management in Engineering, 241-252

Azhar, S., Efimova, O., Ghaffarianhoseini, A., Ghaffarianhoseini, A., Naismith, N., Raahemifar, K., and Tookey, J. (2017). "Building Information Modelling (BIM) uptake:

Clear benefits, understanding its implementation, risks and challenges." Renewable and Sustainable Energy Reviews, 75, 1046-1053

Azhar, S., Hein, M., and Sketo, B. (2012). Building Information Modeling (BIM): Benefits, Risks And Challenges, Leadership And Management Engineering, 11(3), 241-252

Azhar, S., Hein, M., and Sketo, B., (2008). Buiding Information Modeling (BIM): Benefits, Risks And Challenges

Azhar, S., Khalfan, M., and Maqsood, T. (2012). "Building Information Modelling (BIM): Now and Beyond." Australasian Journal of Construction Economics and Building, 12, 15-28

Aziz, N. D., Nawawi, A. H., and Ariff, N. R. M. (2016). "Building Information Modelling (BIM) In Facilities Management: Opportunities To Be Considered By Facility Managers." In Procedia-Social And Behavioral Sciences, 234, 353-362

Becerik – Gerber, B., Jazizadeh, F., Li, N., and Calis, G. (2012). "Application Areas And Data Requirements For BIM – Enabled Facilities Management." Journal Of Canstruction Engineering Management, 138, 431-442

BIM Institute. (2017). Bizcommunity. www.bizcommunity.com/Article/196/545/161075.html

Brewer, G., Jefferies, M., and Manderson, A. (2015). "Building Information Modelling and Standardised Construction Contracts: A Content Analysis of the GC21 Contract." Construction Economics and Building, 15(3), 72-84

Burns, N., and Grove, S. K. (2003). The Practice Of Nursing Research: Conduct, Critique And Utilisation

Cabinet Office. (2016), Government Construction Strategy: 2016-2020, https://www.gov.uk/government/publications/government-construction-strategy-2016-2020

Cao, D., Li, H., Wang, G., and Huang, T. (2017). “Identifying and Contextualizing the Motivations for BIM Implementation in Construction Projects: An Empirical Study in China.” International Journal of Project Management, 35(4), 658-669

Cerovskek, T., (2011). A Review And Outlook For A Building Information Model (BIM): A Multi-Stand Point Framework For Technological Development, Advanced Engineering Informatics, 25(2), 224-244

Chao-Duivis, M. A. B. (2011). Some Legal Aspects of BIM in Establishing Collaborative Relationship, International Construction Law Review, 28(3), 264-275

Chenail, R. J., Thomas-Purcell, K. B., George, S. and Wulff, D. (2018), An Introduction To Qualitative Meta-Synthesis, Nova Southeastern University

Chien, K. F., Wu, Z. H., and Huang, S. C. (2014). “Identifying and Assessing Critical Risk Factors for BIM Projects: Empirical Study.” Automation in Construction, 15, 1-15

Chimhundu, S. (2015). A Study on the BIM Adaptation Readiness and Possible Mandatory Initiatives for Successful Implementation in South Africa, 3-61

Chong, H. Y., Fan, S. L., Hsieh, S. H., Sutrisna, M., and Tsai, C. M. (2017). “Preliminary Contractual Framework for BIM-Enabled Projects.” Journal of Construction Engineering and Management, 143(7)

Christensen, S., McNamara, J., and O’Shea, K. (2007). Legal Contracting Issues in Electronic Project Administration in the Construction Industry, Structural Survey, 25(3/4), 191-203

Coates, P., Arayici, Y., Koskela, L., Kagioglou, M., Usher, C., and O’Reilly, K. (2010). The Limitations of BIM in the Architectural Process, First International Conference on Sustainable Urbanism

Crotty, R. (2016). The Impact of Building Information Modelling Transformation Construction, Routledge

Cubitt, B., and Coldwell R. (2014). “A Brief Legal Guideline: Where BIM Is Implemented On A Project.” Clyde And Co, Australia

Denscombe, M. (2010). The Good Research Guide for Small-Scale Social Research Projects, 4th Edition, Open University Press

Doumbouya, L., Gao, G., and Guan, C. (2016). “Adoption Of The Building Information Modeling (BIM) For Construction Project Effectiveness: The Review Of BIM Benefits, American Journal Of Civil Engineering And Architecture.” 4(3), 74-79

Du-Plooy-Celliers, F., Davis, C., and Bezuidenhout, R. (2014). Research Matters, Paarl Media, South Africa

Eadie, R., Browne, M., Odeyinka, H., McKeown, C., and McNiff, S. (2013). “BIM Implementation Throughout the UK Construction Project Lifecycle: An Analysis.” Automation in Construction, 36, 145-151

Eadie, R., Odenyika, H., Browne, M., McKeown, C., and Yohanis, M. (2014), Building Information Modelling Adoption: An Analysis of the Barriers to Implementation, Journal of Engineering and Architecture, 2(1), 77-101

Eadie, R., Odeyinka, H., Browne, M., Mckeown, C. and Yohanis, M. (2013). An Analysis of the Drivers for Adopting Information Modelling, Journal of Information Technology in Construction

Eastman, C., Eastman, C. M., Teicholz, P., and Sacks, R. (2011), BIM Handbook: A Guide To Building Information Modeling For Owners, Managers, Designers, Engineers And Contractors, John Wiley And Sons

Eastman, C., Teicholz, P., Sacks, R., and Liston, K. (2008). BIM Handbook: A Guide to Building Information Modelling for Owners, Managers, Designers, Engineers and Contractors, John Wiley and Sons, New Jersey, USA

Elmualim, A., and Gilder, J. (2014). “BIM: Innovation in Design Management, Influence and Challenges of Implementation.” Architectural Engineering and Design Management, 10(3-4), 183-199

Emuze, F., and Smallwood, J. J. (2014). Collaborative Working In South African Construction: Contractors' Perspectives, Journal Of Engineering, Design And Technology

Erwin, E. J., Brotherson, M. J., and Summers, J. A., (2011). "Understanding Qualitative Meta-Synthesis: Issues and Opportunities in Early Childhood Intervention Research." Journal of Early Intervention, 33 (3), 186-200

Ezy, M., Saghatforoush, E. and Abbasianjahromi, H. (2018). An Investigation of the Advantages and Disadvantages of Offsite Manufacturing: A Meta-Synthesis, International Journal of Project Organisation and Management, 10(4)

Fazli, A., Fathi, S., Enferadi, M. H., Fazli, M., and Fathi, B. (2014). Appraising Effectiveness Of Building Information Management (BIM) In Project Management, Procedia Technology, 16, 1116-1125

Finfgeld, D. L. (2003), Metasynthesis: The State Of The Art-So Far, Qualitative Health Research, 13(7), 893-904

Fitzemeyer and Tocci Associates Inc. (2017). "Using Building Information Modeling to Control Lifecycle Costs." Fitzemeyer and Tocci Associates

Fouche, H., Smallwood, J., and Emuze, F. (2011). Technology Management In Construction: Lessons For The Practice Of Architecture, Acta Structilia, 18(2), 1-18

Froise, T. and Shakantu, W. (2014). Diffusion of Innovations: An Assessment of Building Information Modelling Uptake Trends in South Africa, Journal of Construction Project Management and Innovation, 4(2), 895-911

Gardezi, S. S. S., Shafiq, N., Nurudinn, M. F., and Farhan, S. A. (2014). Challenges for implementation of building information modeling (BIM) in malaysian construction industry, applied mechanics and materials, 567, 559-564

Gemma, R. (2008), Introduction To Positivism And Critical Theory, Nurse Researcher, 25(4), 41-49

Ghaffarianhoseini, A., Tookey, J., Naismith, N., Azhar, S., Efimova, O., and Raahemifar, K. (2015). “Building Information Modelling (BIM) Uptake: Clear Benefits, Understanding its Implementation, Risks and Challenges, Renewable and Sustainable Energy Reviews.”

Giel, B., and Issa, R. R. A. (2014), Framework For Evaluating The BIM Competencies Of Building Owners, Computing In Civil And Building Engineering , 552-559

Gill, J., and Johnson, P. (2010). Research Methods for Managers, 4th Edition, London, Sage

Griffiths, A. (2008). An Examination Into The Efficacy Of Police Advanced Investigative Interview Training?, Unpublished PhD Thesis, University of Portsmouth

Gu, N., and London, K. (2010). “Understanding and Facilitating BIM Adoption in the AEC Industry.” Automation in Construction, 19(8), 988-999

Ham, Y., and Gilparvar – Fard, M. (2014). “Mapping Actual Thermal Properties To Building Elements In gbXML – BASED BIM for Reliable Building Energy Perfomance Modeling.” Automation in Construction

Hancock, C., Tang, L., Jin, R., and De Light, H. (2017), Building Information Modelling in China, BIM for Surveyors, Pre Conference Workshop

Hardin, B., (2009). BIM and Construction Management, Proven Tools, Methods And Workflows, Sybex

Harris, M., Che-Ani, A. I., and Tarmizi-Haron, A. (2014). “The way forward for Building Information Modelling (BIM) for Constructions in Malaysia.” Malaysian Construction Research Journal, 15(2), 1-9

Ibrahim, K. F., Abanda, H., Vidalakis, C., and Wood, G. (2017). “BIM Big Data System Architecture for Asset Management: A Conceptual Framework.” Proceedings of the Joint Conference on Computing In Construction, 289–296, Heraklion, Greece

Jiang, S., Man, Q., Shen, L., Skibniewski, M., and Sun, C. (2017). “A Literature Review of the Factors Limiting the Application of BIM in the Construction Industry.” Technological and Economic Development of Economy, 23(5), 764-779

Jin, R., Hancock, C. M., Tang, L., and Wanatowski, D. (2017). “BIM Investment, Returns, and Risks in China’s AEC Industries.” Journal of Construction Engineering and Management, 143(12)

Johnson, S., (2014). Advantages and Disadvantages Of Positivism. Ehow. http://www.ehow.com/info_12088541_advantages-disadvantages-positivism.html

Jordani, D. (2008). BIM: A Healthy Disruption to a Fragmented and Broken Process, Journal of Building Information Modelling, Matrix Group, Houston

Jung, Y., and Joo, M. (2011). Building Information Modelling (BIM) Framework for Practical Implementation, Automation in Construction, 20(2), 126-133

Kekana, T. G., Aigbavboa, C. O. and Thwala, W. D. (2014). Building Information Modelling (BIM): Barriers in Adoption and Implementation Strategies in The South Africa Construction Industry, International Conference on Emerging Trends in Computer and Image Processing, Pattaya, Thailand

Kelly, G., Serginson, M., Lockley, S., Dawood, N., and Kassem, M. (2013). BIM for Facility Management: A Review and a Case Study Investigating the Value and Challenges, Proceedings of the 13th International Conference on Construction Applications of Virtual Reality, London, UK

Kestle, L. (2009). Remote Site Design Management, Thesis, University of Canterbury

Khosrowshahi, F., and Arayici, Y. (2012). “Roadmap for Implementation of BIM in the UK Construction Industry.” Engineering, Construction and Architectural Management, 19(6), 610-635

Kiprotich, C. J. K. (2014). “An Investigation on Building Information Modelling in Project Management: Challenges, Strategies and Prospects in the Gauteng Construction Industry.” University of the Witwatersrand, Johannesburg, South Africa

Kivunja, C., and Kuyini, A. B. (2017). Understanding and Applying Research Paradigms In Educational Contexts, International Journal Of Higher Education, 6(5), 26

Kotze, C., (2013), BIM Technology Uptake Increasing in SA (online) Available from: https://engineeringnews.co.za/print-version/bim-technology-uptake-increasing-in-sa-2013-06-14 (Accessed 15 October 2020)

Kuiper, I., and Dominik, H. (2013). “Rethinking the Contractual Context for Building Information Modelling (BIM) in the Australian Built Environment Industry.” Australian Journal of Construction Economics and Building, 13(4), 1-17

Lacey, A., and Luff, D. (2009), Qualitative Research Analysis. The NIHR RDS For The East Midlands/Yorkshire and the Humber

Latiffi, A. A., Mohd, S., Kasim, N., and Fathi, M. S (2013). Building Information Modeling (BIM) Application in Malaysian Construction Industry, International Journal Of Construction Engineering And Management, 2(4A), 1-6

Lawrence, T. M., Watson, R. T., Boudreau, M. C., Johnsen, K., Perry, J., and Ding, L. (2012). “A New Paradigm For The Design And Management Of Building Systems.” Energy And Buildings, 51(0), 56-63

Lee, S. K, An, H. K., and Yu, J. H. (2012). An Extension of the Technology Acceptance Model for BIM-Based FM, Construction Research Congress, DOI:10.1061/9780784412329.061

Levin-Rozalis, M. (2010). Using Abductive Research Logic To Construct A Rigorous Explanation Of Amorphous Evaluation Findings

List, C. (2018). Levels: Descriptive, Explanatory, and Ontological

London, K., Singh, V., Taylor, C., Gu, N., and Brankovic, L. (2008). Building Information Modelling Project Decision Support Framework, In Proceedings of the Twenty-Fourth Annual Conference Association of Researchers in Construction Management (ARCOM), Cardiff, UK

Love, P. E.D., Simpson, I., Hill, A. and Standing, C. (2013). From Justification to Evaluation: Building Information Modelling for Asset Owners, Journal of Automation in Construction 01581, 1-9

McArthur, J. J. (2015). “A Building Information Management (BIM) Framework and Supporting Case Study for Existing Building Operations.” Maintenance and Sustainability, In Procedia Engineering

McAuley, J., Johnson, P., and Duberley, J. (2013), Organisation Theory, Challenges And Perspectives, 2nd Edition, Pearson

Memon, A. H., Rahman, I. A., Memon, I., and Azmon, N. I. A. (2014). “BIM in Malaysian Construction Industry: Status, Advantages, Barriers and Strategies to enhance the implementation level.” Research Journal of Applied Sciences, Engineering and Technology, 8(5), 606-614

Miettinen, R., and Paavola, S. (2014). “Beyond the BIM Utopia: Approaches to the Development and Implementation of Building Information Modelling.” Automation in Construction, 43, 84-91

Migilinkas, D., Popov, V., Juocevicius, V., and Ustinovichius, L. (2013). “The Benefits, Obstacles and Problems of Practical BIM Implementation.” Procedia Engineering, 57, 769-774

Mihindu, S., and Arayici, Y. (2008). Digital Construction Through BIM Systems will Drive the Reengineering of Construction Business Practices, International Conference Visualisation, IEEE Computer Society, 29-34

Mitchell, V. (1996). Assessing the Reliability And Validity Of Questionnaires: An Empirical Example, Journal Of Applied Management Studies, 5, 199-208

Mohanta, A., and Das, S. (2016). “BIM as Facilities Management Tool: A Brief Review.” 7th International Conference on Sustainable Built Environment (ICSBE), Kandy, Sri Lanka

Mohd, S. and Latiffi, A. S. (2013). Building Information Modelling (BIM) Application in Construction Planning, Seventh International Conference on Construction in the 21st Century (CITC-VII) “Challenges in Innovation, Integration and Collaboration in Construction and Engineering”, Bangkok, Thailand

Monteiro, A., and Martins , J, P. (2013). A Survey On Modeling Guidelines For Quantity Takeoff-Oriented BIM-Based Design, Automation In Construction, 35, 238-253

Myers, M. D. (2009). Qualitative Research In Business And Management, Sage, London

Newman, S. L. (2013). Building Information Modelling: Enabling Smart Design, Construction and Facilities Management. Research Publication: Real Estate Institute, New York

Noghli, F., Saghatforoush, E. and Forghani, Z. (2017). Evaluating the Need to Use Integrated Project Delivery (IPD) Approach as a New Alternative Implementation System in Developing Countries

Odubiyi, T. B., Aigbavboa, C., Thwala, W., and Netshidane, N. (2019). Strategies for Building Information Modelling Adoption in the South African Construction Industry, Modular and Offsite Construction, Canada

Olatunji, O. (2015). “Constructing Dispute Scenarios in Building Information Modelling.” Journal of Legal Affairs and Dispute Resolution in Engineering and Construction, 8(1)

Oluwole, A. (2011). A Preliminary Review on the Legal Implications of BIM and Model Ownership, Journal of Information Technology, 16, 687-696

Owen, R., Amor, R., Palmer, M., Dickinson, J., Tatum, C. B., Kazi, A. S., Prins, M., Kiviniemi, A., and East, B. (2010). “Challenges For Integrated Design And Delivery Solutions.” Architectural Engineering And Design Management, 6(4), 232-240

Peterson, C. (2009). Minimally Sufficient Research, https://doi.org/10.1111/j.1745-6924.2009.01089.x

Pham, L. T. M. (2018). Qualitative Approach To Research, A Review Of Advantages And Disadvantages Of Three Paradigms: Positivism, Interpretivism And Critical Inquiry, The University Of Adelaide

Pinsent Masons. (2013). “BIM: Modelling the Future, Managing Legal Risk – Legal Implication and Intellectual Property Right Issues Associated with Building Information Modelling.” CIC Conference

Polit, D. F., and Beck, C. T. (2012). Nursing Research: Generating And Assessing Evidence For Nursing Practice, 9th Edition, Philadelphia: Wolters Kluwer Health/Lippincott Williams and Wilkins

Polit, D. F., and Hungler, B. P. (2014). Nursing Research-Principle And Methods, Lippincott Williams and Wilkins, Philadelphia

Porwal, A., and Hewage, K. N. (2013). “Building Information Modeling (BIM) Partnering Framework for Public Construction Projects.” Automation in Construction, 31, 204-214

PWC (2017). SA Construction: Highlighting Trends in the South African Construction Industry, www.pwc.za/construction

Race, S. (2012). BIM Demystified, 2nd Edition, RIBA, London

Rahim, M. A. and David, W. N. W. (2015). The Case Study Method in Business, Scholars Journal of Arts, Humanities and Social Sciences, 3 (1B), 105-109

Rekola, M., Kojima, J., and Makelainen, T. (2010). “Towards Integrated Design And Delivery Solutions: Pinpointed Challenges Of Process Change.” Architectural Engineering and Design Management, 6(S1), 264-278

Rokooei, S. (2015). “Building Information Modelling in Project Management: Necessities, Challenges and Outcomes.” Procedia-Social and Behavioural Sciences, 210, 87-95

Rowlinson, S., Collins, R., Tuuli, M. M., and Jia, A. Y. (2010). Implementation of Building Information Modelling (BIM) in Construction: A Comparative Case Study, Proceedings of the 2nd International Conference on the Enhancement and Promotion of Computational Methods in Engineering and Science, 572-577

Salleh, H., and Fung, W. P. (2014). “Building Information Modelling Application: Focus-Group Discussion.” Gradevinar, 66(8), 705-714

Saunders, M. N. K., Lewis, P. and Thornhill, A. (2016). Research Methods for Business Students, Pearson Education Limited

Saxon, R. G. (2013). Growth through BIM. London: Construction Industry Council

Singh, V., Gu, N., and Wang, X. (2011). “A Theoretical Framework Of A BIM-Based Multi-Disciplinary Collaboration Platform.” Automation in Construction, 20(2), 134-144

Smith, P. (2014). BIM Implementation – Global Strategy, Creative Construction Conference, Procedia Engineering, 85, 482-492

Somekh, B., and Lewin, C. (2006). Research Methods In The Social Sciences, British Journal Of Educational Studies, 54(1), 118-120

Stephen, M., and Robert, T. (2007). “Building Information Modelling: A New Frontier for Construction Engineering Education.” Proc. 114th Annual ASEE Conference and Exposition, ASCE, Pittsburgh

Succar, B., Sher, W. and Williams, A. (2012). Measuring BIM Performance: Five Metrics, Architectural Engineering and Design Management, 8(2), 120-142

Talebi, F., and Saghatforoush, E. (2017). “Evaluating The Need For Measuring Maturity Level Of Consulting Engineers Companies In Applying Building Information Modeling.” 5th International Congress On Civil Engineering, Architecture And Urban Development, CIVILICA, Tehran, Iran.

Talkhabi, H., Jalal, M. P., and Golabchi, M. (2014). “Analysis Of The Causes Of Contractor’s Claims In The DB Contracts Of Underground Projects In Iran, Journal Of Tunneling And Underground Space Engineering, 3(1), 17-33

Thomson, D. B., and Miner, R. G. (2010). “Building Information Modeling – BIM: Contractual Risks are Changing with Technology.” Aepronet

Tombs, M., and Pugsley, L. (2020). How To: Understand Research Philosophies And Paradigms In Medical Education, Centre For Medical Education, Cardiff University

Trochim, W. M. k. (2006). The Qualitative Debate, Research Methods Knowledge Base, http://www.socialresearchmethods.net/kb/qualmeth.php

Tulenheimo, R. (2015). “Challenges of Implementing New Technologies in the World of BIM – Case Study from Construction Engineering Industry in Finland.” Procedia Economics and Finance, 21, 469-477

Udom, K. (2012). BIM: Mapping Out the Legal Issues

Volk, R., Stengel, J., and Schultmann, F. (2014). “Building Information Modeling (BIM) for Existing Buildings - Literature Review and Future Needs.” Automation in Construction, 38, 109-127

Walsh, D., and Downe, S. (2005). Meta-Synthesis Method For Qualitative Research: A Literature Review, Journal Of Advanced Nursing, 50(2), 204-211

Watson, A. (2010). BIM – A Driver for Change, Proceedings of the International Conference on Computing in Civil and Building Engineering

Weitz, C. (2016). The Disposition Towards BEM Adaptation Among Clients for The Minimisation Variance Orders Relevant to South African Building Industry, 1-45

Welman, J. C., Kruger, F., Mitchell, B., and Huysamen, G. K. (2005), Research Methodology, Oxford University Press, Oxford, Cape Town

Wilkinson, D. and Birmingham, P. (2003). Using Research Instruments. London: Routledge Falmer.

Wu, C., Xu, B., Mao, C., and Li, X. (2017). Overview of BIM Maturity Measurement Tools, Journal of Information Technology in Construction, 22, 34-62

Yan, H., and Damian, P. (2008). Benefits and Barriers of Building Information Modelling, 12th International Conference of Computing in Civil and Building Engineering, 161

Yin, R. K. (2014). Case Study Research Design And Methods, 5th Edition, Thousand Oaks:CA, Sage

Zakaria, Z., Mohamed Ali, N., Tarmizi Horan, A., Marshall-Ponting, A. J., and Abd Hamid, Z. (2013). “Exploring the Adoption of Building Information Modelling (BIM) in the Malaysian Construction Industry: A Qualitative Approach.” International Journal of Research in Engineering and Technology, 2(8), 384-395

Zhang, S., Teizer, J., Lee, J. K., Eastman, C. M. and Venugopal, M. (2013). Building Information Modelling (BIM) and Safety: Automatic Safety Checking of Construction Models and Schedules, Journal of Automation in Construction, 29, 183-195

Zielinski, R., and Wojtowicz, M. (2019), BIM Maturity Levels In Teaching The Design Process, World Transaction On Engineering And Technology Education, 17(2), 170-175

Appendix A: Questionnaire

BIM Definition: Building Information Model (BIM), BIM is a model defining the physical and the functional characteristics of a facility in a digital representation form. BIM concept is to build a structure in a virtual environment before the actual physical construction so that the problems and their potential impacts that will be encounter during the actual construction can be detected and solved before construction.

SECTION A

A01. Please indicate your gender (Tick [✓] as applicable)

Male	
Female	
Prefer not to say	
Other please specify……....	

A02. Please select the age category to which you belong (Tick [✓] as applicable).

Under 18 years	
18 - 25 years	
26 - 35 years	
36 – 45 years	
46 – 55 years	
56 – 65 years	
Over 65 years	

A03. Please indicate your highest qualification (Tick [✓] as applicable).

Diploma	
Bachelor's degree / BTech degree / Advanced Diploma / Higher Diploma	
Honours Degree / Post Graduate Diploma	
Master's Degree	
Doctorate Degree	

Other, please specify…….……..	

A04. Please indicate your professional background relative to the following:

Profession	**Years**	
	Private	**Public**
Architect		
Engineer		
Quantity Surveyor		
Construction Manager		
Construction Project Manager		
Other, please specify…….		

05. Which of the following local and international built environment bodies are you affiliated with? (Tick [✓] as applicable).

The South African Council for the Project & Construction Management Professions (SACPCMP)	
The South African Council for the Quantity Surveying Profession (SACQSP)	
The South African Council for Architectural Profession (SACAP)	
Project Management Institute (PMI)	
Association for Project Management (APM)	
Royal Institution of Chartered Surveyors (RICS)	
Engineering Council of South Africa (ECSA)	
The Chartered Institute of Building (CIOB)	
Other, please specify…….	

SECTION B

B01. On a scale of 1 (not at all familiar) to 5 (extremely familiar), please answer the following question?

	Not at all familiar……Extremely familiar				
What is your level of familiarity with Building Information Modelling?	**1**	**2**	**3**	**4**	**5**

B02. Have you ever used BIM on any construction project?

Yes ◯ **No** ◯

B03. On a scale of 1 (extremely unlikely) to 5 (extremely likely), to what extent does the implementation of BIM enhance productivity within the construction companies, relative to the following criteria?

Criteria	**Extremely Unlikely…… Extremely Likely**				
	1	**2**	**3**	**4**	**5**
Cost and time savings in creating redundant building models					
Improved project presentations to clients and for approval process					
Facilitation of the examination and verification of architectural design concepts					
Reduced production time					
Increased quality of the outputs					

B04. On a scale of 1 (strongly disagree) to 5 (strongly agree), the implementation of BIM is affected by the following factors.

Criteria	**Strongly Disagree.....…Strongly Agree**				
	1	**2**	**3**	**4**	**5**
Software learning curves					
Lack of support from company leadership					

Lack of support from operational staff					
Initial investment costs					
Other, please specify……					

05. What is the current state of BIM in South African construction companies, relative to the following maturity levels? (Tick ✓ as applicable)

BIM Level	
Level 0 – Low collaboration	
Level 1 – Partial collaboration	
Level 2 – Full collaboration	
Level 3 – Full integration	

B06. From the descriptions provided below, indicate the most suitable one in which your company uses to exchange information with the design team in a project. (Tick ✓ as applicable)

Maturity Level Description	
2D CAD drafting only is utilised, mainly for production information, Output and distribution is via paper or electronic prints, or a mixture of both.	
Mixture of 3D CAD for concept work, and 2D for drafting of statutory approval documentation and production information. Electronic sharing of data is carried out from a common data environment, this is often managed by the contractor	
CAD software that construction and project team is capable of exporting to one of the common format Construction Operation Building Information Exchange	
Interdisciplinary models which have rich data fully integrated, interoperating data known as a common data environment. An Example of data model at this stage includes intelligent model with design, analysis, lean construction principles, maintenance schedules and the whole life costing of the structure	

B07. Indicate whether the following statements are applicable for your company in a project during sharing of information with the design team. (Tick ✓ as applicable)

Method to Exchange Information	
Unmanaged computer aided design including 2D drawings	
Text with paper based or electronic exchange information without a common standard process between the contractor and design team.	
Managed CAD with increasing introduction of spatial coordination, standardised structures, and format	
Includes 2D and 3D information such as virtualisations or concept development models	
Data includes construction sequencing 4D, and cost information 5D	
A single collaborative online project model with construction sequencing 4D, cost5D and the whole life cycle information 6d.	
Data may include concepts of improved social outcome and wellbeing	

SECTION C

C01. If you have any other comments, feel free to add them below.

……

C02. Do you require the outcome of this survey?

Yes	
No	

C03. If yes, please provide your contact details

Email: ……

Thank you for your participation

Appendix B: Accompanying Letter

UNIVERSITY OF THE
WITWATERSRAND,
JOHANNESBURG

School of the Construction Economics and Management
Cell: +27 (83) 601 4401
e-mail: hpmasuku@gmail.com
Contact person: Hlengiwe Masuku

16 October 2020

TO WHOM IT MAY CONCERN

Dear Sir or Madam

Re: MSc Study – A framework to improve BIM implementation among South African Construction Companies based on their maturity level.

You have been randomly selected to participate in my study. As an established member of the built environment your inputs are extremely important for this study. I would therefore urge you to please complete the full questionnaire.

This study constitutes the research portion towards my MSc in the Built Environment, which aims at providing a framework for improving BIM implementation among South African construction companies based on their existing maturity levels. The study involves penetrating questions concerning factors that affect the planning of key parameters for successful BIM implementation.

The questionnaire begins with a brief definition of BIM, it consists of 15 (fifteen) questions, and you are mainly required to select options, and in a very few cases make comments. It should not take more than 20 (twenty) minutes to complete the questionnaire. Please feel free to be open and candid with your answers, as all information will remain confidential and your anonymity is assured. It would be highly appreciated if you can return the questionnaire within two weeks from receipt.

Your participation is highly appreciated.

Thank you in anticipation.

Yours faithfully,

Hlengiwe Masuku, MSc Candidate **Dr E Saghatforoush, Supervisor**

Appendix C: Interview Protocol and Guide

The purpose of an interview protocol is to set out the procedure for conducting an interview. Without a doubt, it is key to place care on the selection and building of trust with participants, location and length of interview during the preparation for conducting interviews. According to Patton (2015) and Brinkmann and Kvale (2015), an interview protocol will not be complete without including the order, quality and the clarity of questions and the overall process of conducting an interview. The four-step interview protocol as designed by Castilli-Montonya, (2016), comprise of:

1st Step - Interview and research questions alignment

The research aim, objectives and questions were set out in Chapter 1. Therefore, interview questions should be set out in such a way that they completely answer the research questions, achieve the research aim and objectives.

2nd Step - Constructing an inquiry-based conversation

Since an interview protocol is an instrument of inquiry and a platform on which specific information related to the aims of the study are asked (Patton, 2015). This step assists the researcher with the development of an inquiry-based conversation since the protocol contains interview questions written differently from the research questions but aligned to the aim and objectives of the research. This is supported by Maxwell (2013), who is of the view that, research questions form what the researcher wants to understand while the interview questions are what you ask people to gain that understanding.

3rd Step - Receiving feedback on the interview protocol

The purpose of obtaining feedback is to provide the researcher with information about how well participants understand the interview questions and whether their understanding meets the set research questions, aim and objectives (Patton, 2015).

4th Step - Piloting the interview protocol

Lastly, the researcher will run a pilot interview in real conditions with the participants who mirror the sample of the actual participants of the interview (Maxwell, 2013). The idea is to

simulate the actual interview in as real conditions as possible to determine whether the design and order of questions is perfectly suited for the actual interview.

INTERVIEW GUIDE

1. Assuming the Government passes policies, making BIM mandatory in both public and private sector, what is your take on such policies?
2. In your view, should the Government take responsibility of supporting small construction companies in the implementation of BIM and why?
3. The introduction and teaching of BIM in academic institutions makes the implementation process easier. What is you view of this statement?
4. One of the major drawbacks in the implementation of BIM is the need to fund training and software costs. How best can South African construction companies deal with challenges of this nature?
5. Do you think that BIM Specific contracts with legal agreements are necessary for proper implementation of BIM? Why?
6. Stakeholder involvement is key in the successful implementation of BIM. What is your view?
7. What other suggestions do you think can assist construction companies with proper BIM implementation in South Africa?

Appendix D: Ethics Clearance Certificate

School of Construction Economics & Management

University of the Witwatersrand, Johannesburg -PO Box 20, Wits 2050, South Africa • Tel: +27 (0)11 717 7652/77669 - Fax: +27 (0)11 717 9729 Email:CEM@wits.ac.za

SCHOOL OF CONSTRUCTION ECONOMICS AND MANAGEMENT RESEARCH ETHICS COMMITTEE

CLEARANCE CERTIFICATE	**PROTOCOL NUMBER CEM/20/12/HM1**
PROJECT TITLE	A framework to improve BIM implementation among South African Construction Companies based on their maturity level.
INVESTIGATORS	Hlengiwe Masuku (390955)
SCHOOL/DEPARTMENT	**SCHOOL OF CONSTRUCTION ECONOMICS AND MANAGEMENT**
DATE CONSIDERED	01/12/2020
DECISION OF THE COMMITTEE	Approved conditionally with respect to the declaration
EXPIRY DATE	30th Dec 2021
DATE 1//5/2020	**CHAIRPERSON** Dr. Kola Ijasan

cc: Supervisor: : Prof Ehsan Saghatforoush

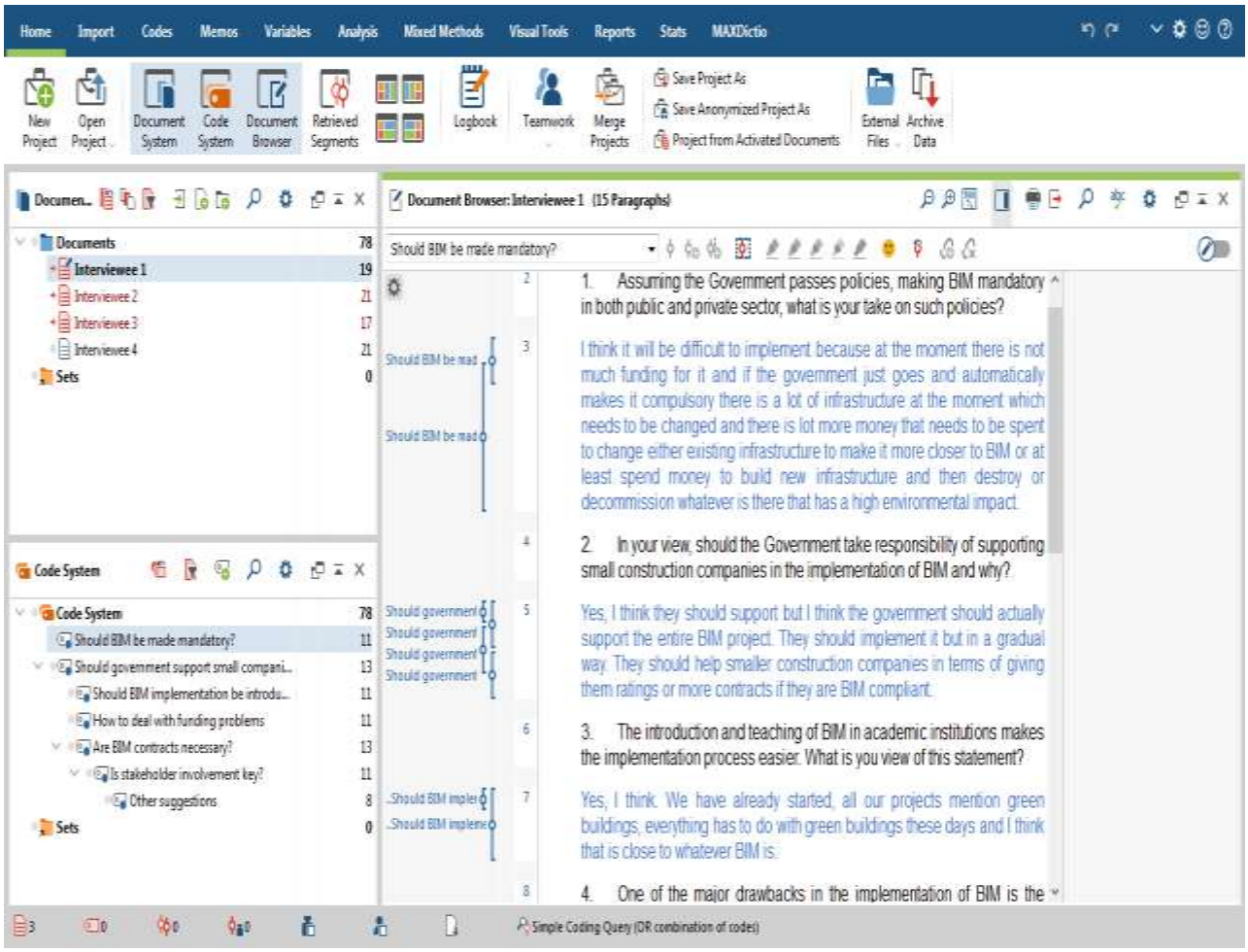
DECLARATION OF INVESTIGATOR

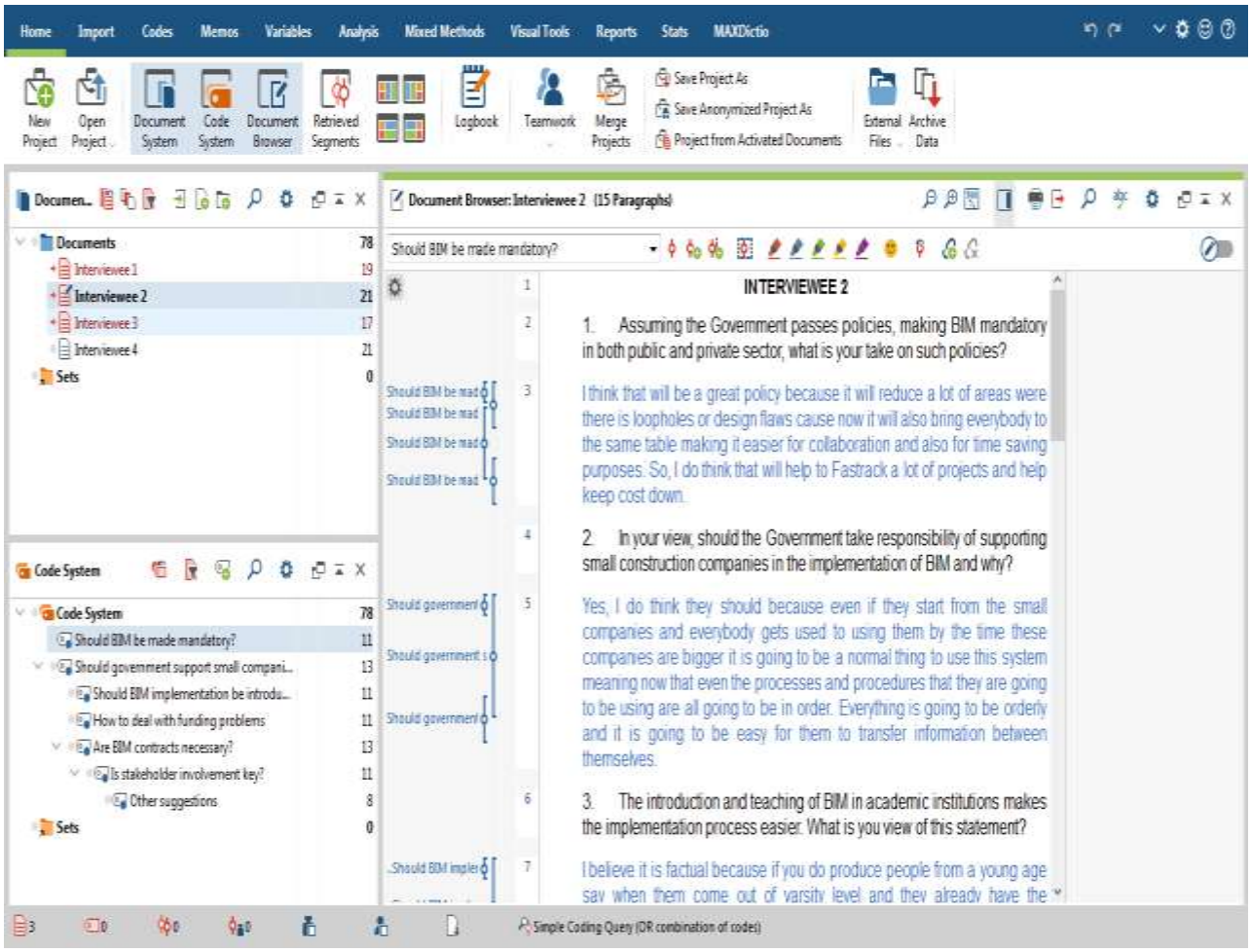
To be completed in duplicate and **ONE COPY** returned to the Secretary Michelle Kirsten at the CEM reception desk.

I/We fully understand the conditions under which I am/we are authorized to carry out the abovementioned research and I/we guarantee to ensure compliance with these conditions. Should any departure to be contemplated from the research procedure as approved I/we undertake to resubmit the protocol to the Committee. **I agree to completion of a yearly progress report.**

Signature **Date** _23_/_12_/_2020_

Appendix E: MAXQDA Analysis

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Should BIM be made mandatory? 11
Should government support small compani... 13
Should BIM implementation be introdu... 11
How to deal with funding problems 11
Are BIM contracts necessary? 13
Is stakeholder involvement key? 11
Other suggestions 8
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Document Browser: Interviewee 2 (15 Paragraphs)
Should BIM be made mandatory?
INTERVIEWEE 2
1. Assuming the Government passes policies, making BIM mandatory in both public and private sector, what is your take on such policies?
I think that will be a great policy because it will reduce a lot of areas were there is loopholes or design flaws cause now it will also bring everybody to the same table making it easier for collaboration and also for time saving purposes. So, I do think that will help to Fastrack a lot of projects and help keep cost down.
2. In your view, should the Government take responsibility of supporting small construction companies in the implementation of BIM and why?
Yes, I do think they should because even if they start from the small companies and everybody gets used to using them by the time these companies are bigger it is going to be a normal thing to use this system meaning now that even the processes and procedures that they are going to be using are all going to be in order. Everything is going to be orderly and it is going to be easy for them to transfer information between themselves.
3. The introduction and teaching of BIM in academic institutions makes the implementation process easier. What is you view of this statement?
I believe it is factual because if you do produce people from a young age say when them come out of varsity level and they already have the
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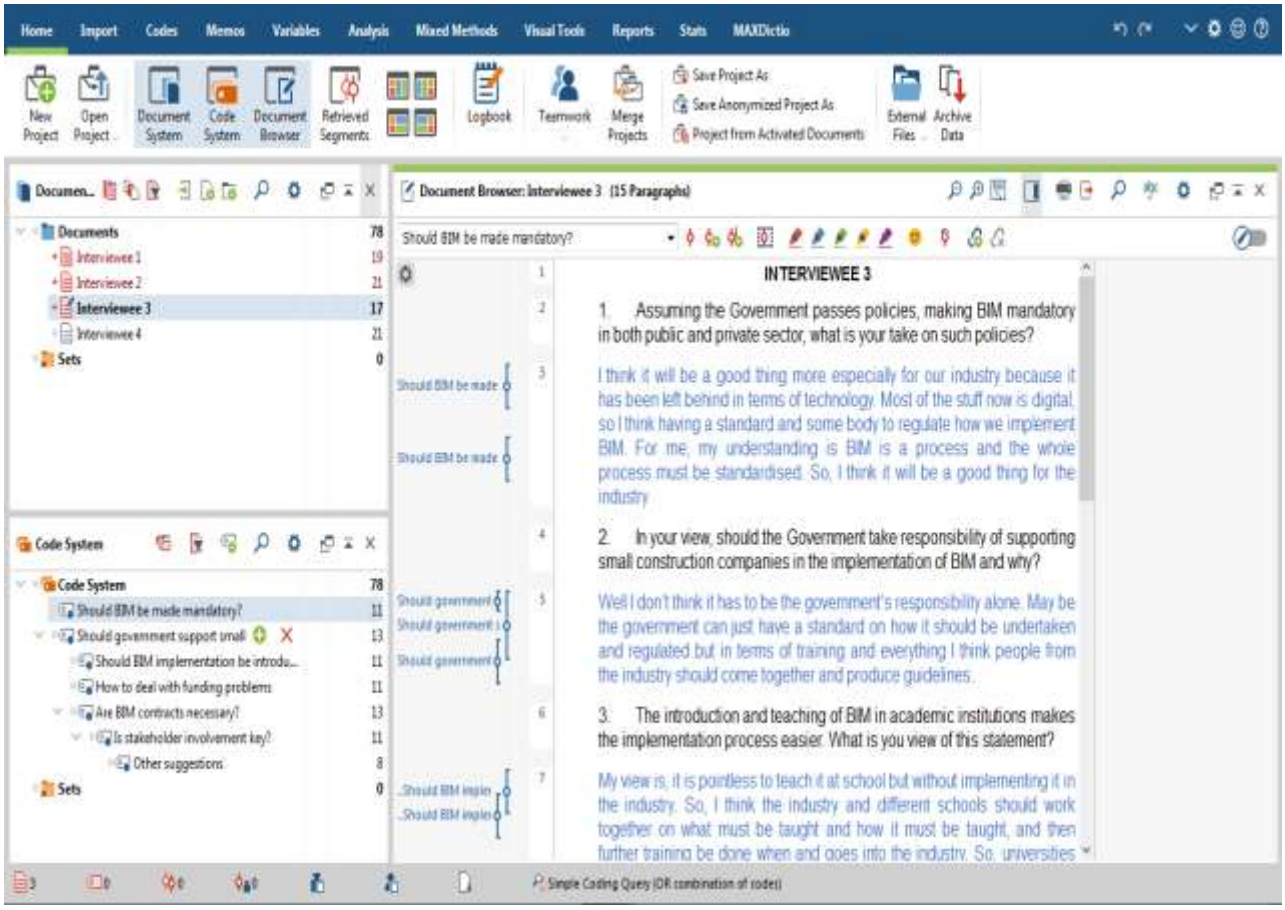
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Are BIM contracts necessary?
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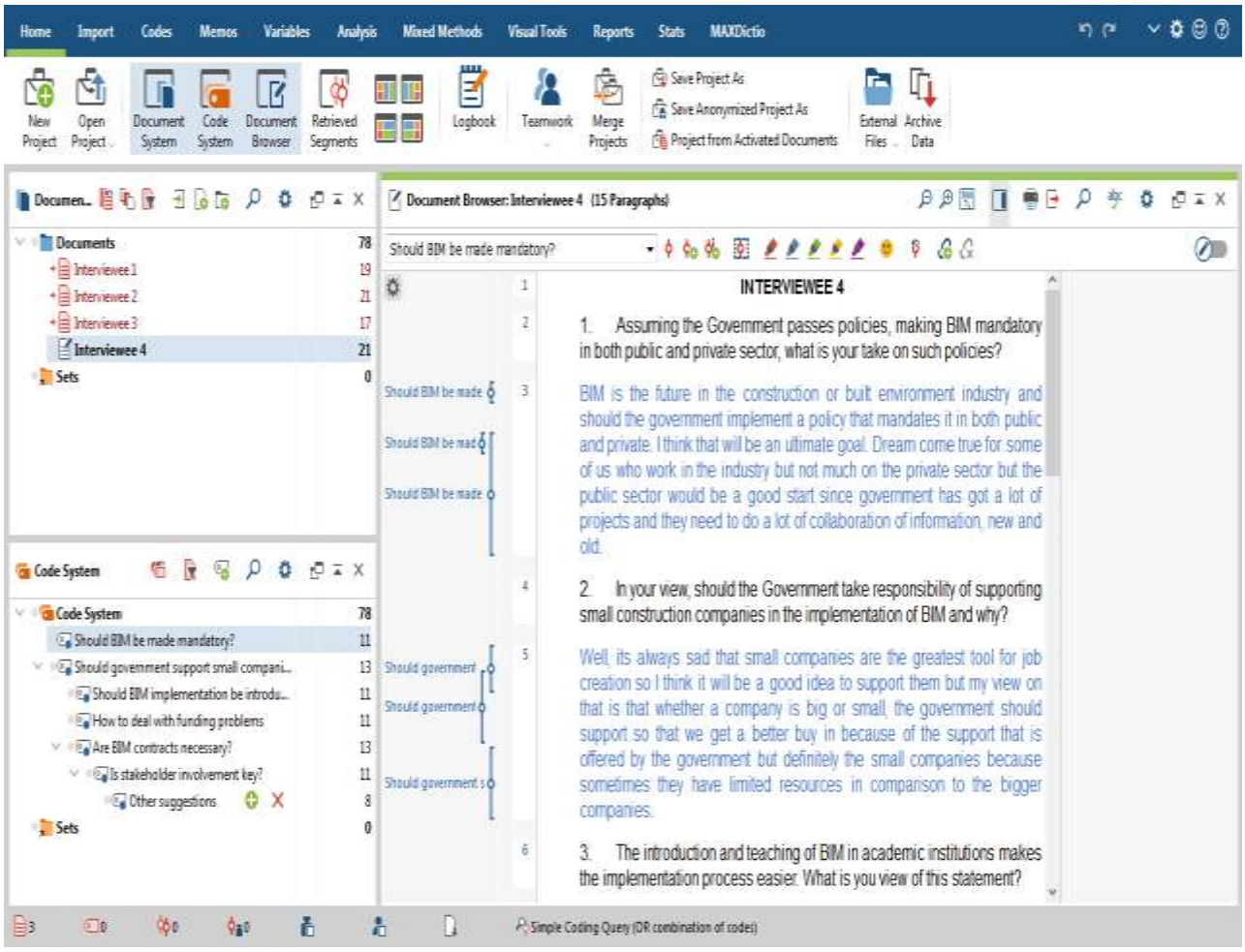
Other suggestions
Document Browser: Interviewee 3 (15 Paragraphs)
Should BIM be made mandatory?
INTERVIEWEE 3
1. Assuming the Government passes policies, making BIM mandatory in both public and private sector, what is your take on such policies?
I think it will be a good thing more especially for our industry because it has been left behind in terms of technology. Most of the stuff now is digital, so I think having a standard and some body to regulate how we implement BIM. For me, my understanding is BIM is a process and the whole process must be standardised. So, I think it will be a good thing for the industry
2. In your view, should the Government take responsibility of supporting small construction companies in the implementation of BIM and why?
Well I don't think it has to be the government's responsibility alone. May be the government can just have a standard on how it should be undertaken and regulated but in terms of training and everything I think people from the industry should come together and produce guidelines.
3. The introduction and teaching of BIM in academic institutions makes the implementation process easier. What is you view of this statement?
My view is, it is pointless to teach it at school but without implementing it in the industry. So, I think the industry and different schools should work together on what must be taught and how it must be taught, and then further training be done when and does into the industry. So, universities
Simple Coding Query (OR combination of codes)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Should government support small compani... 13
Should BIM implementation be introdu... 11
How to deal with funding problems 11
Are BIM contracts necessary? 13
Is stakeholder involvement key? 11
Other suggestions 8
Sets 0
Document Browser: Interviewee 4 (15 Paragraphs)
Should BIM be made mandatory?
INTERVIEWEE 4
1. Assuming the Government passes policies, making BIM mandatory in both public and private sector, what is your take on such policies?
BIM is the future in the construction or built environment industry and should the government implement a policy that mandates it in both public and private. I think that will be an ultimate goal. Dream come true for some of us who work in the industry but not much on the private sector but the public sector would be a good start since government has got a lot of projects and they need to do a lot of collaboration of information, new and old.
2. In your view, should the Government take responsibility of supporting small construction companies in the implementation of BIM and why?
Well, its always said that small companies are the greatest tool for job creation so I think it will be a good idea to support them but my view on that is that whether a company is big or small, the government should support so that we get a better buy in because of the support that is offered by the government but definitely the small companies because sometimes they have limited resources in comparison to the bigger companies.
3. The introduction and teaching of BIM in academic institutions makes the implementation process easier. What is you view of this statement?
Simple Coding Query (OR combination of codes)