ASSESSMENT OF RISKS ASSOCIATED WITH IMPLEMENTATION OF BUILDING INFORMATION MODELLING IN MAINTENANCE OF COMMERCIAL BUILDINGS IN GAUTENG

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A research report submitted to the Faculty of Engineering and the Built Environment, of the University of the Witwatersrand, Johannesburg, in partial fulfilment of the requirements for the Master of Science (Building) in Construction Project Management

04 October 2019

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DECLARATION

I, the undersigned, declare that the contents of this report are a product of my own hard work unless were due acknowledgement is given. I agree that the University of the Witwatersrand can make use or refer to the contents of this report on condition that due credit is given.

Signature ……………………………….

Student Name Ernest Mutingwende

ABSTRACT

The greatest wealth of the world is made up of real estate, which is estimated at more than 50% of total global worth. Research has shown that the cost of maintaining real estate is greater when compared to the cost of development in the long run. Building Information Modelling (BIM) is regarded as an approach of minimising huge maintenance costs. As such, countries including UK, UAE, Canada, New Zealand, Australia and USA have introduced BIM in their building and construction projects. In South Africa, despite advocacy by the BIM Institute and other construction industry players, BIM adoption is still behind the global trend. This research applies the risk management process for those risks related with the implementation of BIM in maintenance of commercial buildings in Gauteng, South Africa. The mixed research method is used in this study through archival research, survey strategy and case study approach. Qualitative data analysis through descriptive and pattern coding is done using NVivo software, while quantitative data analysis is done using the risk matrix analysis tool.

The results show that the major risk categories for BIM implementation in maintenance of commercial buildings are Technical, Financial or Economic, Legal and Management related. A total of fifteen risks from all the categories were identified to be the riskiest and recommendations on the best response measures were made. The conclusion is that asset managers do not realize the benefit of BIM largely due to lack of BIM education, wrong and misleading information and the fear of the unknown. Subsequently, there is a need to follow in the footsteps of property industries such as the Irish industry that recognized 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.

Keywords: Building Information Modelling, Risk Assessment, Building Maintenance

DEDICATION

To my sister, Lisa, for all the support during my stay in the Republic of South Africa. May the Almighty God richly bless you and your family.

ACKNOWLEDGEMENTS

I would like to acknowledge all my lecturers over my two years of study at the University of the Witwatersrand, School of Construction Economics and Management. I have tapped into your philosophies freely. I also would like to thank all my research participants, whose will and support I greatly appreciate. Although your names remain a secret, I salute every one of you for making this project a success. My greatest appreciation to Anine Eschberger Wortmann for her support during the early stages of this project. Finally, I thank my supervisor Dr Ehsan Saghatforoush for his astute guidance.

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LIST OF ACRONYMS

AEC	Architecture Engineering Construction
BIM	Building Information Modelling
BSI	British Standards Institute
CAD	Computer Aided Drawings
CAFM	Computer Aided Facilities Management
CASP	Critical Appraisal Skills Program
CDE	Common Data Environment
CIDB	Construction Industry Development Board
CRAAP	Currency, Relevance, Authority, Accuracy and Purpose
DoPW	Department of Public Works
ERM	Enterprise Risk Management
FM	Facilities Management
GDP	Gross Domestic Product
HVAC	Heating, Ventilation and Air Conditioning
ICT	Information Communication Technology
IRM	Institute of Risk Management
ISO	International Standards Organization
RBS	Risk Breakdown Structure
ROI	Return on Investment
UAE	United Arab Emirates
UK	United Kingdom
USA	United States of America

LIST OF PUBLICATIONS

Conference Paper:

Mutingwende, E. and Saghatforoush, E., (2018). Assessment of building information modelling related risks in preventive maintenance of building services installations. 10th Construction Industry Development Board (CIDB), Postgraduate Conference: Towards a better route to enhanced productivity, performance and transformation of construction. Port Elizabeth, South Africa, 25 – 27 February 2018.

Journal Articles:

Three articles are expected to be published from this research, titled:

Identifying and categorising BIM risks in the operation and maintenance of buildings.

An analysis of BIM risks in the operation and maintenance of buildings.

BIM risk response in the operation and maintenance of buildings.

1.0 INTRODUCTION

1.1 Background

Buildings provide an important means of production to an economy. The level of construction activity taking place within a country is an economic indicator of how that economy is performing. Simply put, infrastructure is the backbone of any successful economy. An estimated 85% of total building life cycle costs are said to be incurred beyond the construction stage (HM Government, 2012; Yalcinkaya and Singh, 2014; Aziz *et al*, 2016). This figure is significant for national and international investors seeking investments into the real estate sector (Kelly *et al*, 2013). However, building information modelling (BIM) can significantly reduce these costs through proper maintenance of a facility (Ashcraft, 2008; Azhar, 2011).

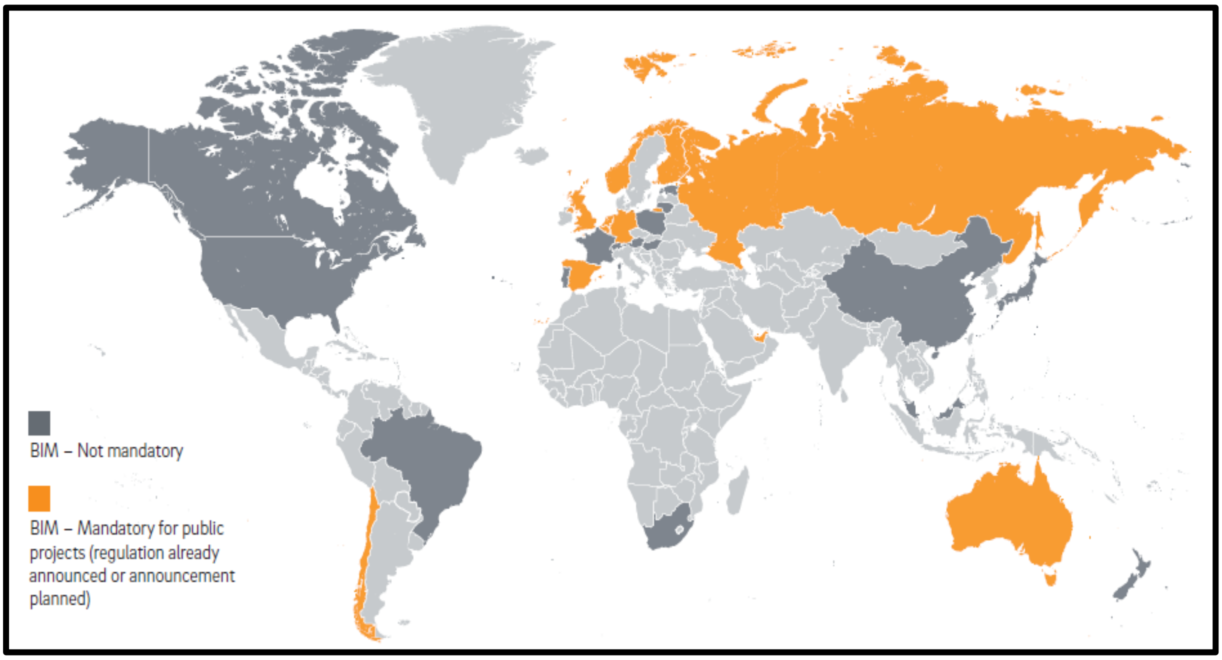
BIM can potentially revolutionise the appearance and functionality of facilities, planning, designing, construction and operation during the lifecycle (Fitzemeyer and Tocci Associates, 2017). The effective implementation and use of the concept of BIM can greatly free resources used in operating, maintaining and managing building facilities thereby allowing organizations to focus on their primary business functions (Fitzemeyer and Tocci Associates, 2017). Previous technologies were developed and designed for each specific phase of a building life, for instance, design or management but the collaborative nature of BIM provides an added advantage to building owners and operators (Azhar *et al*, 2012; Smith and Tardif, 2012; Takim *et al*, 2013).

Most international governments, especially in developed countries, are showing growing interest in adopting BIM for infrastructure development projects, with a growing number of them enforcing it through means of legislation, thereby making it a compulsory obligation as shown in Figure 1 (Bui *et al*, 2016; Wortmann *et al*, 2016; Berger, 2017). Patacas *et al* (2015), point out that, building maintenance involves multidisciplinary efforts with massive information requirements. Building maintenance aims to save energy, increase the building life span, improve satisfaction levels of facility users and most importantly reduce the building running costs (Nakama *et al*, 2015).

Globally, the construction industry is regarded as the slowest in terms of adopting new technologies (Takim *et al*, 2013; Berger, 2017). This is evidenced by the current disputed state of BIM in South Africa even though the concept is meant to ease collaboration among the various construction industry stakeholders (Association of South African Quantity

Surveyors, 2017; Hamma-Adama and Kouider, 2018). This has had a negative impact in the implementation of BIM within the South African built environment and with the Government seemingly reluctant, the adoption of BIM is likely going to take a while.

Figure 1: Global Implementation of BIM (Adopted from Berger, 2017)



In South Africa, it would seem as if BIM is lacking the teamwork required to realise it nationally, regardless of the notable advocacy by groups such as the BIM institute (Association of South African Quantity Surveyors, 2017). According to the Association of South African Quantity Surveyors (2017), South Africa is possibly five years behind the global BIM trends since the concept has been mainly driven by large international organizations who have employed it from their head offices and has been filtered to regional and local offices.

Research has shown various advantages to be enjoyed through the implementation of BIM from the conception stage into the operation and maintenance phases (Korpela *et al*, 2015; Alizadeh *et al*, 2016; Aziz *et al*, 2016). Without a doubt, if asset management organizations and the department of public works (DoPW) are to transform and become the drivers of change, then, the South African construction industry should be worried about the unexpected consequences of not using BIM (BIM Institute, 2017). Undeniably, this clearly shows that there are risks associated with not using BIM in the long run. However, the fact that risk can be unpredictable makes research on the risks associated with the introduction and implementation of BIM in maintenance of buildings interesting (Alizadeh *et al*, 2016).

Besides, risk management is key in strategic, tactical and operational management of any organization (IRM, 2002).

1.2 Research Problem

Proper infrastructure maintenance should be viewed as a fundamental objective if any economy wishes to grow (Azhar, 2011). Emphatically, the successful maintenance of buildings is rooted on the availability of maintenance information provided when the building is handed over at the commissioning stage. Consequently, to avoid buildings and or infrastructure failure, maintenance should be done timeously.

Evidently, the introduction of BIM has largely dealt with this information challenge (Demian and Walters, 2013; Eadie *et al*, 2014). This is since BIM combines data for all the components within a building, making it a possibility for the stakeholders to easily retrieve the information for almost any purpose, thereby reducing the risk of mistakes and inconsistencies while minimising maintenance expenses (Gabryk and Scott, 2016).

However, the research seeks to solve the problem of high building maintenance costs. According to Ogbu (2017), maintenance cost refers to the cost of ensuring that a building remains in a habitable condition. It is therefore the total cost required to keep, restore or improve a building in each financial period (Faremi *et al*, 2016). Maintenance cost can be as a result of a planned maintenance activity or a cost incurred because of a breakdown (Al-Najjar, 1999).

Without a doubt, the remark by Lateef (2008) that, effective building maintenance requires preplanning of all the foreseeable mechanical components that will require maintenance in future and the time the maintenance will be required is fundamental in understanding the basic need of risk management in building maintenance. This remark emphasises the need for preplanning to maintain the operation of the building at an optimal level.

Therefore, this research seeks to cover the gap of risks concomitant with the implementation of BIM in the maintenance of commercial buildings in Gauteng, South Africa, a concept which is proving to be vital in dealing with maintenance issues and costs.

1.3 Research Aim

This research aims to identify, categorise and analyse the risks associated with implementation of BIM in the maintenance of commercial buildings in Gauteng, South Africa.

1.4 Research Questions

1. What are the risks and their categories associated with BIM implementation in maintenance of buildings?
2. What are the effects of BIM implementation risks in maintenance of buildings?
3. How can the maintenance team effectively deal with BIM implementation risks in maintenance of commercial buildings in Gauteng, South Africa?

1.5 Research Objectives

1. To identify and categorise the risks associated with BIM implementation in maintenance of buildings.
2. To analyse the risks associated with BIM implementation in maintenance of buildings.
3. To provide recommendations of dealing with BIM implementation risks in maintenance of commercial buildings in Gauteng, South Africa.

1.6 Scope of Study

The research focuses on stakeholders including property owners, asset managers, construction sector academics and BIM practitioners. Consequently, the outcome of the research relies on primary, secondary and tertiary sources of literature. These include thesis reports, conference reports, company reports, government publications, books, journals, internet, abstracts, dictionaries and bibliographies. Such information is evaluated using the currency, relevance, authority, accuracy and purpose (CRAAP) test (see Appendix A). Furthermore, information is also generated from online questionnaire surveys and interviews conducted by the researcher.

1.7 Research Significance

The findings of this research can indeed help the public and the private sector when deciding on the implementation of BIM in the maintenance of buildings. Lee *et al* (2012) claims that, about US$10.6 billion out of US$15.8 billion losses caused by interoperability inefficiencies are attributed to the operations and maintenance phase of a building. These figures are telling and should thus provide a motivation for the need to properly manage buildings during the operation and maintenance phase. This calls for intensive research aimed at reducing the claims made by Lee *et al* (2012). This research covers the operation phase including the risks associated with the implementation of BIM to reduce maintenance costs.

Lazarus and Hauptfleisch (2010), found out that, for several reasons, the operations and maintenance teams fail to reasonably budget for building maintenance related costs and this results in budget overruns and usually early replacement of building services. The reason for this is the lack of historical maintenance information of the various building services which makes the forecasting of operating and maintenance costs difficult. Through BIM, maintenance costs estimation, budgeting processes and building up of detailed maintenance history is achieved (Gabryk and Scott, 2016). The findings by Lazarus and Hauptfleisch (2010), provides a motivation for public and private sector bodies to instigate organised maintenance management frameworks while bearing in mind cost and preservation of assets.

Both the BIM Task Group (2013) and Teicholz (2013) agree that, BIM brings positive value, but no mention is made on the need for risk management in their researches. Surprisingly, no comprehensive research has focused on answering the question;

What could go wrong if BIM is implemented in the maintenance of buildings and what is the best response to such unforeseen events?

Thompson and Miner (2007) emphasize that, prior to the full implementation of BIM, the risks associated with its use should not only be identified and assigned, but the implementing costs should also be paid for. This clearly shows the need for identifying and dealing with the risks associated with the use of BIM before it is implemented as failure to do this may result in unnecessary spending.

Without a doubt, the views of Thompson and Miner (2007) provide the motivation for this research which assesses the risks related with the implementation of BIM in maintenance of commercial buildings in Gauteng, South Africa. The result being to avoid and or eliminate some or all those risks when BIM eventually becomes mandatory. According to Alizadeh *et al* (2016), the great accuracy of BIM may lead to managers underestimating risks and neglecting risk management. Thus, there is a strong need to educate asset managers and building owners on the importance of understanding the risks associated with the implementation of BIM in maintenance of buildings.

Moreover, the research significance is since, the management of risk is of paramount importance in ensuring the success of any endeavour. For this reason, there is a need to care about the risks relating to the implementation of BIM in maintenance of commercial buildings in order to contain any threats that may arise as a result of these risks. The following section deals with the consequences of this research.

1.8 Research Consequences

The previous section dealt with the research significance; this section will probe into the consequences of this research. Building maintenance should be well-timed to avoid the formation of hazards related to the defectiveness and inefficiency of buildings. Improper maintenance practices may lead to building failure which in turn leads to risking of lives and the costs that will follow. Without a doubt, BIM continues to be adopted in the infrastructure development industry from conception stages, extending into the operation and maintenance stages.

According to Chien *et al* (2014), the implementation process of an innovative technology faces various challenges, hence the function of such novel technology might be negatively affected by unidentified risk factors existing during implementation. Therefore, a comprehensive understanding of such risk factors enables BIM users to respond to potential risks at an early stage, thus enhancing the possibility of implementing BIM successfully (Jin *et al*, 2017).

Azhar (2011) agrees indeed that, facilities management departments stand to benefit through BIM as it can be used for works such as renovating, planning space and operations and maintenance operations. Despite the benefits of using BIM in maintenance, there are risks in using BIM during maintenance which this research seeks to establish and provide recommendations for. In any case, ethical considerations are pivotal when conducting research. Thus, the next section provides an overview of how ethical issues will be approached in this research.

1.9 Ethical Guidelines

The preceding section covered the consequences of this research; however, this section deals with ethical considerations. Ethics are behaviour standards that guide a researcher to respect the rights of respondents and anyone who can be directly or indirectly affected by the research (Saunders *et al*, 2016). According to Denscombe (2010), a good researcher should aim to minimise non-responses and maximise the response rate. To achieve high response rate, the researcher carefully considers the type of respondents, research subject, identity of the researcher, nature of contact and the social climate as part of the ethical considerations (Denscombe, 2010).

Compliance with the University of the Witwatersrand ethical standards is highly adhered to during this research, especially during the data collection stage (see Appendix F). As a motivation for the collection of unbiased data, care is undertaken in ensuring that the respondents participate without any prejudice or harassment but voluntarily. As such all respondents are provided with full details on what this research seeks to achieve. Furthermore, research participants are guaranteed confidentiality and anonymity during the collection and analysis of data. The following section provides an overview of the research structure.

1.10 Research Structure

This research is split into five sections as follows: -

Chapter one: introduces the research and gives a brief background overview of BIM, the research problem and gap. Furthermore, the research aim, objectives, questions, scope, significance and consequences are also dealt with in this chapter.

Chapter two: deals with the review of existing literature in the fields of BIM, risk management and the operation and maintenance of buildings. This chapter is based on secondary sources that include but are not limited to books, journal articles and web references. The goal of this chapter is to show that there is indeed a research gap existing in the risk management process of the implementation of BIM in building maintenance.

Chapter three: this is a data gathering chapter which outlines the research methodology adopted in this research to answer the research questions and to achieve the research objectives. The sections covered under this chapter include the research method, data collection methods, target population, sampling and more importantly the data analysis section.

Chapter four: deals with data presentation and analysis of the findings made through the collection methods mentioned in chapter three. Furthermore, the chapter lays a foundation for the achievement of the research aim. The questions and objectives on identification and categorization of risks, BIM risk analysis and the recommendations of dealing with such risks are dealt with in the chapter.

Chapter five: this is the concluding chapter of the research which deals with discussion of findings and relating them to chapter two findings. Moreover, the chapter deliberates on the limitations that were encountered in the research process as well as the recommendations for future research.

1.11 Summary

This chapter was aimed at introducing the research setting in terms of the problem, the objectives and the questions which this research seeks to answer. Sections 1.4 and 1.5 dealt with research objectives and research questions respectively. Section 1.8 dealt with the consequences of this research. Since good research should be ethical, section 1.9 focused on the ethics considerations for this research. The next chapter analyses the existing body of knowledge and shows the gap to be covered by this research. The chapter begins by giving a global view of world infrastructure projects in terms of the future developments from a demand and supply perspective. This is followed by a section on maintenance of buildings and then the introduction of BIM. Lastly the chapter introduces Risk Management which is the bedrock of this research.

2.0 LITERATURE REVIEW

2.1 Introduction

This section discusses literature in the current body of knowledge. The first part introduces world infrastructure projects followed by a section dealing with the importance of building maintenance. This is followed by a section on benefits and challenges of adopting BIM. Subsequently, a section on risk management process follows and lastly the section dealing with the research gap to be covered by this research.

2.2 World Infrastructure Projects

According to Oxford Economics (2014), expenditure on global infrastructure is expected to grow by about US$5 trillion per year in 2012 to over US$9 trillion yearly by 2025 and in overall, about US$78 trillion is expected to be spent worldwide between 2014 and 2025. On the other hand, McKinsey & Company (2016) assert that, for the global community to meet the expected levels of GDP growth, the world will have to spend roughly US$57 trillion on infrastructure projects by the year 2030. In fact, approximately 66% of the US$57 trillion will be required in emerging markets including South Africa and many other African countries, with rising middle-class population, national growth in population, rapid urbanization, and increased economic growth (McKinsey & Company, 2016).

There is a great need to place focus on global urbanization and the effects on and of climate change due to the rising population density. The results for this are the continuous rise in the demand of infrastructure thereby making sustainability practices critical in ensuring that the environment does not suffer as a result of infrastructure development, operation and maintenance (McKinsey & Company, 2016). According to Oxford Economics (2014), improved transit, effective freight linkages, reduced jamming, enhanced connectivity, greater capacity, improved communications, highly efficient water and sewer systems, clean and sustainable energy, guaranteed power supplies and emerging aviation assets are vital tools in the creation of solid, well linked economies.

Moreover, the rise in infrastructure demand has resulted in increased investment interests from investors such as pension funds seeking low risk and tangible investments as well as financial institutions providing the much-needed capital to fund infrastructure developments. According to Arcadis (2016), the privatisation of key infrastructure assets in developed markets is achieving asking values that greatly exceed the anticipated values, thereby raising even more capital for the public sector.

However, technological advancements may have a negative effect on infrastructure and investment needs hence going forward; stakeholders will have to cover their projections against technological innovations (McKinsey & Company, 2016). For instance, a technological invention could result in certain infrastructure becoming obsolete due to the shift in demand. In fact, there are plenty building disruptions currently taking place worldwide and these are having significant implications on costs and investment needs. China's Broad Group, for instance, built a 30-storey tower in just 15 days (Arcadis, 2016). Without a doubt, such technologies have disrupted the built environment and will continue to do so into the future. Perhaps the biggest factors to the built environment will be the continuous lowering of costs, enablement of faster urbanisation as well as the achievement of sustainable practices.

The use of highly advanced technologies such as drones has become a reality and has completely turned the infrastructure space around more so in most first world countries. Meanwhile these technological advancements bring about vast opportunities to virtually all stakeholders, there is also a greater need to consider their uncertainties (Oxford Economics, 2014). As a result, all central and local governments that evolve with time will most likely have a competitive edge within the infrastructure space as well as within the industries making use of such infrastructure, thus improving the standard of living for citizens while economising infrastructure investments into the future (McKinsey & Company, 2016).

With this massive world infrastructure need, coupled with the technological advancements taking place, there is a clear need for preserving such infrastructures to achieve optimal performance always. Therefore, the preservation of such investments can be achieved through proper and timely maintenance. The next section deals with the maintenance of buildings.

2.3 Building Maintenance

The previous section gave an overview of world infrastructure projects and acts as a foundation on which this chapter is built. This section covers the aspects of building maintenance, which, as alluded to in chapter one, is the broad problem in this research. The British Standards Institute (BSI) (2010) broadly defines maintenance as a combination of practical as well as administrative and supervisory actions meant to preserve a component or reinstate it to a condition in which it performs the desired function(s). On the other hand, Scarret (1995:106) defines building maintenance, as work undertaken in order to preserve, refurbish or improve every part of a building, its services and surrounds, to a currently accepted standard and to sustain the utility and value of the building.

2.3.1 Importance of Building Maintenance

Maintenance of buildings is crucial since it is natural for building materials to deteriorate over time because of climate and usage (Chanter and Swallow, 2007; Bortolini *et al*, 2016). Through maintenance management, capital expenses can be preserved while ensuring that the building users enjoy a good working environment (Cloete, 2002).

Furthermore, the implementation of good maintenance requires an understanding of several building components, their operability and maintenance necessity, classification, planning, implementation, impact and cost estimating (Lazarus and Hauptfleisch, 2010). Shah Ali (2009) recognized prevailing conditions of the building, age of the building, received complaints on the performance of the building, request made by clients, funding availability and health and safety obligations as factors to be considered when deciding on maintenance cost.

Moreover, maintenance involves a combination of both practical and administrative actions which contribute to the safeguarding and acceptable operation of an asset (Wahab and Basari, 2013). Thus, failure to implement maintenance may create defective hazards on dead loads which in turn lead to building failure thus putting live loads at health and safety risks which may subsequently become costly to rectify.

Wahab and Basari (2013) affirm that proper maintenance preserves building value while at the same time it makes the building occupation more enjoyable. However, building structures relatively have longer life spans when compared to the mechanical components that are installed within. Many a time these mechanical components become defective in their operations and thus require repair or servicing or even replacement. Effective building maintenance therefore requires preplanning of all the foreseeable mechanical components that will require maintenance in future and the time the maintenance will be required.

It is evident that, the maintenance of building infrastructure is expensive throughout the lifecycle. According to Fitzemeyer and Tocci Associates (2017), various building components contribute to the high maintenance costs coupled with expenditures on energy, equipment repair and replacement. Expenditure on energy alone is categorised as the biggest operating disbursement for buildings and for instance a commercial building in the USA wastes roughly 30% of energy (Fitzemeyer and Tocci Associates, 2017).Undeniably, the proper maintenance of a heating, ventilating, and air condition (HVAC) system might reduce energy costs by between 5% to 40% based on the type of system and or equipment that is involved (Building Efficiency Initiative, 2011).

According to Fitzemeyer and Tocci Associates (2017), quantifying or predicting expenses related to maintenance, repair or replacement including the time taken in identifying a problem, the outage time and operational effects can be a daunting task for building owners and managers. In addition, minor issues could lead to momentous challenges for organizations operating large and complex facilities. For instance, utility outages can result in building closure, displacement of building occupants and users thereby resulting in big financial damages. Furthermore, events such as these can have reputational damages to the organization if speedy resolutions are not made to fix the issue (Fitzemeyer and Tocci Associates, 2017).

Moreover, the continuous neglecting and deferring of routine maintenance leads to defective buildings and when maintenance is eventually carried out, the repair works could be more serious and costly. Without reservation, existing buildings often face outdated information due to omissions in updating as-built documentation which configures a challenge to the BIM use in this context (Volk *et al*., 2014).

However, progressive institutional and individual building owners must integrate BIM into operating, maintaining and managing their properties in the long term as this gives them control over the lifecycle of their buildings (Fitzemeyer and Tocci Associates, 2017). According to the South Africa Department of Public Works (2006), the cost of not maintaining infrastructure is no longer affordable to South Africa. This shows the importance of maintaining infrastructure and built facilities in ensuring an adequate quality of life while supporting the country’s economy.

2.3.2 Classes of Maintenance

There are various classes of building maintenance depending on the geographical location in which the maintenance work will be carried out. However, all these classes fall under planned and unplanned maintenance (Zulkarnain *et al*, 2011) or routine and remedial (Chanter and Swallow, 2007). Chanter and Swallow (2007) point out seven distinct types of maintenance summarised in Table 1. The fact that BIM is not specifically designed for different forms of maintenance but for maintenance in general purposes provides a motivation for focusing on maintenance in general, in this research.

Table 1: Classes of maintenance (Adopted from Chanter and Swallow, 2007)

Class of Maintenance	Description
Planned Maintenance	Maintenance carried out at predetermined intervals or according to prescribed criteria and intended to reduce the probability of failure or the degradation of the functioning of an item (British Standards Institute, 2010).
Unplanned Maintenance	Maintenance carried out without a predetermined plan.
Corrective Maintenance	Maintenance carried out after the occurrence of a failure and is intended to restore the component back to its original state.
Emergency Maintenance	Immediate maintenance aimed at avoiding profound consequences.
Condition Based Maintenance	A form of preventive maintenance which occurs because of knowledge gained from routine checks of the property.
Scheduled Maintenance	A form of preventive maintenance carried out to predetermined years of operations, mileage etc.
Preventive Maintenance	Maintenance carried out to reduce or eliminate the risk of failure. Preventive planning avoids overworking of mechanical components found in a building beyond their life span. This helps in the prevention of breakdowns that can lead to undesirable or even fatal situations.

2.3.3 Maintenance Procedure

Bothma and Cloete (2000) are of the view that, the following questions must be answered before drawing up long term solutions to maintenance management;

- What requires maintenance?

  In answering this question, the maintenance team should establish all the building components that require maintenance to ensure optimal performance of the building.
- What is the state of repair for the components requiring maintenance?

  Having drawn up a list of the components requiring maintenance, the maintenance team should establish the state of repair or disrepair of such components to allow for proper maintenance.
- How can maintenance be carried out?

  This is an important question since failure to determine the proper way of maintaining buildings can bring about risks that can be devastating to all the stakeholders involved. The first step would be to refer to the maintenance manuals of each of the concerned components before engaging the appropriate maintenance personnel.

- How can the available resources be efficiently allocated to the maintenance process? Having determined the components requiring maintenance and the procedure of maintaining such building components, the last step is to decide on how scarce resources can be allocated efficiently to ensure that buildings operate at optimal levels.

2.3.4 Benefits of Proper Maintenance

Without any doubt, the goal of maintenance should be to ensure that buildings are operating at optimal level at any given time. Furthermore, Bothma and Cloete (2000) point out that, the proper implementation of a maintenance system brings benefits such as:

- Maintenance planning at a strategic level
- A limited resources allocation system alongside priorities
- Formal maintenance strategies and plans
- Precise zero-based budgets
- History of genuine maintenance expenditure
- Equipment records
- Recording of equipment condition

Lastly, Bothma and Cloete (2000) emphasise that, properly implementing and managing a maintenance system results in long run advantages which include:

- A change to planned from unplanned maintenance
- Long term reduction in maintenance expenditure
- Reduction in life cycle costs
- Prolonged economic life of equipment
- Reduction in down time

The next section deals with BIM, which is regarded as a concept and or technology that can reduce the money expended into maintenance of infrastructure. This is since BIM is regarded as an information rich model usable by anyone at any time without necessarily having to engage the project team which was involved during the construction or development stage (Gabryk and Scott, 2016).

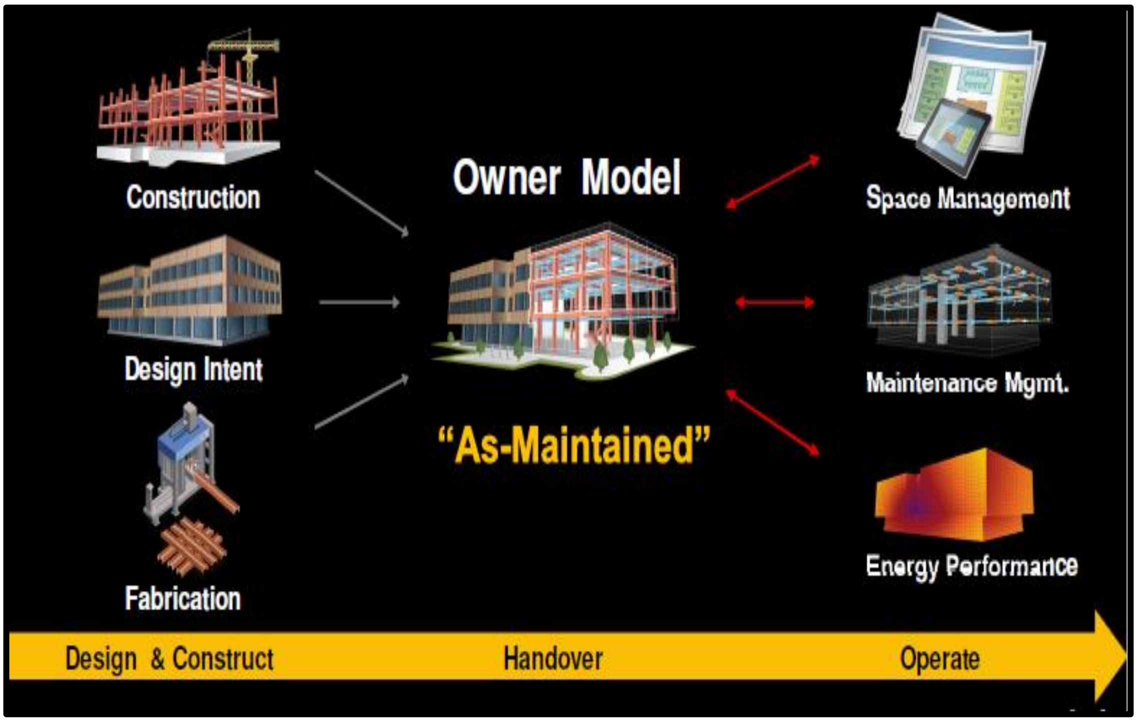
2.4 Building Information Modelling

The previous section covered building maintenance, this section introduces BIM, a cornerstone concept in the maintenance of buildings. BIM is a tool and process which increases productivity and accuracy in the design and construction of buildings while supporting continued and immediate availability of the design scope of the project, the schedule and cost information which is of higher quality, reliability, integration and full coordination (Forbes and Ahmed, 2011).

Pasarnezhad and Dimyadi (2014) argue that accessibility of information is vital to efficient management and operation of facilities. Without information of the facility, the job of a facilities manager is limited as maintenance to the facility becomes difficult to implement. As a result, high time and monetary costs are experienced by the owners of the facility. Ultimately, BIM is not only about technology or processes but how a collaborative process can be integrated to meet stakeholder expectations (Gillis, 2013).

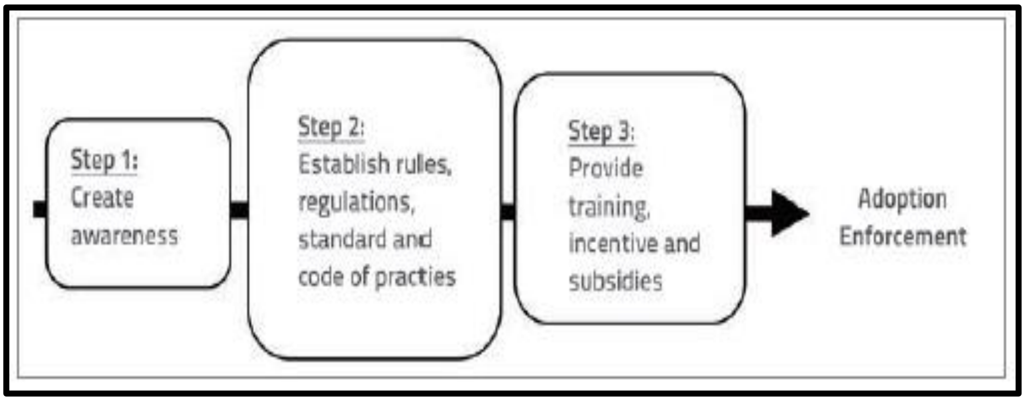
Figure 2 illustrates the collaborative nature of BIM throughout the construction lifecycle. The Figure depicts a scenario whereby during handover, the BIM model will contain information about the construction, design and fabrication of the building which will then be of assistance in the operation of the building for space management, maintenance management and energy performance management purposes.

Figure 2: Collaborative nature of BIM (Adopted from Gillis, 2013)



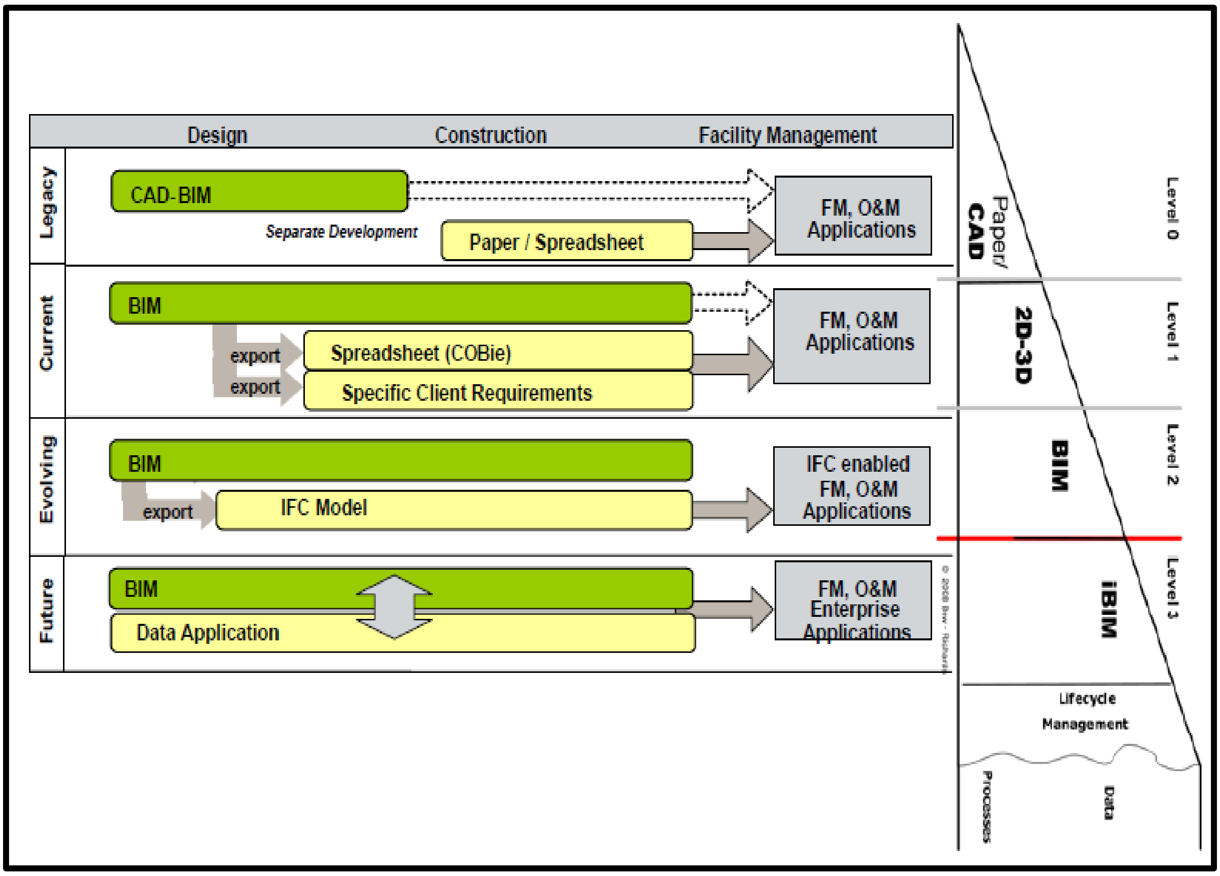
Salleh and Fung (2014) identified various strategies that can be used to enhance the implementation of BIM as shown in Figure 3. These strategies include but are not limited to the provision of BIM training and increasing levels of awareness, increased demand by clients and Government support as has been the case in countries were BIM has been made mandatory for all government projects.

Figure 3: BIM adoption strategies (Adopted from Salleh and Fung, 2014)



According to Gabryk and Scott (2016), there are four levels of BIM commonly referred to as maturity levels that can be summarised as follows in Figure 4:

Figure 4: BIM Maturity Levels (Adopted from BIM Task Group, 2012)



- **Level 0**: this is the oldest and more traditional way of handling building information using Computer Aided Drawings (CAD), Microsoft Word and Microsoft Excel

Spreadsheets. This is elementary stage containing distinct information sources which are mainly in hard copies (Tan, 2017).

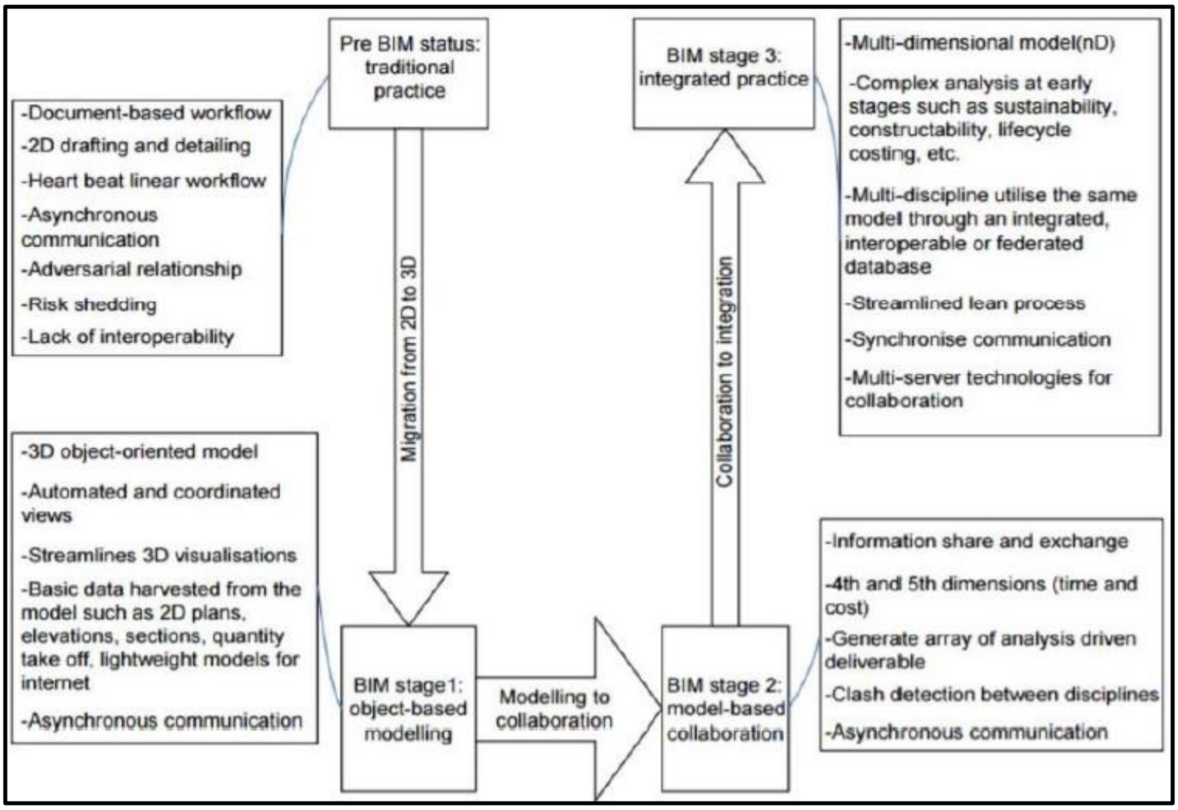
- **Level 1**: this level provides a higher level of 2D and/or 3D CAD as well as any other information produced in a more collective way. Semi-structured electronic documents are contained in this level (Tan, 2017).
- **Level 2**: at this level, 3D modelling and data individually produced by professionals and contractors, is then produced and coordinated into a model made subject of BIM protocols. It is expected, at this stage that, each project member produces their contribution to BIM in the form of models which are gradually enhanced with data relevant to their respective disciplines, scope of work and stage of project. This data is then merged to produce a combined model, usable throughout the life cycle of the asset (Tan, 2017).
- **Level 3**: Gabryk and Scott (2016) refer to this stage as the most sophisticated level since it has not yet been fully defined. This level requires the creation of data and modelling which is accurately interoperable, data-rich and facilities management ready (Gabryk and Scott, 2016). It involves a full collaboration between all the disciplines by means of a single, collective project model which is kept in a central repository. While this removes the risk of conflicting information (open BIM), it also helps all the involved parties to access and modify that same model. Level 3 BIM is a wholly integrated and collaborative process which includes project lifecycle and facility management information enabled by web services (Tan, 2017).

According to Gabryk and Scott (2016), in jurisdictions such as the UK, BIM protocols and industry standards are being adopted as the use of a protocol is considered the highly effective way in ensuring that the activities of all project participants are controlled. This so that BIM mechanisms and standards are applied from commencement of the project through to delivery of the project and are of enduring value to the asset operator in the facity and operation and management stage.

The UK government introduced BIM level two which is efficient, cumulative and informative while involving collaborative working (BSI, 2016; Gabryk and Scott, 2016). This level has been implemented across public sector funded construction projects (Gabryk & Scott, 2016). According to BSI (2016), BIM level two is regarded as cooperative BIM as it sees organised, information rich models prepared, advanced, and exchanged throughout the project life cycle, according to a defined framework. The involved parties make use of their own 3D CADs thus they need not necessarily work on a single, shared model. The differentiating feature is that all the design information is shared through a common file format which enables any organization to be able to combine that data with their own.

BIM level two has been considered as a remarkable success by the UK Government as huge operating expenses of up to 33% have been saved (BSI, 2016). The UK Government seeks to introduce BIM level three which will also be made mandatory for all government construction projects. Hijazi and Omar (2017) have illustrated the maturity stages that have been followed in BIM implementation in the UK up to the current stage (stage 3) as shown in Figure 5.

Figure 5: BIM implementation stages in the UK (Adopted from Hijazi and Omar, 2017)



There are two market conditions that provide a motivation for institutions and individual building owners to make a decision of whether to use BIM beyond the construction stage which are the cost of maintaining the functionality of the buildings as well as the capability to react urgently to repair needs, emergencies and disasters (Fitzemeyer and Tocci Associates, 2017). The following subsection deals with the various benefits that can be enjoyed by various stakeholders as a result of the adoption of BIM.

2.4.1 Benefits of Adopting BIM

Since BIM encourages project parties to jointly and transparently work throughout the project and beyond, this helps in the early identification of design matters, reduce workloads and costs and in the end facilitate efficiency and effectiveness in the design, construction and operation of a building (Doumbouya *et al*, 2016; Gabryk and Scott, 2016; Aziz *et al*, 2016). Simply put, BIM is meant to reduce the frequency of professional liability claims.

Most contractors are required to handover drawings and any other documents containing information about the building for ease of reference by the facilities managers (Patacas *et al*, 2015). This makes the information handed over to be inaccurate and incomplete at times (Lucas *et al*, 2013). Lee *et al* (2012), pointed out that about US$10.6 billion out of US$15.8 billion losses caused by interoperability inefficiencies are attributed to the operations and maintenance phase of a building. Research has proven that BIM will enable the smooth handover of real time information, for example, Motamedi *et al* (2014) noted that, the 3D visualisation which comes along with BIM helps facility managers to use their cognitive and perceptual reasoning for problem solving.

The greatest potential of BIM could be in the optimization of building operations and management and data capturing for operations purposes to enable quicker incorporations in future designs (Berger, 2017). According to Schober *et al*, (2017), a structural scenario might arise say 30 years after the construction process and if BIM is implemented, it will help in tracing the root problem which in turn helps to eliminate such a problem in future. As such, the operations team could make use of BIM for better visualization of the buildings under management for effective reduction of operating costs while improving the competitiveness of the firm.

According to Aziz *et al* (2016), the following advantages can be enjoyed using BIM;

- Effective operational cost

  Without a doubt, BIM allows for sustainability considerations and operating costs throughout the life of a building. This enables productivity within the workplace since all considerations will be made based on reliable information (Smith and Tardif, 2012). The implementation of BIM has ripple effects on the improvement of quality and accuracy of financial outlook which might result in complex endeavors that ultimately lead to mistakes regardless of the skills possessed by the team members (Smith and Tardif, 2012).

- Less decision-making time

  Effective analysis and evaluation of information can be achieved through the adoption of BIM which can be designed to allow for a much quicker process (Ani *et al*, 2015). For an example, a case study of a USA Coast Guard Facility Planning saved roughly 98% on time spent in the creation and updating of a database containing the facility data using BIM (Eastman *et al*, 2008; Akcamete *et al*, 2010).
- Decision making resource

  Reliability of information is guaranteed using BIM throughout facilities systems thereby allowing facility managers to retrieve and analyse all the information about a facility (Akcamete *et al*, 2010). Moreover, BIM allows facility managers to analyse the performance of a building over a period which helps in the decision-making process on issues such as maintenance work planning (Akcamete *et al*, 2010; Volk *et al*, 2014).
- Improved documentation system

  BIM models are in real time and soft copy format, thus, facilities managers and even building owners can easily reconcile information and quickly implement an action plan through the model to deal with a problem (Golabchi and Akula, 2013). Therefore, the use of BIM allows for the migration from a paper environment to a paperless environment which is also regarded as a sustainable practice.
- Collaboration and work flexibility

  The collaborative nature of BIM leads to communication improvement, service delivery improvement, improved commutation amongst business partners, cycle time reduction, improved energy efficiency, cost efficiencies and productivity within the workplace (Smith and Tardif, 2012; Motawa and Almarshad, 2013). According to Bouchlaghem and Shelbourn (2012), ICT tools such as BIM help in the interaction process regardless of hierarchical levels within an organization, geographical location and time zone differences.
- Real-time information and clash detection

  The nature of BIM is such that when a change is made within the system, the change is automatically reflected and incorporated into the whole system (Akcamete *et al*, 2010; Golabchi and Akula, 2013). Furthermore, the BIM concept can detect clashes within the system which allows for a faster and more effective way of solving problems without greatly affecting the operation of the facility (Weygant, 2011; Levy, 2012). For instance, in facilities management, BIM allows the facility managers and building owners to use the facility for various purposes through the conducting of detailed analyses (Smith and Tardif, 2012)

The BIM task group (2013) suggested that the success of future designs is dependent on the successful management of information through the various ways available within BIM. BIM brings positive value as it will improve the quality and reliability of data which results in improved efficiencies within the workforce (Teicholz, 2013; Aziz *et al*, 2016). According to the BIM task group (2013), BIM provides a fully populated asset data set into CAFM systems thereby reducing time wasted in obtaining and populating asset information while optimising the performance of stakeholders, reducing operating costs and refining targeted outcomes. According to Parn *et al* (2017), there are various benefits of BIM in FM and these are summarised in Table 2. The following subsection discusses the various challenges faced in the adoption of BIM.

Table 2: Benefits associated with BIM and FM integration (Adapted from Parn *et al*, 2017)

Benefits	Results
Increased utility and speed for data retrieval from a centralised BIM model.	Information is more easily shared, can be value added and reused.
Enhanced collaboration through BIM processes and modelling.	Built assets proposals can be rigorously analysed across disciplines and organizations. Simulations can be quickly executed and performance benchmarked, enabling improved and innovative solutions.
Improved embedded building data in a centralised model.	Requirements, design, construction, and operational information can be used in FM resulting in better management of assets.
Visualisation of assets.	The value of 3D visualisation eliminates misinterpretation. Navigation of information becomes more fluent in a 3D environment.
Larger equipment asset life.	Through better knowledge of existing assets and CAFM integration preparation and planning enables longer asset life.
More effective space/ move planning.	In-depth knowledge on the assets that are fixed, or movable means better space movement can be planned and executed.

2.4.2 Challenges of Adopting BIM

Whilst there are significant benefits resulting from the introduction of BIM, there are barriers that tend to affect its implementation as the remarked by Aziz *et al* (2016). New software necessitates training and more work needed to update BIM (Berger, 2017). Becerick *et al* (2012) identified technology and organizational challenges in the implementation of BIM in the operation and maintenance phase.

a) Technology related challenges

The issue of unclear and undefined roles and responsibilities in working with BIM was noted as one of the major setbacks in its adoption (Kelly *et al*, 2013). Other technology related challenges include interoperability issues, ineffective alliance between project stakeholders for modelling and model use, and lack of interests (Becerick *et al*, 2012). However, the technology related setbacks can be viewed as avenues for growth and effective management of facilities. This is since, facilities managers can be trained and equipped with the knowledge on how to work effectively with BIM and with the evolving nature of the information, communication and technology (ICT) sector this knowledge will prove vital in future.

Another technology related challenge is the weakness in the design of software and tools. The software and application designers of BIM must realize the differences between construction and manufacturing industries (Alizadeh *et al*, 2016). As software developers take ideas from industries, they should also consider characteristics of them (Alizadeh *et al*, 2016). It should be noted that construction projects require specific extensive decision-making procedures and highly specialized skills (Sanders, 2004).

b) Organizational challenges

The organizational issues related to the adoption of BIM includes resistance from the workforce, high initial capital outlays in adopting the model and proof of positive return on investment (Becerick *et al*, 2012; Salleh and Fung, 2014). One may argue that the issues of workforce resistance is experienced in organizations were workers are not challenged with new targets hence the need to engage workers before introducing new systems.

Another organizational related challenge is the absence of proper organization culture. To achieve these innovations, enhancing digital technologies won’t be helpful, but help in the creation new partnerships between employers, designers and contractors (Alizadeh *et al*, 2016). Promoting proper organization culture, creating training programs to support it and invented new processes to increase the impact of its delivery, can be very effective (Sanders, 2004; Salleh and Fung, 2014).

According to Fitzemeyer and Tocci Associates (2017), there are three challenges faced by institutions when deciding to use BIM in the operations and maintenance of buildings. These include:

- Dealing with legacy buildings

  The designing and construction of new buildings in present day requires the construction team to make use of BIM to deliver electronic models and data files that have complete information about the system of the building and associated equipment. In so doing, owners and operators of such buildings will have all the data they need about the building at the click of a button thus aiding the decision-making process.

  Critical to note is the fact that many institutions have a smaller percentage of new buildings when compared to those buildings that are already in existence. As such, most of these existing and old buildings rely on CAD or PDF drawings while some rely on hard copy hand drawings for information on the construction, operation and maintenance of such buildings.

  While the hand drawings mentioned before are not highly accurate, the present-day use of BIM allows for more accurate drawings (Fitzemeyer and Tocci Associates, 2017). The as built hand drawings generally lack meaningful coding which enables stakeholders that were not involved during the construction process to clearly read the drawings. The challenge therefore for the facility managers and owners is to translate the old standards into current standards when developing BIM models for old buildings.

  Translating legacy building information to a BIM interface is a time consuming and laborious activity due to the standardization problem noted before. This process will take a lot of resources from the building owners thus decision making becomes difficult. These resources include survey costs to capture buildings data before feeding it into the BIM system since the available legacy data might not be comprehensive. The other option would be to capture data during renovation, but the draw back here is that the building might not be renovated in full thus allowing for only a portion of the building to be captured into the BIM interface at that given time.

The capturing of data for legacy buildings brings about management challenges to the owners and managers during the migration process. This is because the managers and owners will have to strategize their management functions since they will be dealing with both soft and hard data when managing the buildings.

- Implementation

  As alluded to, the implementation of BIM requires commitment of time and monetary resources. With some institutions, bureaucracy issues can drag the implementation for several years due to the time taken to approve the use of BIM, planning the implementation process, capturing, integration and validation of the data into the BIM system.

  When dealing with cost issues, institutional and individual building owners should consider many factors that include but may not be limited to adequate hardware requirements for storage of large volumes of data generated by BIM. Furthermore, it is advisable for such institutions and individuals to draft a budget for all the implementation expenses and classify them as capital expenditure due to the high initial costs that can be involved.

  Moreover, there are various packages that are available for building owners and these include Navisworks, Revit and AutoCAD, each with its own merits and demerits. The greatest demerit of the packages is that they are not collaborative like BIM as they only deal with specific sectors of the construction process. The success of a project is founded on time and cost management and likewise the successful management of buildings requires quick response rates to issues. The advantage of BIM is that data can be accessed instantly and remotely through mobile devices and tablets.

- Ensuring complete process integration

  The greatest challenge faced by many institutional and individual real estate investors is that of integrating BIM into existing operational and maintenance activities within institutions. Facility managers will most likely be asked to increase their workloads since the institutions will be trying to contain costs. Therefore, such a scenario might force institutions to be reluctant in changing the existing processes since the adoption of BIM could take between three to five years of learning.

  Facility managers are always busy with building maintenance and as such they might not have adequate time required to learn the use and integration of BIM data into an existing process. As alluded to, during the transition period, Facility managers face the daunting task of trying to balance the use of BIM in operations and maintenance of some of the buildings and the operation and maintenance using the old school way thereby complicating the whole process.

According to Berger (2017), the other drawbacks for the widespread adoption of BIM besides software and hardware costs are the challenges for the selection of appropriate projects for BIM implementation, doing away with non-BIM models, getting skilled BIM workers and the need to appraise the transition costs. Ibrahim (2017) categorises the BIM-FM challenges into business and legal, human and organizational and technical as detailed in Table 3.

Table 3: BIM-FM challenges, barriers, and descriptions (Adopted from Ibrahim, 2017)

Challenge	Barrier	Description
Perception of BIM	• Business and Legal • Human and Organizational	• Lack of benefits, real world projects • Lack of proof of positive return of investment • Lack of standards and guidelines
Fundamental difference between project and lifecycle management	• Business and Legal • Human and Organizational	• Different methodology between BIM and FM • BIM implementation for running existing projects or buildings
Contractual and Legal Framework	• Business and Legal	• Model contents and required data for FM • Model ownership and protection of data • Model exchange format • Model design liability • Intellectual property ownership
Training, roles, and responsibilities	• Human and Organizational	• Trainings • Shortage in skilled BIM-FM employees • Unclear roles and responsibilities • Lack of collaboration between project stakeholders
Cost	• Business and Legal • Human and Organizational	• Cost of software and hardware • Cost of training and BIM consultant • Cost of hiring new employees
Interoperability	• Technical	• Diversity between BIM and FM tools and platforms • Open standard limitations • Lack of common interest between the software’s vendor

FM tasks supported by BIM include space management, predictive maintenance, preventive maintenance, scheduling, asset management, record modelling and building systems analysis (Mohanta and Das, 2016). These benefits show that there are more benefits to be derived from the use of BIM. Wijekoon *et al* (2016) are of the view that BIM research has focused on the positive side of things if adopted in FM. They point out that the success of BIM depends on the information it holds. However, the fact that they realise the important role information plays in the success of BIM is a sure sign that if handled properly, BIM can bring numerous benefits to maintenance of buildings.

2.4.3 Implementing BIM for Operations and Maintenance

The concept of “cradle to grave” accountability is one of the major drivers for the implementation of BIM since it includes the operations and maintenance activities after the project completion. Since the BIM model is updated continuously during construction, the “as-built” record of the constructed project is current and accurate at the time it is turned over to the person in charge of operating and maintaining the facility. Not only that, but the information regarding all the products, materials and systems installed in the project can now be directly linked with the equipment and maintenance manuals utilised by the facility’s personnel. Fitzemeyer and Tocci Associates (2017), are of the view that the effective implementation of the BIM concept for the operation and maintenance management of buildings depends on the following five steps:

- ❖ Step 1: Definition of how an organization will use BIM

The first and most important step is to gain an understanding of how an organization will use BIM. This involves making considerations on how the organization will use the BIM concept beyond the design and construction phases into the digital documentation, operation and maintenance phases.

- ❖ Step 2: Identifying significant Return on Investment (ROI)

Databases can be filled up with finer details about all the aspects of a building, from operations of building services such as HVAC system to information about the door hinges. Nevertheless, most of the information loaded on to the database might never be used by the facility managers and building owners. It is therefore prudent for BIM implementing organizations to determine what information will be required for the efficient and effective operation of a building.

- ❖ Step 3: Identifying work processes and needs

During this step, it is vital for both the owner and facility managers to deliberate on the existing building information and determine the amount of work that will be required in ensuring that the information is useful. Afterward, considerations on existing operations and maintenance and FM processes should be made with the aim of coming up with solutions on how to integrate them with BIM. Lastly, there is a need to be futuristic in terms of operations and maintenance data that will be required in the future so that the data can be currently loaded into the database.

- ❖ Step 4: Identification of organizational champions

Without a doubt, anyone affected by the implementation of BIM within an organization should consider prioritizing it. Stakeholders such as building owners, managers, IT teams that will be working with BIM in operations and maintenance of systems such as HVAC should clearly understand the advantages of BIM. These will be the champions that will assist in ensuring that everyone within the organization understands BIM.

- ❖ Step 5: Identifying financial resources

Organizations incorporate BIM into their budgets in several ways. In certain instances, costs associated with software, hardware as well as data can be classified as capital expenses (CAPEX) for new construction products. Moreover, in other cases, such costs might be specifically allocated under renovation projects budgets and in other instances these costs can be apportioned under operation and maintenance budgets (OPEX).

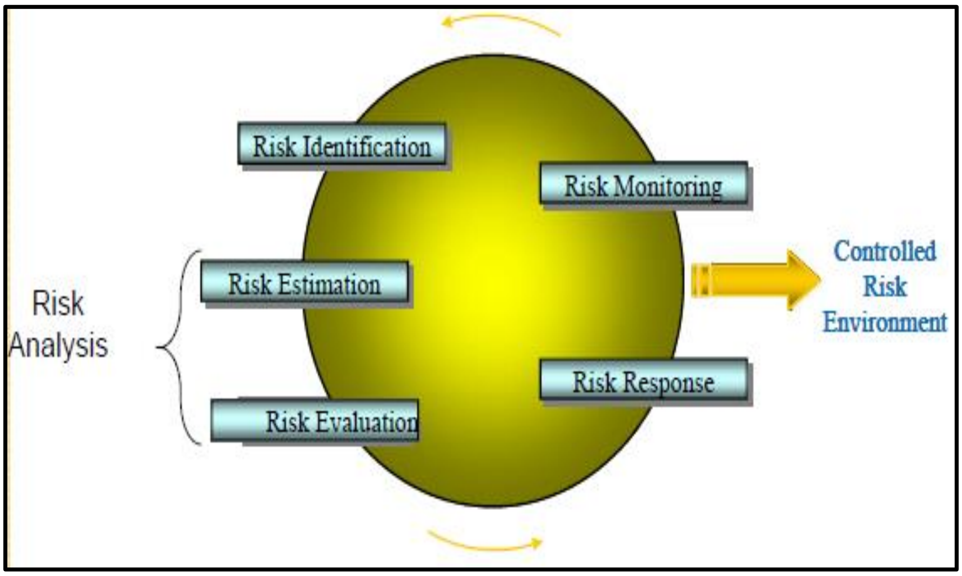
This section dealt with BIM, a concept that is proving to be effective in the operation and maintenance of buildings. The following section deals with risk management which is the main gap that this research seeks to cover.

2.5 Risk Management

Risk is an unknown, unexpected, undesirable and unpredictable endeavour. Risks can be classified as physical, technological, financial and economic and political and environmental (Pryke, 2016). Risk management is a four-stage process which starts with the identification of risk, followed by risk analysis which is mainly done through estimation and evaluation of the risk, followed by risk response and then monitoring. These stages are shown in Figure 6 and are defined in detail in the following sections.

All projects have some element of risk, be it cost overruns, delays or failure of the building performance to meet expectations (Pryke, 2016). Furthermore, Pryke (2016) is of the view that adopting BIM cannot eradicate all risks but can de-risk most sections throughout the project life cycle.

Figure 6: Risk management cycle



According to case study results carried out by (Pryke, 2016), savings of up to 45% on unplanned maintenance activities and 20% on planned maintenance tasks have been achieved using BIM. Pryke (2016), further notes that the response rates to problems have also improved by 54% and productivity increased by 50% during planned preventive maintenance tasks. All these statistics are proof that BIM has benefits in the maintenance of buildings. However, Thompson and Miner (2007) point out that, regardless of all the savings and efficiencies associated with the use of BIM, it is vital to note that its use is not without risk.

The benefits of a formal risk management process include:

- Helping to deliver successful outcomes.
- The establishment of a project risk profile, which enables proper risk allocation.
- Allowing the project team to effectively manage risks and thus freeing up resources for other uses.
- Increases owner and end user project success confidence as it allows the projects to be delivered on time while meeting quality expectations.
- Through the process of quantifying risks, the management team will be assisted to avoid raising unnecessary funds.
- This allows for proper and regular risk reporting to the appropriate management.

The construction industry is vast and varied. Without a doubt, technological advancements continue to revolutionise the construction business operations just as with other industries. According to Jackson (2010), the built environment is fast becoming complex hence there is a strong need for innovativeness. This is evidenced by the increased computerised control of building services such as temperature, airflow, levels of lighting and building access management.

Before reaching a contract agreement, the parties involved must be wary of legal implications arising from using BIM to manage risks that may arise during the contract (Cubitt and Coldwell, 2014). The believe that, technological advances of BIM, combined with greater teamwork between parties, will result in reduced liabilities and risks on construction projects could lead to greater short-term risks for insurers, at least. If BIM is used fittingly, the time, costs and claims of construction can be greatly reduced.

According to Jackson (2010), the business of construction is risky to all the involved stakeholders. The greatest challenge within this sector is that of allocating risk to parties that are willing and able to effectively manage it. It is critical to note that, after the risk identification process, there is a strong recommendation for the implementation of proper and adequate response measures.

Solutions to problems are discovered by using critical and creative thinking skills and by being very resourceful. Maintenance managers should be able to not only anticipate all forms of risks that are associated with the buildings under their management but should also come up with response measures that ensure success of their endeavours. Although the goal is to find, flush out and eliminate every possible snag and snafu in the way of successful maintenance of buildings, the reality is that bombshells can be dropped on any day of the operation phase.

Once risks are rated, it can be determined which ones to focus on and how best to mitigate them. The evaluator’s analysis is subjective hence the need to engage with experienced and specialised respondents. The concept behind risk mitigation is to anticipate negative influences to provide and implement responsive actions to deal with them. The risks that pose the greatest threat are the ones that require full attention on risk mitigation strategy.

Thomson and Miner (2010) emphasise that the inaccuracy of the BIM generated data can be disastrous. Azhar (2011), broadly classifies BIM risks into legal (contractual) and technical. The first risk identified by Azhar (2011) is that of ownership of BIM data. Disputes are most likely going to arise between the Owner of the building and the project team on who owns the BIM data. Obviously, the owner, as the funder of the project would assume ownership whereas the project team, having played a role in the collaboration process, would also want ownership rights of the information. This is also affirmed by Thomson and Miner (2010) who add that, there is a need to determine ownership of the generated BIM data as well as its protection through copyright and other legal frameworks. It is critical to take note of the fact that the realisation of the model's potential must not be affected despite these challenges.

The second risk as identified by Azhar (2011) arises from the issue of who is supposed to control data entry. According to Thomson and Miner (2010), accepting the responsibility of updating BIM information and guaranteeing its accuracy involves great risk. Considering a scenario where say, the owner of the building sues the project team over a perceived maintenance program error, there is a significant need to know who lies with the responsibility.

However, Azhar (2011) suggested that the best way to respond to such risks will be to have integrated project delivery contracts that are collaborative and in which all the risks associated with the implementation of BIM are available to all the involved the stakeholders. Tomek and Matejka (2014), reiterate the importance of the topic of risks in BIM by suggesting that the use of BIM creates big impacts on standard risk levels. Furthermore, there is an increased exposure around data security and cyber liability when using BIM.

2.5.1 Risk Identification

This is the first step in the risk management process in which potential and relevant risks are identified (Ya'acob *et al*, 2018). The identification of risk(s) can be done through brainstorming, checklist analysis, Delphi technique, assumption analysis and expert judgement (Project Management Institute, 2008).

- ***Brainstorming***

This technique allows for the grouping of experts in each field, in this case BIM risks, who then deliberate on the identification, analysis, response and monitoring of risks. Such generation of risk ideas is usually done with the help of facilitation through techniques that include traditional free form brainstorming sessions in which the participants share ideas and mass interviewing sessions whereby individual contributions are made. The findings from these brainstorming sessions are then defined in detail and then categorised to allow easy interpretation by all the stakeholders.

- ***Checklist analysis***

The development of checklists is dependent on the availability of historical data and knowledge gained over a period from the projects that have been undertaken or from any other sources of data such as the risk breakdown structure (RBS). However, it is key for the checklist to be continuously checked and improved as new information is obtained, thus one can safely say checklists are work in progress.

- ***Delphi technique***

This allow for the reaching of a consensus anonymously among risk experts. This is done through interviews and the distribution of questionnaires to solicit ideas of risks involved in an endeavour.

- ***Assumption analysis***

This explores the level of assumptions validity during their application to a project. The analysis process helps with the identification of project risks paying greater attention to accuracy, stability, consistency and completeness of the assumptions.

- ***Expert judgement***

Risk identification and analysis is done by experienced experts who have been involved in similar projects. Their expertise is very vital since they understand the risk environment for projects.

Risk identification seeks to determine an organization’s exposure to uncertainty. IRM (2002) emphasises that the identification process requires an in-depth knowledge and understanding of the organization, the market environment of the organization, lawful, societal, political, and traditional environments in which it exists, as well as the development of a thorough understanding of its long and short term goals, including those critical factors ensuring its success as well as strengths, weaknesses, threats and opportunities related to the accomplishment of the goals. Business activities and decisions can be classified in different ways which include but is not limited to strategic, operational, and financial, knowledge management and compliance.

2.5.2 Risk Analysis

Risk analysis involves potential risk impact estimation so that decisions on either retaining or transferring the risks can be made. It involves risk estimation and risk evaluation. Evaluation of risk is critical in decision making since the significance of the risks will determine the appropriate response measures. In fact, risk evaluation is important to compare the estimated risks against the organization’s established risk criteria.

The risk analysis is done using various techniques depending on whether the risk is quantitative or qualitative nature. The identified risk ladder depends on probability of occurrence and impact during and after the occurrence. On the other hand, quantitative risk analysis is dependent on the existing data, enabling the quantification of probabilities and their impacts. A proper quantitative analysis requires an estimate of the likely risks and their characteristics as well as their variability and maximum likely risk estimate.

Pivotal to note is the fact that, the risk resultant impact can be in various forms which may include but are not limited to increased costs, reduction in performance or quality and time extensions trying to rectify the impact. Table 4 below shows the various analysis techniques available in risk analysis;

Table 4: Risk Analysis Techniques

Quantitative	Qualitative
Probability Analysis	Ranking Options
Sensitivity Analysis	Comparing Options
Simulation Techniques	Descriptive Analysis

Risks will be ranked on a four-point scale (risk matrix) reflecting the probability and impact of the risk as shown in Table 5. The risks ranked Grade 1 are the most important since they have a high probability of occurrence and high consequence. As such, these are the risks that require response mechanisms and monitoring whereas the risks ranked Grade 4 are the least important and can even be discarded due to their low probability of occurrence and low consequence.

Table 5: Risk Matrix

		Probability of Occurrence	
		High	Low
Consequence	High	1	3
	Low	2	4

2.5.3 Risk Response

Risk response can be done through various means which include elimination, transfer, retention (active or passive) and reduction. Active retention is a thoughtful managing plan after a conscious evaluation of the possible losses and costs of alternative ways of handling risks while Passive retention occurs through negligence, ignorance or absence of decision.

- ***Elimination***

This involves changing the project management plan to eliminate the threat entirely. Isolating the project objectives from the risk's impact or changing the objectives that are in danger is another way of eliminating risks. The elimination process can also be done through clarification requirements, obtaining information, improving communication or acquiring expertise.

- ***Transfer***

Involves shifting some or all the negative impact of a threat, along with ownership response to a third party. Pivotal to note is the fact that transfer of risk does not eliminate it but only gives another party responsibility of its management. This form of dealing with risk is most effective when dealing with financial risk exposure and mostly involves payment of a risk premium to the part assuming the risk. Risk transfer can be done through insurance, warranties, guarantees etc.

- ***Retention***

The strategy is adopted because it is rarely possible to eliminate all threats from a project. This strategy indicates that the project team has decided not to change the project management plan to deal with a risk or is unable to identify any other suitable response strategy. This strategy can either be passive which requires no action except to document the strategy, leaving the project team to use an incrementalistic approach in dealing with risks and active which seeks to establish a contingency reserve, including amounts of time, money or resources to handle risks.

- ***Reduction***

This involves the mitigation in the probability and or impact of an adverse risk event to be within acceptable threshold limits. This method is effective when compared to acting after the risk has occurred.

2.5.4 Risk Monitoring

Having implemented a response measure, the following step is the monitoring of risk. This is a process of choosing and implementing measures to modify the risk. It includes risk control or mitigation, risk transfer just to mention a few. The following section covers the various benefits associated with risk management.

2.5.5 Benefits of Risk Management

Pryke (2016) points out that the adoption of BIM cannot eradicate all risks but can de-risk most sections throughout the project life cycle. What's more important in the work of Pryke (2016) is the fact that there has been an acknowledgement that there are certainly risks associated with the use, the research done by (Pryke, 2016), reports that up to 20% savings have been achieved from the use of BIM in maintenance of buildings. This figure is significant because lifecycle costs of buildings are higher during the operation and maintenance stages.

The research done by Pryke (2016) also claims that there has roughly been a 54% improvement in response rates to problems using BIM in maintenance of buildings. These statistics clearly show that BIM has some major benefits in maintenance and will likely result in more organizations adopting the concept. The major challenge though is that BIM risks need to be assessed for improved results. Cubitt and Coldwell (2014) claim that, the ability to de-risk projects through greater efficiency is long during the operations and asset management phase of a facility's life.

According to the Institute of Risk Management (IRM) (2002), risk management gives value and protection to organizations and their stakeholders through;

- ❖ The provision of an organizational structure enabling a consistent and controlled manner of future activities.
- ❖ Optimisation of operational efficiency.
- ❖ The development and support of people and the organization's knowledge base.
- ❖ Protection and enhancement of assets and the company image.
- ❖ Reduction of volatility in the non-essential areas of business.
- ❖ Contributing to more efficient use/allocation of capital and resources within the organization.
- ❖ Improvement in decision making, planning and prioritisation by comprehensive and structured understanding of business activity, volatility and project opportunity or threat.

This section covered the various benefits of carrying out risk management. The following section covers the various risks that are linked to BIM.

2.6 Research Gap

As noted earlier, demand for infrastructure continues to rise due to factors such as rapid urbanisation and high population growth (McKinsey & Company, 2016). As such Governments and private sector investors are globally faced with the dilemma of ensuring that the rising demand for infrastructure services is met by adequate supply for such facilities to avoid market failure while ensuring sustainable practices (McKinsey & Company, 2016; Arcadis, 2016). Governments should strive to reach an equilibrium point between the demand and supply of infrastructure. Failure to meet such a position will result in overuse and at times abuse of the available infrastructure which makes maintenance a daunting task especially when resources are limited.

While the potential for meeting the ever-rising infrastructural demand is available, there is also a strong need to consider the proper management of such infrastructure (Chanter and Swallow, 2007; Azhar, 2011; Bortolini *et al*, 2016). Moreover, with the rapid technological advancements taking place, there is need for strategic planning to ensure that these advancements will have positive benefits to the management of infrastructure (McKinsey & Company, 2016).

According to Volk *et al* (2014), for building maintenance to be a success, there is strong need to manage building information efficiently. Interestingly, the collaborative nature of BIM solves this conundrum through the provision of real time building information (Forbes and Ahmed, 2011; Gillis, 2013; Tan, 2017). This allows building owners and managers to make informed decisions about their buildings. However, despite the cost savings on maintenance as well as improved response rates to problems using BIM as identified by Pryke (2016), there is a strong need to identify what could go wrong in trying to achieve those savings.

It is evident that considerable research has been done on risks associated with BIM during the construction stage. Although research has proved that BIM has benefits in the maintenance of buildings through the provision of real-time information on available services and permits with precise assessments of the conditions of assets (Gabryk and Scott, 2016), there is a strong need for identifying, categorising, analysing and recommending ways of responding to risks associated with relying on BIM for maintenance purposes (Ashcraft, 2008; Araszkiewicz, 2015; Alizadeh *et al*, 2016).

Therefore, the same process followed during any risk management activity should also be implemented in managing risks associated with the implementation of BIM in maintenance of buildings (Alizadeh *et al*, 2016). In summary, this research seeks to cover the gap of risks associated with the implementation of BIM in the maintenance of commercial buildings in Gauteng, South Africa, a concept which is proving to be vital in dealing with maintenance issues and costs.

2.7 Summary

This chapter presented literature on world public infrastructure projects and the investment needs for such projects at a global stage. Furthermore, the chapter also deliberated on commercial buildings in South Africa, the research setting for this study. Since high building maintenance costs are the problem of this research, the different classes of building maintenance as well as the components requiring maintenance in buildings were also discussed in this chapter. Following this was the section introducing BIM, an innovative concept that has attracted much interests from AEC professionals across the globe for the various benefits it brings across the building life cycle especially the operations and maintenance stage which is the focus of this research. The last section dealt with risk management, the research gap which this study seeks to cover. The following chapter deals with the research methodology adopted in answering the research questions. The main sections covered in the chapter are the research method, data collection method and the data analysis section.

3.0 RESEARCH METHODOLOGY

3.1 Introduction

Chapter two focused on analysis of the existing body of knowledge on building maintenance, BIM, risk management and showed the gap to be covered in this research. This chapter deliberates on the exploratory and evaluative study approach utilised in this research to discover and gain insights and recommend solutions on the risks associated with implementation of BIM in maintenance of commercial buildings in Gauteng, South Africa. The chapter is primarily guided by the research questions identified in chapter one in coming up with a methodology of answering each of the questions. In short, this Chapter together with the first and second Chapters provide a skeletal structure of this project.

3.2 Research Method

Denscombe (2010), defines research methods as tools that enable the researcher to gain a clear understanding of a subject, precise measurement of things as well as the truths and evidence about the issue at hand. According to Saunders *et al* (2016), there are basically three types of research designs that is quantitative, qualitative and mixed methods. The quantitative method relates to any data collection technique for example a questionnaire or any data analysis procedure such as graphs which produces or makes use of numerical data. The qualitative method on the other hand relates to any data collection technique such as an interview or any data analysis procedure like categorising data which produces and uses non-numerical data.

The distinction between quantitative and qualitative methods is pivotal, but it is important to note that in real world most researches combine the two (Saunders *et al*, 2016). Without a doubt, the mixed method design was used in this research because in practice qualitative and quantitative research draw elements from each other (Denscombe, 2010). Figures 7 and 8 show the basis on which the research methodology for the research is founded. Figure 7 illustrates the research onion and how various layers can be peeled by a researcher from research philosophy to data collection techniques and procedures thereby giving the researcher a clear path leading to the achievement of the set objectives. Figure 8 summarises factors critical in influencing the achievement of research objectives. Saunders *et al*, (2016) define mixed methods research as a branch of research methods combining quantitative and qualitative data use and analytical procedure.

Figure 7: Research Onion Justifying the Research Methodology

(Adapted from Saunders *et al*, 2016:124)

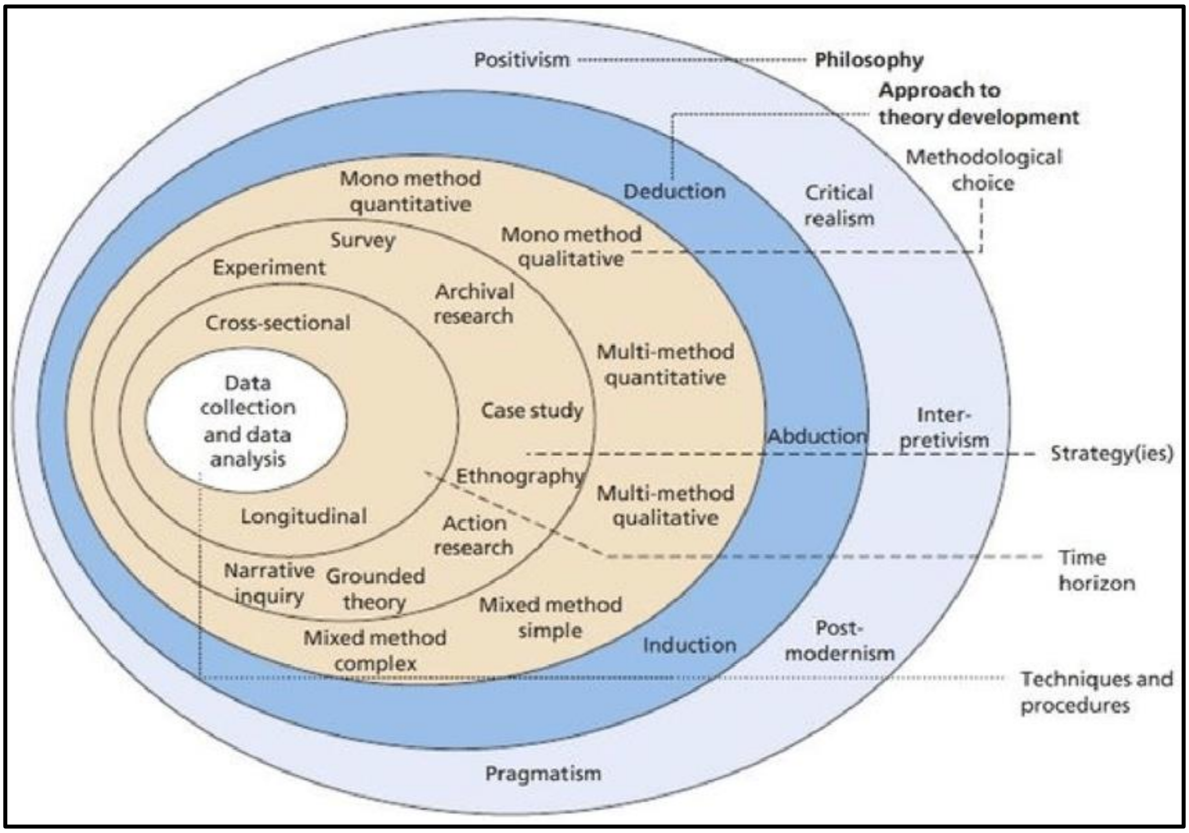
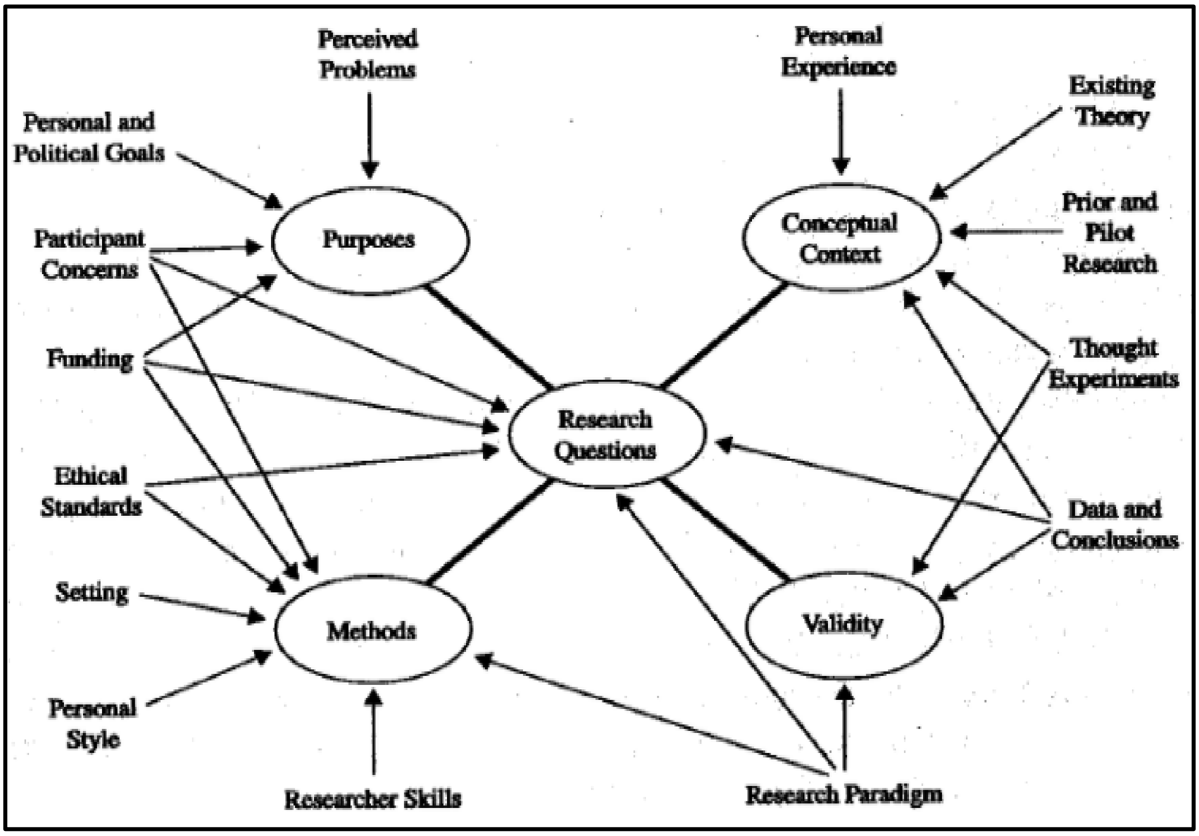


Figure 8: Contextual Factors Influencing Research (Adapted from Maxwell, 2005)



There are several research strategies such as experiment, case study, survey, archival research, ethnography, action research, grounded theory and narrative inquiry (Saunders *et al*, 2016). However, this research relies on literature or archival, survey and case study strategies which are carefully developed and structured to generate insights that have been generalised to some larger population (see Table 7). These strategies are explained in detail in the following subsections.

3.2.1 Literature Review

The literature review or archival research strategy has become more popular due to the information age which has seen the digitisation of data and creation of online archives (Saunders *et al*, 2016). Pivotal to note is the fact that, the efficiency and effectiveness of this research strategy is heavily inclined on the aptness of the research questions and the ability to access adequate and suitable documents (Saunders *et al*, 2016).

The advantages of using this strategy include among others the high degree of saving particular resources such as time and money, the unearthing of previously unknown facts, the ease of comparing collected data and literature as well as creating an unobtrusive sense among the respondents since the information is already in the public domain (Denscombe, 2010; Saunders *et al*, 2016). On the other hand, the disadvantages of this strategy include the fact that the data available in literature might not match the needs of the researcher, assess to such data may be challenging and expensive in the event that the data was collected for commercial purposes and the quality of the data might be poor (Denscombe 2010; Saunders *et al*, 2016).

As alluded to in the first chapter under the scope of the study, this research strategy relies on thesis reports, conference reports, company reports, government publications, books, journals, internet, abstracts, dictionaries and bibliographies to answer the first question and to achieve the first objective of this research. This is since some of these publications are written by experts, thus creating a likely hood of collecting valid information based on authenticity, representativeness, meaning and credibility (Scott, 1990). Moreover, this research adopts the CRAAP test (Appendix A) and the Metasynthesis approach (see CASP analysis, Table 11) to ensure adequacy and suitability of literature or archival documents.

3.2.2 Survey

According to Denscombe (2010), surveys measure some facets of a social fact or trend as well as gathering facts in order 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. Without a doubt, this strategy is used as a basis to answer the second question and to achieve the second objective of this research.

The survey strategy is closely related to a deductive research approach and is usually used to answer 'what', 'who', 'where', 'how much' and 'how many' questions (Saunders *et al*, 2016). Saunders *et al* (2016), affirms that this strategy allows the researcher to gather and analyse quantitative data using descriptive and inferential statistics. Since descriptive statistics enables the researcher to describe and or compare variables numerically, the choice of statistics should be dependent on the research questions and objectives (Denscombe, 2010; Saunders *et al*, 2016). Inferential statistics on the other hand are highly valuable but require a greater appreciation of statistical knowledge which project researchers might not have (Denscombe, 2010).

3.2.3 Case Study

The case study strategy relies on one or a few cases of a certain phenomenon with the aim of providing a comprehensive account of events, relationships, experiences or processes taking place in that case (Denscombe, 2010). Amongst many other advantages, the main benefit of using a case study strategy is that it enables the holistic analysis of factors (Denscombe, 2010). However, the major critiquing point of the case study strategy is in relation to its credibility of generalisations made from its findings and thus the need for the researcher to demonstrate reasonably the extent to which the case is similar to or contrasts with other cases (Denscombe, 2010).

A single case study approach is adopted to achieve the third objective and to answer the third question of this research. This is since there are few asset managers that are actively using BIM in South Africa and that a single case study is more manageable than multiple cases. Case studies are one of the various qualitative and quantitative data collection methods available to a researcher (Atkinson, 2002). According to Yin (2014), a case study is a detailed research carried out within a realistic setting. The case study allows the researcher to gain real insights on how asset managers can effectively deal with BIM risks. This is since the case study addresses "how" and "why" type of research questions (Yin, 1994).

Meanwhile this section covered the research methodology adopted in this research to achieve the objectives and answer the research questions, the following section covers the data collection methods that enabled the researcher to gather information from potential respondents who are experts in the area under study.

3.3 Data Collection Methods

Pivotal to note when choosing data collection methods is the fact that decisions should be based on the usefulness of the method in practice rather than a method which is greater than others in absolute sense (Denscombe, 2010). Denscombe (2010:154) emphasises that choosing a method of data collection "is a matter of horses for courses". There are various data collection methods, but the focus of this research is on Metasynthesis, Questionnaires and Interviews (see Table 7).

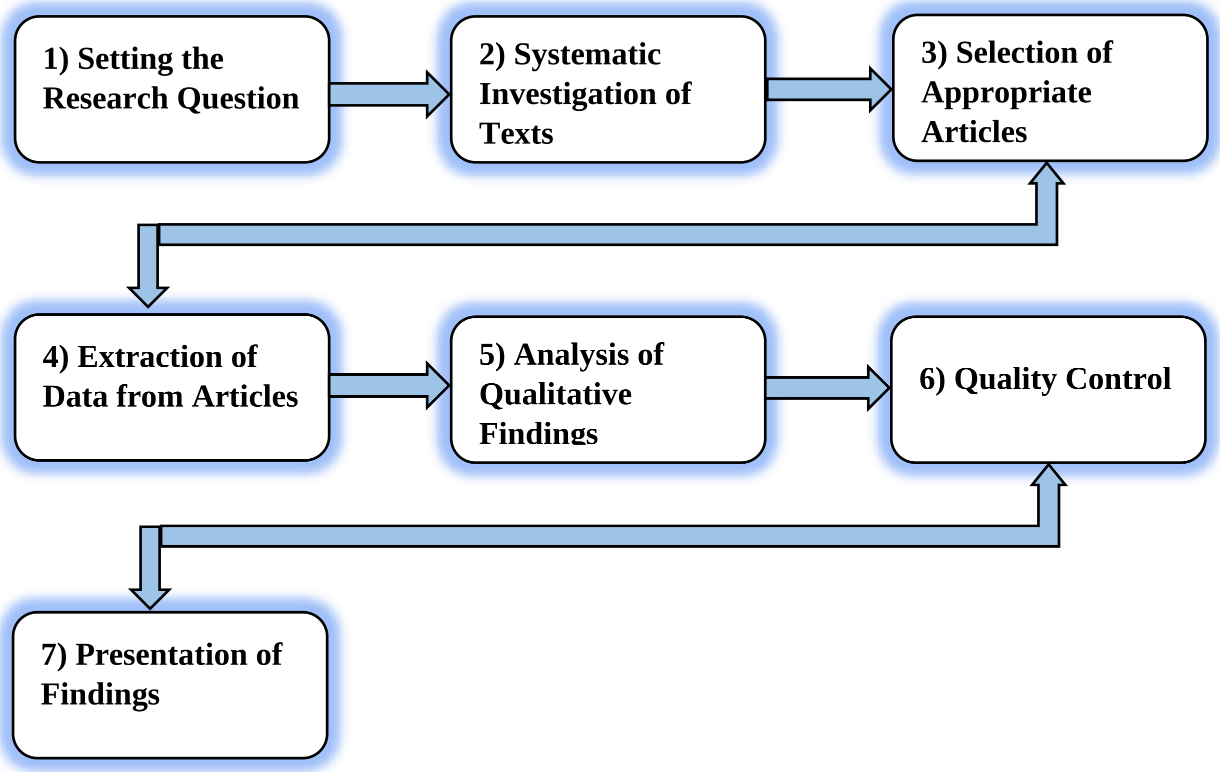
3.3.1 Metasynthesis

Since the aim of this research is to identify, categorize and analyze risks associated with implementation of BIM in maintenance of commercial buildings, the collection of such qualitative data is done through Metasynthesis. Metasynthesis is efficient in qualitative studies and for that reason has attracted attention from various researchers globally (Arbabi *et al*, 2017). To achieve meaningful and valid results, it is important to pay attention to every one of the researches that have been included in the meta-synthesis (Bondas and Hall, 2007; Arbabi *et al*, 2017). A researcher achieves synthesis by maintaining central concepts of each study and comparing them to other key concepts in the results (Poggenpoel and Myburgh, 2009).

According to Jones and Sharp (2007), Metasynthesis encompasses various approaches to synthesize numerous qualitative research studies within a field of study. It uses rigorous qualitative methods to synthesize existing qualitative studies to generate greater meaning through an interpretative process allowing for the classification of data to suit the needs of the researcher (Erwin *et al*, 2011; Arbabi *et al*, 2017). The process of searching and synthesizing information is what has made Metasynthesis a more preferred data collection method by many researchers.

The Metasynthesis process adopted in this research follows the steps illustrated in Figure 9 in their chronological order (Mirzamohammadi, 2006; Poggenpoel and Myburgh, 2009; Arbabi *et al*, 2017).

Figure 9: Metasynthesis Process



The Metasynthesis steps illustrated in Figure 9 are explained in detail in the following paragraphs.

❖ **Step one: Setting the research question (Framing)**

Involves the identification of a research question which can be refined during the synthesis to achieve the needs of the researcher. In coming up with the research question, a researcher needs to answer the what, who, when and how questions:

a) What is the research about?

   The research is about the assessment of risks associated with implementation of BIM in maintenance of commercial buildings.

b) Who is part of the research population?

   To achieve the first objective, the research relies on secondary sources of data such as authentic databases, scholarly articles, company reports, MSc and Doctoral theses and books.

c) From when is the data collected?

   The data collected is since around 2008 when BIM caught the attention of many researchers.

d) How is the data going to be collected?

- **Step two: Systematic investigation of texts (Searching)**

This can be done through reference list checking, citation checking, author searching and hand searches through back issues of selected journals. Issues addressed included deciding on using published or unpublished findings or both, development of a systematic process for selecting relevant studies and whether studies from different qualitative traditions should be analysed together.

Unquestionably, the world is experiencing the information age with the invention of internet. In any case, risk identification can be done using techniques such as brainstorming, use of a standard check list and use of past archival data or standard documents. The risk identification process in this research focuses more on the latter technique.

- **Step three: Selection of appropriate articles (Rating)**

This is important since some studies are better than others though a criterion should be used to determine whether a study is weak or not and whether the weak studies can be included or excluded from review. According to Atkins *et al* (2008), sample quality criteria can be based on whether:

  - The study is of a qualitative nature
  - The research question(s) are clearly stated
  - The approach is appropriate for the research question(s)
  - The qualitative approach is justified
  - The study context is described
  - The role of the researcher is described
  - The sampling method(s) is/are described
  - The sampling method(s) is/are appropriate to the research question(s)
  - The data collection method(s) is/are described
  - The data collection method(s) is/are appropriate to the research question(s)
  - The method(s) of analysis is/are clearly described
  - The analysis is appropriate for the research question(s)
  - The claims are supported by enough evidence

- **Step four: Extraction of data from articles**

During this stage, the researcher selects data relevant to the study being carried out from the articles in order to generate conclusions.

- **Step five: Analysis of qualitative findings (Synthesising)**

The Meta-ethnography approach will be used for synthesising data. According to Noblit and Hare (1988), this approach involves the reciprocal translational analysis whereby key themes or concepts on BIM risks are identified in each study. This is followed by refutational synthesis which notes and attempts to reconcile contradictions between identified themes and or concepts. Lastly, the lines of argument synthesis develop a general interpretation of the phenomena of interest that is grounded in the themes and or concepts of each study.

❖ **Step six: Quality control**

This stage involves the checking of the synthesised data to ensure that all facets of the Metasynthesis approach have been covered.

❖ **Step seven: Presentation of findings (Reporting)**

Reported things include the search strategy, number of studies at each stage of the search process and summary of studies selected for synthesis.

3.3.2 Questionnaires

Quantitative data can be collected using various methods which include questionnaire (see Appendix B) and interview surveys (see Appendix C), biophysical measurements, project records, service provider or facility data and facility assessments (Denscombe, 2010; Rowley, 2014). Due to the spread of the targeted population, and their expected ability to read and understand the subject matter, the achievement of the second objective and the answering of the second question is dependent on questionnaires. This is supported by CDC (2008) which asserts that questionnaires should be used when the available resources for data collection are limited, when gathering unique information including knowledge of a given topic and in the case were participants should be private.

Simply put, a questionnaire is a collection of two or more questions that are used to gather data about a certain phenomenon from individuals commonly referred to as respondents (CDC, 2008). A questionnaire should be user friendly in order to maintain high levels of response and accuracy (Adams and Cox, 2008; Rowley, 2014). Furthermore, factors such as the length and structure of the questionnaire and wording used in questions are key in ensuring high response levels and accuracy (Adams and Cox, 2008).

It is vital to give careful thought during the designing of a questionnaire as this will impact not only data reliability and validity but also response rates (Adams and Cox, 2008; Saunders *et al*, 2016). Moreover, administration of the questionnaire will have an impact on the design. According to Saunders *et al* (2016), questionnaires are broadly classified into self-completed and interviewer completed. While self-completed questionnaires can be administered through the internet, postal services and delivery and collection services, interviewer-completed questionnaires can be administered through telephone and face-to-face means.

In gathering data, questionnaires are structured to collect both facts and opinions about the risks of implementing BIM in maintenance of commercial buildings. As earlier mentioned under subsection 3.2.2, this research relies on a web-based questionnaire (Google Forms) for collection of data. While the response rate of this method cannot be guaranteed, the other limitation that can also accompany this method is the lack of insight knowledge about BIM and willingness by the respondents which may result in distorted data collection. It is highly likely and normal for target respondents to refuse to co-operate (Denscombe, 2010). CDC (2008) suggested that communicating the value of a questionnaire and consequently the findings of the research, follow ups and incentivising respondents are ways that can be adopted to increase response rates. The researcher preserved maximum ethical considerations to ensure that the response rate was high (66%).

3.3.3 Interviews

Saunders *et al* (2016:388) define an interview as “a purposeful conversation between two or more people, requiring the interviewer to establish rapport and ask concise and unambiguous questions, to which the interviewee is willing to respond and to listen attentively.” Many scholars agree that there are various categories used to differentiate interviews but for the purpose of this research, interviews are categorised as structured, semi-structured and unstructured or in-depth.

According to Adams and Cox (2008), interviews are time consuming in nature and as such, proper planning is required. It is also critical to note that interviews are key when a researcher seeks to obtain in-depth information on a research area that might otherwise be gathered on a questionnaire (Mathers *et al*, 1998; Adams and Cox, 2008). Alshenqeeti (2014) is of the view that, researchers should use techniques such as not using questions that are leading in nature, striving to make notes during the interview session as opposed to dependence on recording machines, making an effort to conduct pilot interviews before actual interviews and allowing the interviewee to summarise their points in order to maintain the effectiveness and efficiency of the interview method.

Easwaramoorthy and Zarinpoush (2006) are of the view that, the interviewing process generally begins with an introductory session, followed by a background session. Thirdly, a session on general questions about the research area and then the addressing of key issues. Lastly, there is need for a rounding off session which sums up all the major issues highlighted during the interview (Adams and Cox, 2008).

As mentioned under subsection 3.2.3, data collection through case study can be done through various methods which include interviews. Interviews are better utilised as a data collection method when they are applied to the exploitation of more complex and subtle phenomena (Mathers *et al*, 1998; Easwaramoorthy and Zarinpoush, 2006; Denscombe, 2010). In answering the third research question, the two interview respondents are selected purposively due to their high levels of understanding and experience working with 3D technology and BIM. This allows the researcher to gain deep insights on various ways of dealing with BIM risks.

The major advantage of using interviews is that both the interviewer and interviewee can seek further clarification in grey areas. However, the disadvantages of interviews are that they are time consuming in nature both to set up and carry out and the data analysis tends to be difficult since non-standard responses are produced (Easwaramoorthy and Zarinpoush, 2006; Denscombe, 2010; Alshenqeeti, 2014).

While this section focused on the data collection methods, the next section covers the targeted population of the research and provides justification thereof.

3.4 Target Population

The research focused on property owners, asset managers, BIM practitioners, construction sector risk advisors, and academics who have BIM knowledge and have carried out research on BIM. Due to insufficient information on the research population, the study relies on non-probability sampling as will be detailed in the next section.

The following section gives an overview of sampling techniques, justifying the techniques adopted in this research.

3.5 Sampling

According to Denscombe (2010), the fundamental principle behind sampling is the possibility of producing accurate findings without necessarily collecting data from every member or census of the target population. Pivotal to note is the fact that collecting data from a census does not necessarily provide more useful results than collecting from a sample representative of the whole population (Barnett, 2002; Saunders *et al*, 2016). According to Saunders *et al*

(2016), sampling is a better preference to census in the case of impracticability to survey an entire population, budget and time constraints.

According to Denscombe (2010), samples can either be representative whereby they are linked to larger surveys and with quantitative data or exploratory which are linked to qualitative data and small-scale research. “An exploratory sample is used as a way of probing relatively unexplored topics and as a route to the discovery of new ideas or theories” (Denscombe, 2010:24). In this research, representative sampling is used during the administering of questionnaires whereas exploratory sampling was used during interviews.

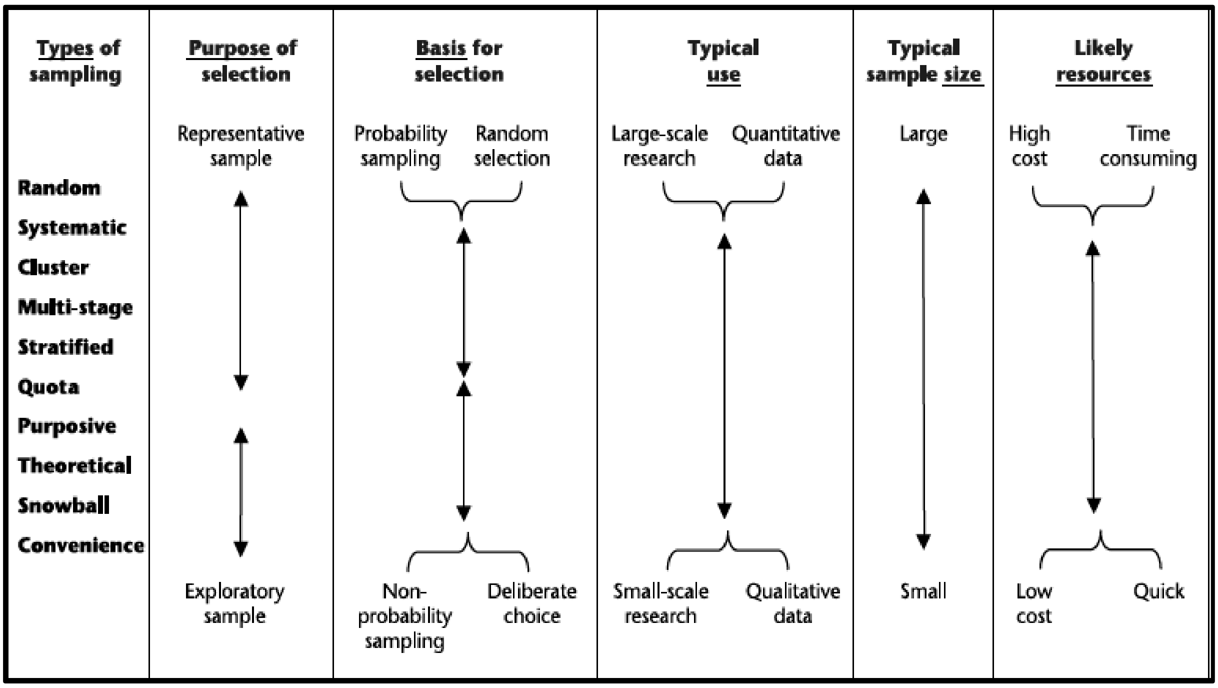
According to Denscombe (2010), sample size is basically calculated using three approaches which are statistical, pragmatic and cumulative. The statistical approach best suites large-scale surveys and probability sampling techniques while the pragmatic approach is used when a researcher is trying to contain costs as well as in the event of the researcher facing challenges in meeting conditions needed for sample size calculation in the statistical approach. Lastly, the cumulative approach is associated with small-scale qualitative research and the researcher continues to increase the size of the sample until a point where the information collected is enough to an extent that no more benefits are derived from adding more information.

Determining the sample size is very important in the research process since a trade-off exists between sample precision and considerations of optimal resource use. “In practice, the complexity of the competing factors of resources and accuracy means that the decision on sample size tends to be based on experience and good judgment rather than relying on a strict mathematical formula” (Hoinville *et al,* 1985:73).

In any case, there are two basic approaches in sample selection, that is, probability and non-probability sampling. Probability sampling is based on statistical theory and is linked to large-scale surveys where the research population is known in terms of number and characteristics (Denscombe, 2010). On the contrary, non-probability approaches are not based on random selection of the sample and are used when it is challenging or undesirable for researchers to select their sample based on pure chance. According to Denscombe (2010), one of the many reasons why researchers choose non-probability approaches is when there is no enough information about the population such as who or how many people make up the research population in order to undertake probability sampling. It is for this reason therefore that this research relies on non-probability sampling.

Denscombe (2010), identifies various probability and non-probability sampling techniques as shown in Figure 10. This research focuses on non-probability sampling techniques, that is purposive and snowball sampling. Purposive sampling allows the researcher to target respondents that are relevant to the study and have knowledge about the research area. This form of sampling is advantageous in the sense that it allows the research to horn in on respondents believed to be critical within the research area. Snowball sampling on the other hand involves a process whereby the researcher is continuously referred from one respondent to another. The major advantages are that the accumulation of respondents is quicker due to the multiplier effect and the researcher approaches the next respondent with reference from the previous respondent thereby enhancing credibility as opposed to approaching a new respondent without reference (Denscombe, 2010).

Figure 10: Summary of Sampling Techniques (Adapted from Denscombe, 2010)



As summarised in Figure 10, the objective of this section is sampling. The types of sampling chosen in this research are purposive and snowball, thereby making the sample exploratory in nature. The basis for selection of the sample is nonprobability and or deliberate choice since the research is typically small-scale with a small sample size while bearing in mind that the research is for the fulfilment of a degree thus must be completed within a limited time frame and budget.

The following section deals with the various data analysis techniques, justifying the options that are adopted in this research.

3.6 Data Analysis

Analysis is important in gaining a better understanding of the collected data (Saunders *et al*, 2016). Meanwhile, techniques such as graphs, tables and statistics can be used by researchers to explore, present, describe and examine relationships and trends during quantitative analysis, qualitative analysis uses techniques such as thematic and template analysis, narrative, discourse and content analysis (Saunders *et al*, 2016). According to Creswell and Clarke (2007), qualitative and quantitative data analysis follows five main stages as shown in Table 6.

Table 6: Stages of data analysis (Adopted from Creswell and Clarke, 2007)

Stages	Quantitative Data	Qualitative Data
Stage 1 **Preparation of Data**	Data coding, categorising and checking	Cataloguing of text and loading to software
Stage 2 **Initial Exploration of Data**	Looking for obvious trends and or correlations	Find out recurrent themes or issues
Stage 3 **Analysis of Data**	Linking statistical tests to research questions	Data coding and comparison
Stage 4 **Data Presentation**	Using tables, figures and written interpretations of statistical findings	Using quotes, figures and tables as well as written interpretation of findings
Stage 5 **Data Validation**	Use of external benchmarks, consistency and comparisons with alternative explanations	Triangulation of both the data and method, member validation and comparison with alternative explanations.

3.6.1 Qualitative Data – NVivo

Although data collection is not easy, the presentation and creation of meaning from the data is neither easy as well. The software package used in data analysis in this research (NVivo) will mainly help with data storage and management, data searching and retrieval, coding, development and testing of theory as well as writing of the thesis (Lacey and Luff, 2007; NVIVO, 2019).

For better and easier data analysis there is need for coding (Smith and Davies, 2010). Simply put, coding involves the organization and categorisation of data (Charmaz, 2006). Coding is achieved using codes that provide a sorted and synthesised summary of the collected data

(Charmaz, 2006). NVivo is used to answer the first research question and to achieve the first research objective.

3.6.2 Quantitative Data – Risk Matrix

The risk matrix is used in answering the second research question and to achieve the second objective. According to Ristic (2013), the ranking of risks is dependent on the risk matrix which ranks consequences and probabilities. It is key, however, to note that although risk matrices are user friendly, they may result in liability issues that may provide an illusional security sense (Dumbrava and Iacob, 2013). However, Ristic (2013) is of the view that effective risk matrices must have features that include simplicity to use and understand. The definition of the terms to be used during risk analysis are as follows:

a) Probability **(P)**: The likelihood that a risk or opportunity will occur (on a scale from 1 to 5 with 5 being the highest).
b) Impact **(I)**: The impact of the risk if it occurs (scale from 1 to 5 with 5 being the highest).
c) Risk Score **(RS)**: Determined by multiplying probability and impact (scale from 0 to 1 with 1 being the riskiest).

3.6.3 Qualitative Data – NVivo

As has been noted in section 3.6.1, NVivo is key in data presentation and the creation of meaning henceforth. Therefore, NVivo is also unquestionably used in the analysis of responses obtained during the interviews to answer and achieve the third question and objective respectively.

Without reservation, this study follows the five stages coined by Creswell and Clarke (2007) in analysing both qualitative and quantitative data in the following chapter. Table 7 provides a summary of the research methodology adopted in this research. Within this table, research objectives and questions are aligned to their respective research method, data collection and analysis technique.

Table 7: Summary of research methodology (Author)

Research Objectives	Research Questions	Research Method	Data Collection Technique	Data Analysis Technique
Objective 1 To identify and categorise the risks associated with BIM implementation in maintenance of buildings.	Question 1 What are the risks and their categories associated with BIM implementation in maintenance of buildings?	Literature Review	Metasynthesis	Qualitative Data – NVivo
Objective 2 To analyse the risks associated with BIM implementation in maintenance of buildings.	Question 2 What are the effects of these risks in maintenance of buildings?	Survey	Questionnaires	Quantitative Data – Risk Matrix
Objective 3 To provide recommendations of dealing with BIM risks in maintenance of commercial buildings in South Africa.	Question 3 How can the maintenance team effectively deal with BIM risks in maintenance of commercial buildings in South Africa?	Case Study	Interviews	Qualitative Data - NVivo

3.7 Summary

This chapter introduced the research methodology followed in this study. The sampling methods and target population sections were preceded by the data collection methods section. Without any reservation, data collection is pointless if the analysis is not effective therefore section 3.6 was devoted to explaining how the collected data is presented and analysed to create meaning. The next chapter deals with the presentation and analysis of the findings. This chapter is important as it answers the questions set out in the first chapter.

4.0 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 gathering techniques employed in this research as alluded to in the previous chapter. The first one is dealt with in section 4.2. This technique aims at identifying the various risks associated with BIM through archival research and Metasynthesis. Following this is the risk analysis in section 4.3, which aims at determining those risks that will most likely occur and have a higher impact in maintenance of commercial buildings. This analysis involves the distribution of questionnaires to various BIM experts for risk rating purposes. Lastly, in section 4.4, the recommendations for dealing with such risks are presented through a case study approach, whereby the risks identified in 4.3 are discussed through interviews with experts that have a building moving towards BIM implementation in maintenance.

4.2 Identification and Categorisation of Risks

In order to identify and categorise BIM risks, the Metasynthesis approach is used to answer the first 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 achieve the first objective.

Step one: Research question

As alluded to in chapter three, the first step involves the identification of a research question through the answering of the what, who, when and how questions. Thus, the research question is;

What are the risks and their categories associated with BIM implementation in maintenance of buildings?

Step two: Systematic investigation of texts (searching)

In keeping with ethical standards, this research is limited to authentic search engines including those shown in table 8.

Table 8: Search Engines used in Data collection

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

The keywords used in searching for information on the risks and their categories are shown in Table 9.

Table 9: Keywords used in searches of BIM risks

Building Information Modelling/BIM
Building Maintenance
Risk Management
Building Information Modelling and Building Maintenance
Building Information Modelling Risks

Step three: Selection of appropriate articles (rating)

As alluded to in chapter three under data collection methods, some studies are better than others hence the need for screening bearing in mind that, a criteria should be used to determine whether a study is weak or not and whether the weak studies can be included or excluded from review. During the screening process, the retrieved data is subjected to a CRAAP test (refer to Appendix A) to ensure that it meets all the required standards. Furthermore, the selection criteria used to compile the articles used in Metasynthesis is summarized in Table 10.

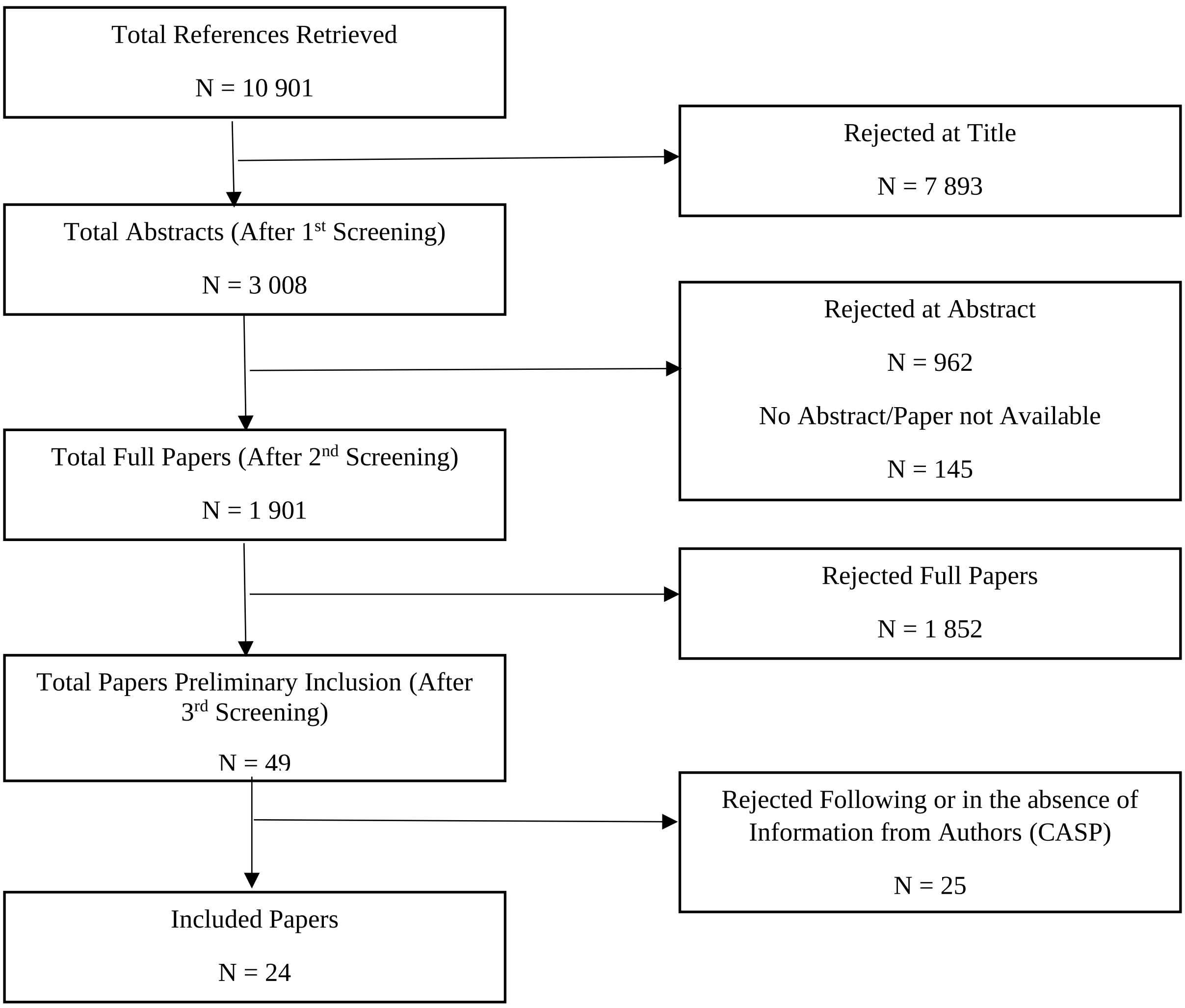
Table 10: Metasynthesis Selection Criteria

❖ Language Used in Searches - English
❖ Publication Timeline – 2008 - 2018
❖ Texts – Qualitative
❖ Resource Type – Thesis, Conference Proceedings, Company Reports, Government Publications, Books, Journals

The timeline selected in this process is based purely on the fact that research into BIM gained more attention since around 2008 when the concept was still relevantly new to the construction industry. This allowed the researcher to gain an extensive assessment of how BIM research has grown over time. Moreover, as alluded to in Chapter 3 (Table 7), the resources used to answer the first question are qualitative in nature as shown by the type of resources and Texts in Table 10.

The results of the review process are illustrated in Figure 11. A total of 10 901 references are initially retrieved and after the review process, 24 relevant references remained (also refer to Table 11). These remaining articles are incorporated into the research to identify risks associated with BIM implementation in the maintenance of buildings.

Figure 11: Data Review Process



The CASP method as alluded to in Chapter 3, analyses each of all the selected articles (that is the remaining articles after the 3rd screening shown in Figure 10 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 between 50% and 100% being selected for the study. Therefore, of the 49 articles that remained after the 3rd screening, a total of 25 articles were further screened using the CASP criteria as shown in Table 11.

Table 11: Critical Appraisal Skills Program (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 taken into account	Data analysis is described and appropriate for the research question	Claims are supported by sufficient evidence	How valuable is the research	**Total Score**
Ashcraft (2008)	9	8	9	8	9	9	10	8	8	7	**85%**
Azhar et al (2012)	8	8	9	7	9	10	10	10	7	10	**88%**
Rokooei (2015)	8	8	10	7	9	10	10	10	7	10	**89%**
Ghaffarianhoseini et al (2015)	8	8	9	7	9	10	10	10	7	10	**88%**
Eadie et al (2014)	10	6	6	9	8	7	8	8	6	7	**75%**
Azhar (2011)	8	9	7	6	10	9	7	6	9	10	**81%**
Chien et al (2014)	8	9	7	6	10	8	7	7	9	7	**78%**
Harris et al (2014)	8	9	7	6	9	8	7	7	10	7	**78%**
Tulenheimo (2015)	8	9	7	6	8	8	7	7	9	7	**76%**
Arayici et al (2017)	9	7	6	6	9	6	6	7	8	9	**73%**
Araszkiewicz (2015)	8	6	7	7	8	6	6	7	6	8	**69%**
Volk et al (2014)	8	9	8	7	6	6	6	7	6	10	**73%**
Zakaria et al (2013)	9	9	9	9	8	9	8	9	8	9	**87%**
Memon et al (2014)	9	8	9	9	7	6	8	7	6	8	**77%**
Alizadeh et al (2016)	10	9	9	8	8	7	8	9	6	8	**82%**
Alreshidi et al (2013)	9	8	9	7	8	6	10	8	9	8	**82%**
Eadie et al (2013)	7	6	10	6	6	8	9	9	7	6	**74%**
Migilinkas et al (2013)	9	7	9	9	8	9	9	8	7	8	**83%**
Kelly et al (2013)	8	8	7	7	9	8	6	6	9	8	**76%**
Kuiper and Dominik (2013)	6	6	6	6	10	8	7	7	6	7	**69%**
Cubitt and Coldwell (2014)	7	7	7	8	9	6	8	7	9	7	**75%**
Thomson and Miner (2010)	6	7	6	6	7	7	7	6	10	6	**68%**
Pinsent and Masons (2013)	8	7	8	8	6	7	9	8	7	8	**76%**
Cao et al (2017)	10	8	8	9	6	7	6	8	7	6	**75%**

Singh et al (2011)	5	4	5	4	5	3	4	5	4	4	43%
Miettinen and Paavola (2014)	6	5	4	3	5	4	5	4	4	4	44%
Zakaria et al (2013)	4	5	3	5	4	3	4	5	5	4	42%
Jin et al (2017)	5	4	4	5	4	3	2	5	6	5	43%
Arensman and Mehmet (2012)	5	3	4	4	5	6	4	5	4	6	46%
Lawrence et al (2014)	6	5	4	5	4	5	4	4	5	6	48%
Elmualim and Gilder (2014)	3	4	5	4	5	4	5	3	4	5	42%
Rekola et al (2010)	5	5	4	4	4	6	5	6	4	5	48%
Gu and London (2010)	4	6	5	4	4	5	4	3	4	5	44%
Ham and Golparvar-Fard (2014)	6	6	5	5	4	3	4	5	2	5	45%
Owen et al (2017)	4	2	4	5	6	4	4	5	2	6	42%
Becerick-Gerber and Kensek (2010)	6	5	7	3	4	2	6	5	4	4	46%
Khosrowshahi and Arayici (2012)	3	4	5	4	5	4	5	4	5	4	43%
Hancock et al (2017)	5	4	4	6	4	5	4	6	5	4	47%
Jiang et al (2017)	4	5	5	5	4	5	4	5	4	5	46%
Olantunji (2015)	5	4	3	4	4	5	6	4	5	5	45%
Chong et al (2017)	6	4	4	5	5	4	4	5	4	6	47%
Kiprotich (2014)	5	4	5	4	4	5	5	5	5	5	47%
Azhar et al (2017)	5	4	5	5	6	5	6	5	4	4	49%
Alwash et al (2017)	4	6	5	6	5	4	5	5	4	4	48%
Steel et al (2012)	4	4	4	5	4	3	5	4	4	3	40%
Brewer et al (2015)	3	5	4	4	5	6	5	5	4	5	46%
McArthur (2015)	5	4	4	5	4	4	5	4	5	4	44%
Porwal and Hewage (2013)	4	5	6	4	4	5	4	4	5	4	45%
Dossick and Neff (2010)	4	5	4	4	3	5	2	4	6	4	41%

Step four: Extraction of data from articles

As has been noted in chapter three, data relevance is key during this stage. As such, a total of 24 articles remained after the scrutinizing and screening process. These articles are analysed during this stage to extract BIM risks in order to answer the research question asked during the first step. The collected data is then coded and classified according to the appropriate risk category.

Step five: Analysis of qualitative findings (synthesising)

During this stage, a thematic review of BIM risk findings is performed as has been noted in chapter three. This involves the classification and coding of common sources as well as analysis using the NVivo qualitative research software (see Appendices C and D).

Step six: Quality control

Acknowledging the fact that quality control is very important in meta-synthesis, the researcher selects reliable articles after the screening process shown in Figure 10. The following final section presents findings of the study.

Step seven: Presentation of findings (reporting)

The goal of this stage is to answer the question asked during step one. From the Metasynthesis process, various risks and their categories are identified, and these have been summarized in Table 12. Appendices C and D show the data analysis results captured from NVivo. Since many scholars generally agree that the categorization of BIM risks should be done in a certain way, the identified risks in this research followed the same categorization pattern. Table 12 shows the various risks that are identified in literature and their respective categories, with the respective reference sources for each risk type also provided in the table.

Table 12: Risk Types and Categories

Risk Category	**Risk Type**	**Resources**
Technical (A)	Insufficient or incorrect building information (A1)	(Ashcraft, 2008; Thompson and Miner, 2010; Azhar, 2011; Chien *et al.*, 2014; Rokooei, 2015)
	Imperfect BIM software (A2)	(Azhar *et al.*, 2012; Kelly *et al.*, 2013; Chien *et al.*, 2014; Eadie *et al.*, 2014; Memon *et al.*, 2014)
	Rapid update of BIM technologies (A3)	(Pinsent and Masons, 2013; Zakaria *et al.*, 2013; Chien *et al.*, 2014; Harris *et al.*, 2014; Memon *et al.*, 2014; Ghaffarianhoseini *et al.*, 2015; Rokooei, 2015; Tulenheimo, 2015)
	Poor adoption of BIM technologies (A4)	(Kuiper and Dominik, 2013; Zakaria *et al.*, 2013; Eadie *et al.*, 2014; Araszkiewicz, 2015)
	Data loss during BIM Industry Foundation Classes (BIM-IFC) file exchange (A5)	(Azhar, 2011; Pinsent and Masons, 2013; Zakaria *et al.*, 2013; Chien *et al.*, 2014; Harris *et al.*, 2014; Memon *et al.*, 2014; Ghaffarianhoseini *et al.*, 2015; Rokooei, 2015; Tulenheimo, 2015)
Financial / Economic (B)	Illusion of maintenance cost estimation (B1)	(Migilinkas *et al.*, 2013; Eadie *et al.*, 2014; Memon *et al.*, 2014; Alizadeh *et al.*, 2016)
	Labour cost increase in training (B2)	(Alreshidi *et al.*, 2013; Chien *et al.*, 2014; Harris *et al.*, 2014; Araszkiewicz, 2015; Rokooei, 2015)
	Long period of BIM return on/of investment (B3)	(Migilinkas *et al.*, 2013; Chien *et al.*, 2014; Memon *et al.*, 2014; Tulenheimo, 2015)

	High initial investment costs (B4)	(Alreshidi *et al.*, 2013; Migilinkas *et al.*, 2013; Rokooei, 2015; Alizadeh *et al.*, 2016)
Legal (C)	Illegal changes in the model (C1)	(Azhar, 2011; Azhar *et al.*, 2012; Memon *et al.*, 2014; Volk *et al.*, 2014; Alizadeh *et al.*, 2016)
	Duty of Care/data security (C2)	(Ashcraft, 2008; Thomson and Miner, 2010; Alreshidi *et al* 2013; Pinsent and Masons, 2013)
	Professional terms of engagement (C3)	(Thomson and Miner, 2010; Kelly *et al.*, 2013; Migilinkas *et al.*, 2013; Pinsent and Masons, 2013; Chien *et al.*, 2014; Volk *et al.*, 2014)
	Information and reliance (C4)	(Ashcraft, 2008; Azhar, 2011; Eadie *et al.*, 2013; Pinsent and Masons, 2013; Harris *et al.*, 2014)
	Different BIM models (C5)	(Kuiper and Dominik, 2013; Pinsent and Masons, 2013; Chien *et al.*, 2014; Cubitt and Coldwell, 2014; Memon *et al.*, 2014; Volk *et al.*, 2014)
	Duplication and the risk of ambiguity (C6)	(Azhar, 2011; Kelly *et al.*, 2013; Migilinkas *et al.*, 2013; Pinsent and Masons, 2013; Alreshidi *et al.*, 2014; Rokooei, 2015; Alizadeh *et al.*, 2016)
	Standardize the BIM process (C7)	(Ashcraft, 2008; Thomson and Miner, 2010; Azhar, 2011; Pinsent and Masons, 2013; Chien *et al.*, 2014; Harris *et al.*, 2014; Memon *et al.*, 2014)
	Coordination and amendment of the BIM model (C8)	(Eadie *et al.*, 2013; Migilinkas *et al.*, 2013; Pinsent and Masons, 2013; Cubitt and Coldwell, 2014; Volk *et al.*, 2014; Araszkiewicz, 2015)
	Ownership conflicts among stakeholders (C9)	(Ashcraft, 2008; Azhar, 2011; Thomson and Miner, 2010; Cubitt and Coldwell, 2014)
	Intellectual property protection (C10)	(Azhar, 2011; Azhar *et al.*, 2012; Kuiper and Dominik, 2013; Chien *et al.*, 2014; Harris *et al.*, 2014; Rokooei, 2015; Alizadeh *et al.*, 2016)
	Damages caused by human errors (C11)	(Eadie *et al.*, 2013; Kelly *et al.*, 2013; Migilinkas *et al.*, 2013; Alreshidi *et al.*, 2014; Chien *et al.*, 2014; Memon *et al.*, 2014; Araszkiewicz, 2015)
	Changes in laws and regulations (C12)	(Thomson and Miner, 2010; Kuiper and Dominik, 2013; Cubitt and Coldwell, 2014; Eadie *et al.*, 2014; Volk *et al.*, 2014; Rokooei, 2015)
	Nonstandard contract form (C13)	(Azhar, 2011; Alreshidi *et al.*, 2013; Kelly *et al.*, 2013; Chien *et al.*, 2014; Harris *et al.*, 2014; Memon *et al.*, 2014)
	Lack of established case law (C14)	(Kuiper and Dominik, 2013; Alizadeh *et al.*, 2016; Rokooei, 2015; Volk *et al.*, 2014; Migilinkas *et al.*, 2013; Kelly *et al.*, 2013; Azhar *et al.*, 2012)
Management (D)	Lack of skilled personnel/BIM expertise	(Alreshidi *et al.*, 2013; Zakaria *et al.*, 2013; Cao *et al.*, 2014; Chien *et al.*, 2014; Memon *et al.*,

	(D1)	2014)
	Unclear specifications (D2)	(Eadie *et al.*, 2013; Kuiper and Dominik, 2013; Araszkiewicz, 2015; Ghaffarianhoseini *et al.*, 2015; Tulenheimo, 2015; Arayici *et al.*, 2017)
	Theft and vandalism of BIM information (D3)	(Kelly *et al.*, 2013; Chien *et al.*, 2014; Harris *et al.*, 2014; Rokooei, 2015; Arayici *et al.*, 2017)
	Poor coordination (D4)	(Azhar *et al.*, 2012; Zakaria *et al.*, 2013; Memon *et al.*, 2014; Rokooei, 2015; Tulenheimo, 2015)
	Cultural barriers towards adopting new technology (D5)	(Migilinkas *et al.*, 2013; Volk *et al.*, 2014; Ghaffarianhoseini *et al.*, 2015; Cao *et al.*, 2017)
	The difficult transition of business procedures (D6)	(Alreshidi *et al.*, 2013; Kelly *et al.*, 2013; Chien *et al.*, 2014; Harris *et al.*, 2014; Memon *et al.*, 2014; Araszkiewicz, 2015; Arayici *et al.*, 2017)
	The difficult transition of management pattern (D7)	(Kuiper and Dominik, 2013; Zakaria *et al.*, 2013; Volk *et al.*, 2014; Araszkiewicz, 2015)
	Lack of knowledge of BIM implementation (D8)	(Alreshidi *et al.*, 2013; Eadie *et al.*, 2013; Memon *et al.*, 2013; Migilinkas *et al.*, 2013; Eadie *et al.*, 2014; Rokooei, 2015; Tulenheimo, 2015)
	Resistance to change from people (D9)	(Kelly *et al.*, 2013; Chien *et al.*, 2014; Harris *et al.*, 2014; Araszkiewicz, 2015; Rokooei, 2015; Arayici *et al.*, 2017; Cao *et al.*, 2017)
	Insufficient commitment of top management (D10)	(Eadie *et al.*, 2013; Kuiper and Dominik, 2013; Zakaria *et al.*, 2013; Ghaffarianhoseini *et al.*, 2015)
	No Research and Development unit for new technology (D11)	(Alreshidi *et al.*, 2013; Eadie *et al.*, 2014; Memon *et al.*, 2014; Volk *et al.*, 2014; Araszkiewicz, 2015; Rokooei, 2015; Tulenheimo, 2015)

For better analysis in section 4.3, the various risks identified through Metasynthesis are coded as shown in Table 12. The four identified risks categories are coded as A, B, C and D. The risk types for category A are coded as A1, A2, A3, A4 and A5. Followed by the risk types for category B which are coded as B1, B2, B3, and B4. Subsequently, the risk types for category C are coded as C1, C2, C3, C4, C5, C6, C7, C8, C9, C10, C11, C12, C13 and C14. Finally, the risk types for category D are coded as D1, D2, D3, D4, D5, D6, D7, D8, D9, D10 and D11.

The next section deals with crux of this research, which is risk analysis. The section provides an analysis of the risks identified in this section in order to determine those BIM risks that have a high probability of occurrence and impact in the maintenance of commercial buildings. This section is the turning point for this research since risk identification is meaningless without analysis to determine those critical risks that require attention to ensure successful maintenance of buildings when using BIM.

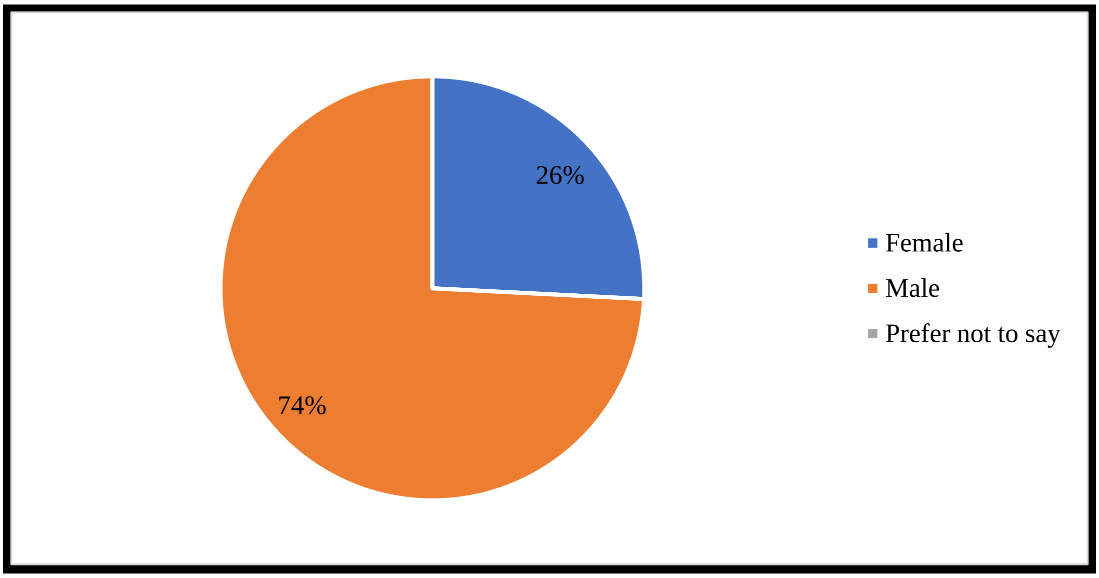
4.3 BIM Risk Analysis

4.3.1 Demographic and Overview Questions Analysis

As mentioned to in the previous section, this section deals with the essential part of this research. The section deals with the presentation and most importantly, the analysis of the online survey findings to determine those risks that require attention when implementing BIM in maintenance of buildings. Since nonprobability sampling is adopted in this research as referred to in section 3.5, a total of 58 respondents were emailed, 11 of these emails bounced back, leaving a total of 47 that were successfully delivered. Out of the 47 successfully delivered emails, 31 were responded to thereby giving a 66% response rate.

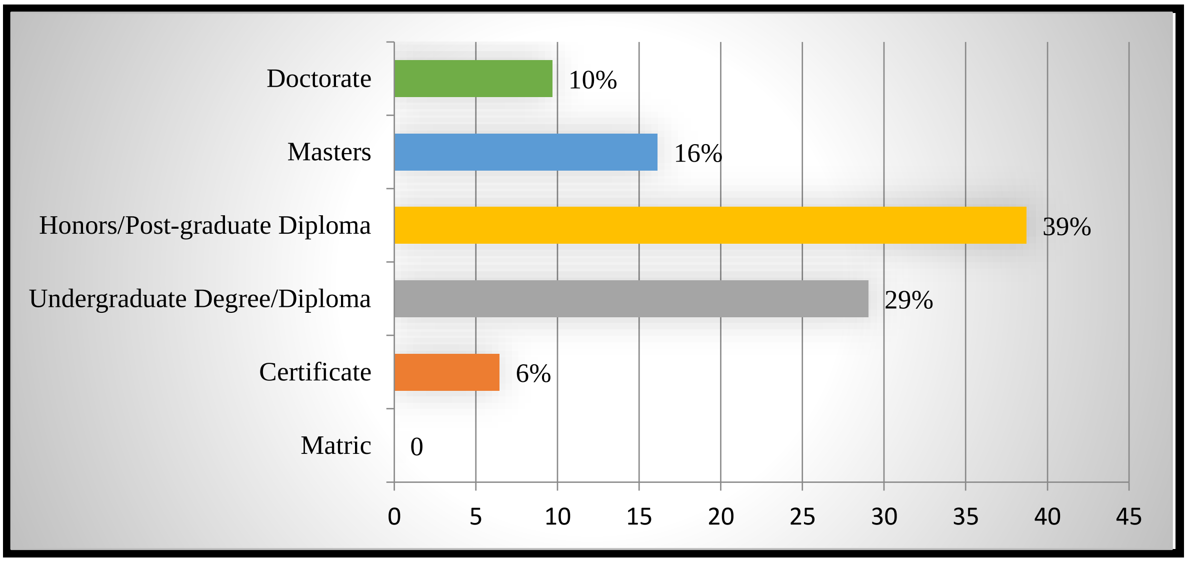
The demographic information of the respondents is summarized in Figures 12, 13, 14 and 15. 74% of the respondents are male while females contributed the remainder (26%) as shown in Figure 12. The 26% female respondents provide a fair representation given the fact that the built environment industry is generally regarded as being male dominated.

Figure 12: Respondents Gender Profile



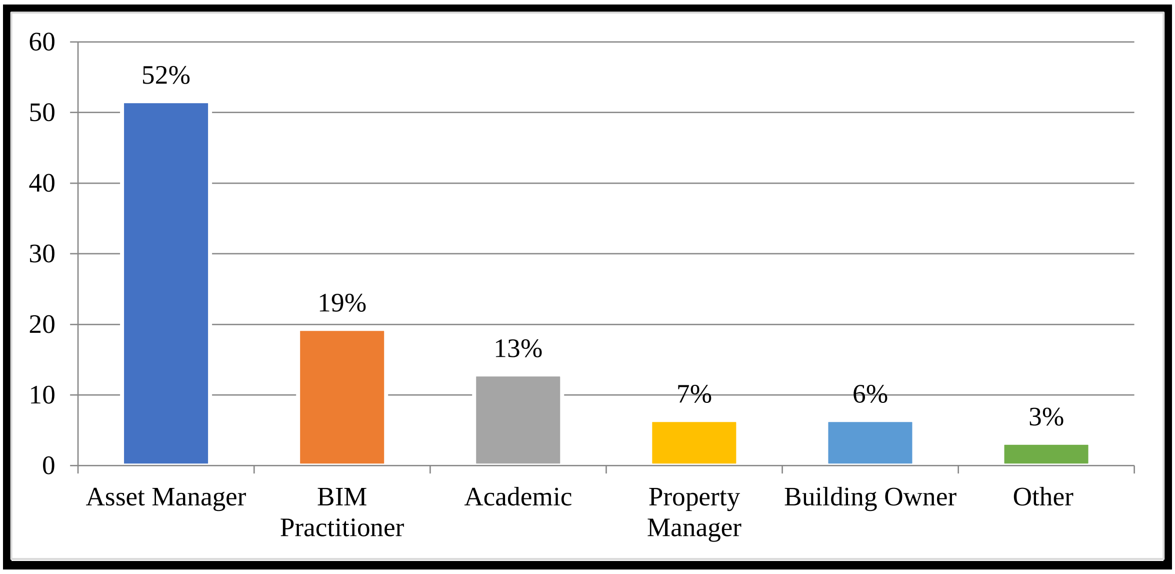
Equally important is the need to determine the levels of academic achievements for the respondents to determine whether there is any form of relationship between academic achievement and BIM knowledge. 10% of the respondents hold PhD qualifications and these are all academic respondents. 16% have an MSc degree while 39% have an Honors degree and or postgraduate diploma. The remaining 35% is made up of those respondents who either have a certificate or an undergraduate degree and or diploma. The findings are summarised in Figure 13 and clearly reveal that most of the respondents are highly qualified from an academic perspective therefore chances of them knowing about the developments of BIM are expected to be high.

Figure 13: Respondents Level of Education



The responses mainly emanate from Asset Managers (52%), BIM Practitioners (19%) and Academics (13%) with Property Managers (7%), Building Owners (6%) and Electrical Design Engineers (3%) also sharing their views as shown in Figure 14.

Figure 14: Respondents Professions



The respondents' industry experience ranges from less than two years to more than ten years, and all respondents have more than two years' experience as presented in Figure 15. 68% of the respondents have experience in excess of ten years while 26% of the respondents have experience between five and ten years while the last 6% of the respondents have experience between 2 and five years. This is an indication that the respondents have a much greater understanding of BIM.

Figure 15: Respondents Experience Levels

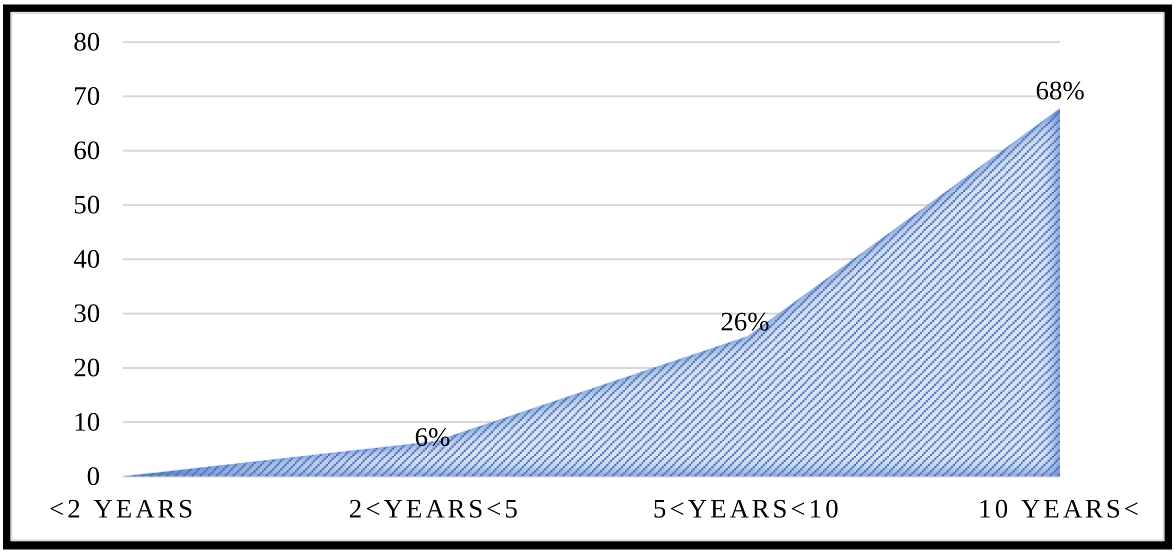
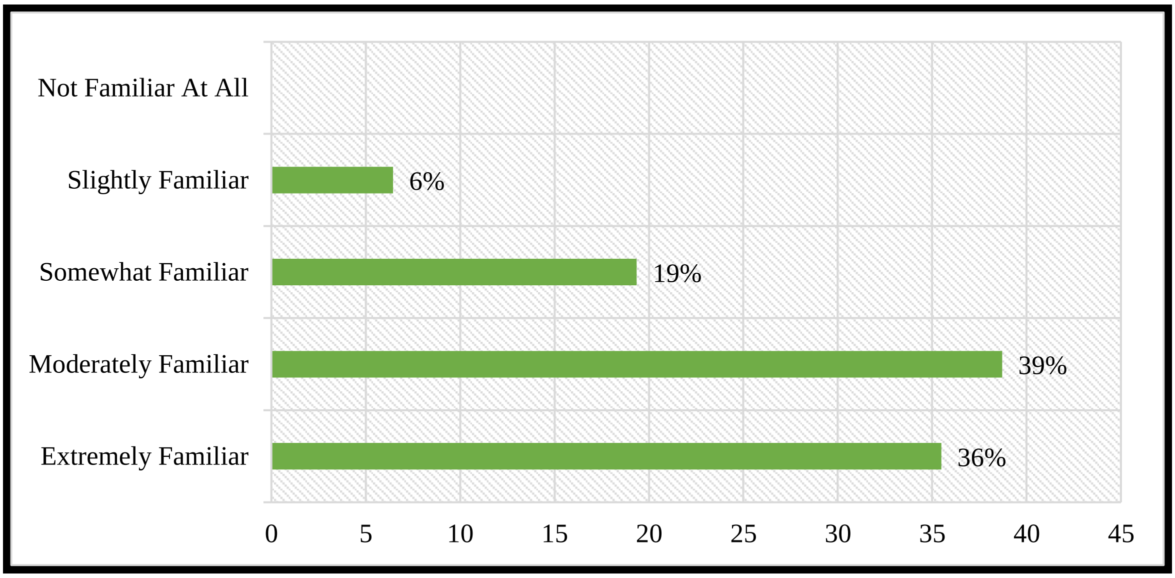


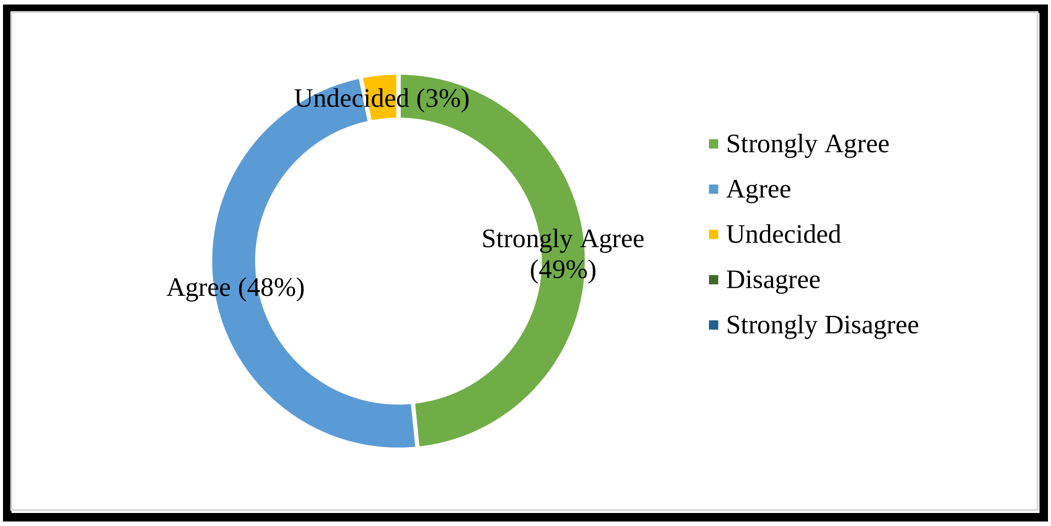
Figure 16 shows that a combined 75% of the respondents are highly familiar with BIM while the remaining 25% have minimal familiarity. The fact that the responses are coming from respondents that are highly familiar with BIM strongly support the findings of the risk analysis.

Figure 16: Respondents Familiarity with BIM



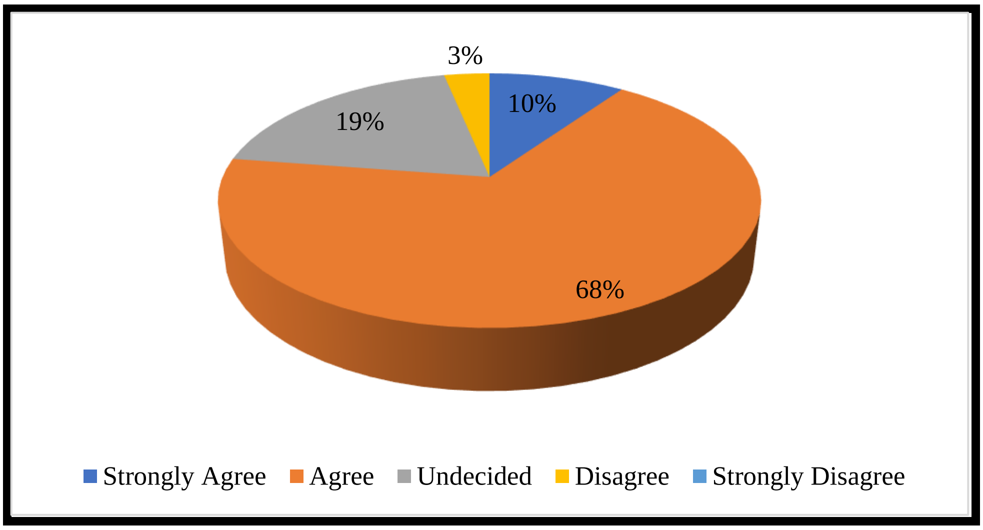
The respondents range from those who have not yet used BIM to those who have fully integrated it within their workflow. Most of the respondents agree that BIM is revolutionizing the built environment as shown in Figure 17. These findings support the efforts made by most international governments in adopting BIM and making it mandatory in their built environments as alluded to in the first chapter of this research.

Figure 17: Respondents Views on BIM Revolutionizing the Built Environment



Asset managers and building owners should prepare themselves for BIM implementation. This is since the findings from the survey suggest that the respondents are of the view that BIM will become a priority in maintenance of buildings in the next 10 years as shown in Figure 18.

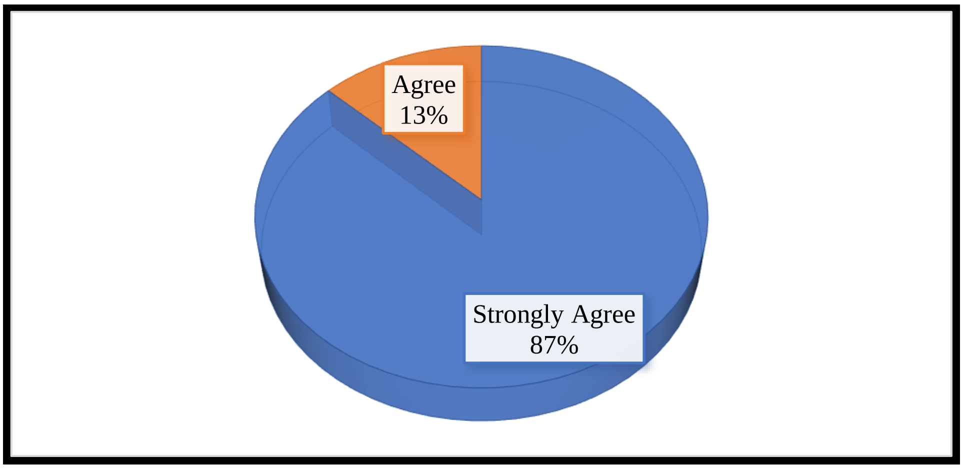
Figure 18: Respondents Views on BIM vs Building Maintenance in the next 10 Years.



One of the greatest risks identified during risk analysis is that of lack of skilled personnel or BIM expertise. Without a doubt, this finding is supported by the respondents' views shown in

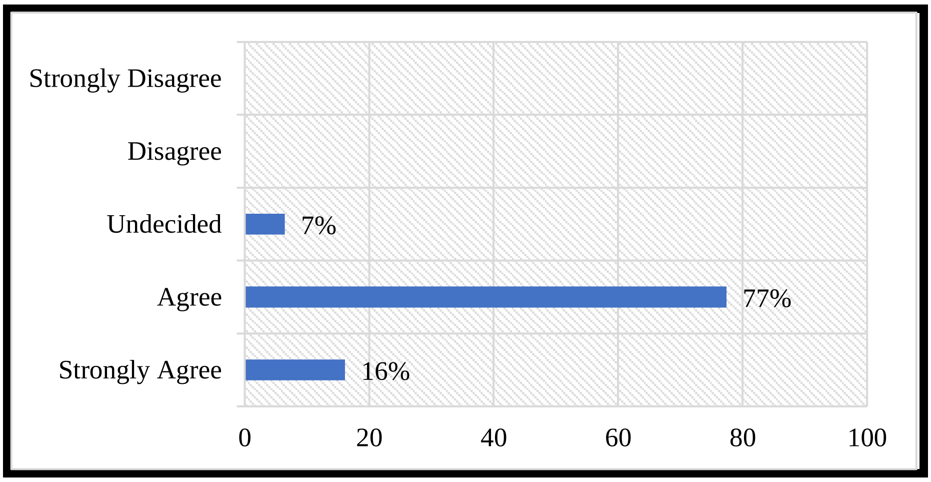
Figure 19. A total of 87% of the respondents strongly agree that BIM should form part of the curriculum content for students studying towards a built environment qualification. The suggestion for achievement of this objective will be for industry to partner with academic institutions and ensure that the industry’s current workforce gets the much-needed academic education on BIM and ensure that current and future students will have BIM incorporated into their course outlines. This is a daunting task but one that is not only achievable but necessary to ensure that the South African construction industry stays up to speed with the developments taking place at an international stage.

Figure 19: Respondents Views on BIM Forming part of the Curriculum for Built Environment Students



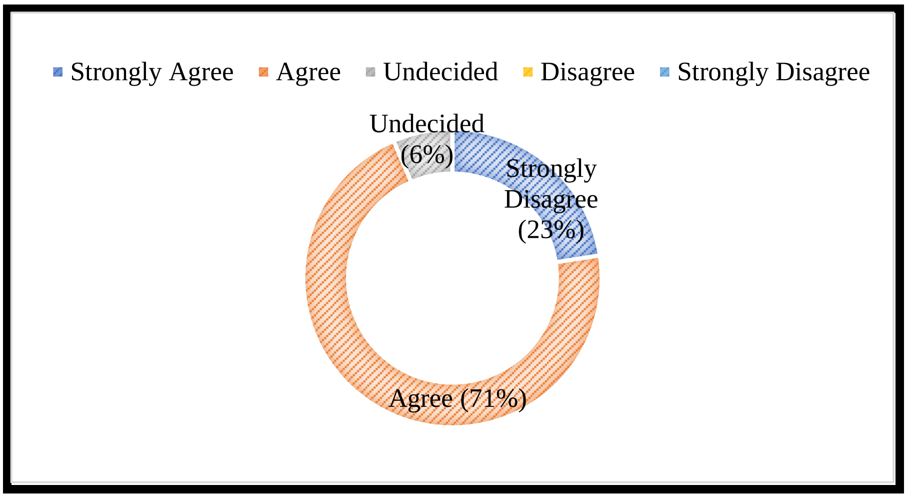
BIM researchers generally agree that there are savings and value addition achievement when BIM is adopted in the maintenance of buildings. Evidently, a combined 93% of the respondents strongly share the same views as shown in Figure 20. The remaining 7% of the respondents are indecisive.

Figure 20: Respondents Views on Achievement of Savings/Value through BIM



Regarding the importance of BIM in ensuring proper maintenance of buildings, 71% of the respondents agree that BIM ensures proper maintenance of buildings with a further 23% strongly in support of this notion. An insignificant 6% of the respondents neither agree nor disagree to this perception.

Figure 21: Respondents Views on the Importance of BIM in Ensuring Proper Building Maintenance



A greater portion of the respondents support the implementation of BIM as has been noted in this subsection. The following section makes an analysis of all the risks that are associated with the implementation of BIM in maintenance of commercial buildings.

4.3.2 Risk Analysis

As alluded to in the previous subsection, this subsection deals with risk analysis. Analysis of risks is done using the risk matrix as earlier mentioned in Chapter 3. The risks are coded and the responses loaded on to the risk matrix (excel spreadsheet) as shown in Tables 13, 14, 15 and 16. All risks with a Risk Score (RS) above 0.5 are considered to be high risk and high impact (highlighted in red) because their probability of occurrence is high as well as their overall impact in the event that they occur. However, those risks that have a RS below 0.5 are not considered because of their low probability and impact.

The researcher considers all those risks with a high certainty and impact thus after capturing all the responses into the risk matrix, those risks that have more risk scores above 0.5 are selected compared to those that have risk scores below 0.5.

4.3.2.1 Technical Risks Analysis

As has been noted under 4.3.2, Technical risks A1, A4 and A5 are regarded to be high risk since a greater portion of their risk scores (RS) is above 0.5 as indicated in red in Table 13. Risks A2 and A3 are disregarded since a greater portion of their RS is below 0.5.

Table 13: Technical Risks Analysis

Respondent	Technical (A)														
	A1			A2			A3			A4			A5		
	P	I	RS	P	I	RS	P	I	RS	P	I	RS	P	I	RS
1	4	4	**0.64**	5	4	**0.80**	4	4	**0.64**	5	2	**0.40**	4	3	**0.48**
2	2	5	**0.40**	2	5	**0.40**	2	2	**0.16**	4	5	**0.80**	4	2	**0.32**
3	4	5	**0.80**	4	4	**0.64**	5	3	**0.60**	5	4	**0.80**	2	5	**0.40**
4	5	4	**0.80**	5	3	**0.60**	4	4	**0.64**	5	4	**0.80**	1	3	**0.12**
5	5	5	**1.00**	4	4	**0.64**	4	4	**0.64**	5	5	**1.00**	5	5	**1.00**
6	4	4	**0.64**	3	3	**0.36**	3	3	**0.36**	4	4	**0.64**	4	4	**0.64**
7	4	4	**0.64**	2	2	**0.16**	2	2	**0.16**	5	5	**1.00**	4	4	**0.64**
8	4	4	**0.64**	2	2	**0.16**	2	2	**0.16**	5	5	**1.00**	4	4	**0.64**
9	4	4	**0.64**	1	1	**0.04**	1	1	**0.04**	4	4	**0.64**	4	4	**0.64**
10	4	4	**0.64**	2	2	**0.16**	2	2	**0.16**	5	5	**1.00**	4	4	**0.64**
11	4	4	**0.64**	2	2	**0.16**	3	3	**0.36**	5	5	**1.00**	4	4	**0.64**
12	4	4	**0.64**	2	2	**0.16**	2	2	**0.16**	5	5	**1.00**	4	4	**0.64**
13	4	4	**0.64**	3	3	**0.36**	2	2	**0.16**	4	4	**0.64**	4	4	**0.64**
14	4	4	**0.64**	3	3	**0.36**	3	3	**0.36**	4	4	**0.64**	4	4	**0.64**
15	4	4	**0.64**	2	2	**0.16**	3	3	**0.36**	4	4	**0.64**	4	4	**0.64**
16	5	5	**1.00**	2	2	**0.16**	2	2	**0.16**	4	4	**0.64**	4	4	**0.64**
17	4	4	**0.64**	3	3	**0.36**	1	1	**0.04**	4	4	**0.64**	4	4	**0.64**
18	5	5	**1.00**	2	2	**0.16**	1	1	**0.04**	4	4	**0.64**	5	4	**0.80**
19	4	4	**0.64**	3	3	**0.36**	2	2	**0.16**	5	5	**1.00**	4	4	**0.64**
20	4	4	**0.64**	1	2	**0.08**	1	2	**0.08**	5	5	**1.00**	4	4	**0.64**
21	4	4	**0.64**	2	2	**0.16**	1	1	**0.04**	1	5	**0.20**	4	4	**0.64**
22	4	4	**0.64**	2	2	**0.16**	3	3	**0.36**	4	4	**0.64**	5	5	**1.00**
23	4	4	**0.64**	4	4	**0.64**	3	3	**0.36**	5	5	**1.00**	5	5	**1.00**
24	4	4	**0.64**	3	3	**0.36**	3	3	**0.36**	4	4	**0.64**	4	4	**0.64**
25	5	5	**1.00**	5	5	**1.00**	4	4	**0.64**	5	5	**1.00**	5	5	**1.00**
26	4	4	**0.64**	2	2	**0.16**	2	2	**0.16**	4	4	**0.64**	3	3	**0.36**
27	4	4	**0.64**	2	2	**0.16**	2	2	**0.16**	5	5	**1.00**	4	4	**0.64**
28	4	4	**0.64**	4	4	**0.64**	3	3	**0.36**	4	4	**0.64**	3	3	**0.36**
29	4	4	**0.64**	4	4	**0.64**	3	3	**0.36**	4	4	**0.64**	3	3	**0.36**
30	4	4	**0.64**	2	2	**0.16**	2	2	**0.16**	4	4	**0.64**	4	4	**0.64**
31	4	4	**0.64**	4	4	**0.64**	2	2	**0.16**	4	4	**0.64**	4	4	**0.64**

4.3.2.2 Financial or Economic Risks Analysis

Likewise, Financial or Economic risks B2 and B4 are regarded as the riskiest due to the higher number of RS above 0.5. While the respondents generally agree that B1 and B3 risks are of little or no significance as shown in Table 14 below.

Table 14: Financial/Economic Risks Analysis

Respondent	Financial/Economic (B)											
	B1			B2			B3			B4		
	P	I	RS	P	I	RS	P	I	RS	P	I	RS
1	4	4	0.64	4	2	0.32	3	2	0.24	4	3	0.48
2	2	5	0.40	4	5	0.80	4	5	0.80	4	5	0.80
3	2	4	0.32	2	3	0.24	3	3	0.36	4	1	0.16
4	4	4	0.64	4	3	0.48	3	5	0.60	4	3	0.48
5	4	4	0.64	5	5	1.00	4	4	0.64	5	5	1.00
6	2	2	0.16	4	4	0.64	3	3	0.36	4	4	0.64
7	4	4	0.64	5	5	1.00	2	2	0.16	4	5	0.80
8	2	2	0.16	4	4	0.64	2	2	0.16	5	5	1.00
9	2	2	0.16	4	4	0.64	2	2	0.16	4	4	0.64
10	2	2	0.16	5	5	1.00	4	4	0.64	4	4	0.64
11	3	3	0.36	5	5	1.00	2	2	0.16	4	4	0.64
12	2	2	0.16	5	5	1.00	2	2	0.16	4	4	0.64
13	3	3	0.36	4	4	0.64	3	3	0.36	4	4	0.64
14	2	2	0.16	4	4	0.64	3	3	0.36	4	4	0.64
15	3	3	0.36	5	5	1.00	3	3	0.36	5	5	1.00
16	2	2	0.16	5	5	1.00	3	3	0.36	5	5	1.00
17	3	3	0.36	4	4	0.64	2	2	0.16	4	4	0.64
18	3	3	0.36	5	5	1.00	3	3	0.36	4	4	0.64
19	2	2	0.16	5	5	1.00	3	3	0.36	5	5	1.00
20	2	2	0.16	5	5	1.00	3	3	0.36	4	4	0.64
21	2	2	0.16	5	5	1.00	3	3	0.36	4	4	0.64
22	3	3	0.36	4	4	0.64	3	3	0.36	4	4	0.64
23	4	4	0.64	5	5	1.00	4	4	0.64	5	5	1.00
24	3	3	0.36	5	5	1.00	3	3	0.36	4	4	0.64
25	5	5	1.00	5	5	1.00	5	5	1.00	5	5	1.00
26	4	4	0.64	5	5	1.00	4	4	0.64	4	4	0.64
27	2	2	0.16	4	4	0.64	3	3	0.36	4	4	0.64
28	3	3	0.36	5	5	1.00	4	4	0.64	4	4	0.64
29	3	3	0.36	4	4	0.64	3	3	0.36	4	3	0.48
30	2	2	0.16	4	4	0.64	2	2	0.16	4	4	0.64
31	2	2	0.16	4	4	0.64	3	3	0.36	4	4	0.64

4.3.2.3 Legal Risks Analysis

The legal risk analysis results as presented in Table 15 show that risk C1, C8, C9, C10, C11, C14 are the riskiest and they have been incorporated into the research so that recommendations for proper risk response can be provided.

Table 15: Legal Risks Analysis

Respondent	Legal (C)																	
	C1			C2			C3			C4			C5			C6		
	P	I	RS	P	I	RS	P	I	RS	P	I	RS	P	I	RS	P	I	RS
1	4	5	**0.80**	3	4	**0.48**	4	4	**0.64**	4	3	**0.48**	4	4	**0.64**	4	5	**0.80**
2	4	5	**0.80**	2	2	**0.16**	3	5	**0.60**	0	3	**0.00**	4	3	**0.48**	3	1	**0.12**
3	4	5	**0.80**	5	5	**1.00**	2	4	**0.32**	3	5	**0.60**	5	2	**0.40**	5	4	**0.80**
4	5	4	**0.80**	3	5	**0.60**	4	3	**0.48**	4	4	**0.64**	3	4	**0.48**	1	3	**0.12**
5	5	5	**1.00**	5	5	**1.00**	4	4	**0.64**	4	4	**0.64**	4	4	**0.64**	4	4	**0.64**
6	4	4	**0.64**	3	3	**0.36**	2	2	**0.16**	3	3	**0.36**	2	2	**0.16**	2	2	**0.16**
7	2	2	**0.16**	4	4	**0.64**	2	2	**0.16**	2	2	**0.16**	2	2	**0.16**	2	2	**0.16**
8	3	3	**0.36**	4	4	**0.64**	2	2	**0.16**	4	4	**0.64**	4	4	**0.64**	4	4	**0.64**
9	4	4	**0.64**	3	3	**0.36**	2	2	**0.16**	2	2	**0.16**	1	1	**0.04**	4	3	**0.48**
10	4	4	**0.64**	3	3	**0.36**	3	3	**0.36**	2	2	**0.16**	1	1	**0.04**	3	3	**0.36**
11	4	4	**0.64**	4	4	**0.64**	3	3	**0.36**	3	3	**0.36**	1	1	**0.04**	2	2	**0.16**
12	4	4	**0.64**	4	4	**0.64**	3	3	**0.36**	2	2	**0.16**	1	1	**0.04**	2	2	**0.16**
13	4	4	**0.64**	3	3	**0.36**	3	3	**0.36**	3	3	**0.36**	2	2	**0.16**	3	3	**0.36**
14	4	4	**0.64**	3	3	**0.36**	3	3	**0.36**	3	3	**0.36**	1	1	**0.04**	2	2	**0.16**
15	5	5	**1.00**	3	3	**0.36**	3	3	**0.36**	3	3	**0.36**	2	2	**0.16**	3	3	**0.36**
16	4	4	**0.64**	3	3	**0.36**	3	3	**0.36**	2	2	**0.16**	1	1	**0.04**	2	2	**0.16**
17	4	4	**0.64**	3	3	**0.36**	3	3	**0.36**	3	3	**0.36**	2	2	**0.16**	3	3	**0.36**
18	4	4	**0.64**	2	2	**0.16**	2	2	**0.16**	3	3	**0.36**	1	1	**0.04**	2	2	**0.16**
19	4	4	**0.64**	4	4	**0.64**	3	3	**0.36**	3	3	**0.36**	2	2	**0.16**	3	3	**0.36**
20	4	4	**0.64**	3	3	**0.36**	2	2	**0.16**	2	2	**0.16**	1	1	**0.04**	3	3	**0.36**
21	4	4	**0.64**	3	3	**0.36**	2	2	**0.16**	3	3	**0.36**	1	1	**0.04**	3	3	**0.36**
22	4	4	**0.64**	4	4	**0.64**	3	3	**0.36**	3	3	**0.36**	2	2	**0.16**	3	3	**0.36**
23	5	5	**1.00**	4	4	**0.64**	4	4	**0.64**	4	4	**0.64**	4	4	**0.64**	5	5	**1.00**
24	4	4	**0.64**	2	2	**0.16**	3	3	**0.36**	2	2	**0.16**	2	2	**0.16**	3	3	**0.36**
25	5	5	**1.00**	4	4	**0.64**	4	4	**0.64**	4	4	**0.64**	4	4	**0.64**	5	5	**1.00**
26	4	4	**0.64**	3	3	**0.36**	3	3	**0.36**	3	3	**0.36**	2	2	**0.16**	3	3	**0.36**
27	4	4	**0.64**	3	3	**0.36**	3	3	**0.36**	3	3	**0.36**	2	2	**0.16**	2	2	**0.16**
28	4	4	**0.64**	3	3	**0.36**	3	3	**0.36**	3	3	**0.36**	3	3	**0.36**	3	3	**0.36**
29	3	3	**0.36**	3	3	**0.36**	3	3	**0.36**	2	2	**0.16**	2	2	**0.16**	3	3	**0.36**
30	4	4	**0.64**	2	2	**0.16**	2	2	**0.16**	2	2	**0.16**	2	2	**0.16**	2	2	**0.16**
31	4	4	**0.64**	2	2	**0.16**	3	3	**0.36**	3	3	**0.36**	2	2	**0.16**	3	3	**0.36**

Table 15: Legal Risks Analysis (continued)

Respondent	Legal (C)																	
	C7			C8			C9			C10			C11			C12		
	P	I	RS	P	I	RS	P	I	RS	P	I	RS	P	I	RS	P	I	RS
1	3	2	**0.24**	3	4	**0.48**	4	3	**0.48**	4	4	**0.64**	4	4	**0.64**	4	2	**0.32**
2	5	5	**1.00**	3	5	**0.60**	2	1	**0.08**	2	1	**0.08**	4	5	**0.80**	2	1	**0.08**
3	2	2	**0.16**	4	4	**0.64**	5	4	**0.80**	2	4	**0.32**	4	4	**0.64**	2	2	**0.16**
4	4	4	**0.64**	4	4	**0.64**	4	4	**0.64**	5	3	**0.60**	5	4	**0.80**	2	3	**0.24**
5	4	4	**0.64**	4	4	**0.64**	5	5	**1.00**	5	5	**1.00**	4	4	**0.64**	5	5	**1.00**
6	4	4	**0.64**	4	4	**0.64**	4	4	**0.64**	4	4	**0.64**	4	4	**0.64**	4	4	**0.64**
7	4	4	**0.64**	4	4	**0.64**	5	5	**1.00**	4	4	**0.64**	4	4	**0.64**	2	2	**0.16**
8	3	3	**0.36**	3	3	**0.36**	4	4	**0.64**	4	4	**0.64**	4	4	**0.64**	2	2	**0.16**
9	2	2	**0.16**	3	4	**0.48**	4	4	**0.64**	4	4	**0.64**	4	4	**0.64**	2	2	**0.16**
10	2	2	**0.16**	3	3	**0.36**	4	4	**0.64**	4	4	**0.64**	4	4	**0.64**	2	2	**0.16**
11	3	3	**0.36**	4	4	**0.64**	4	4	**0.64**	4	4	**0.64**	4	4	**0.64**	2	2	**0.16**
12	2	2	**0.16**	4	4	**0.64**	4	4	**0.64**	4	4	**0.64**	4	4	**0.64**	2	2	**0.16**
13	3	3	**0.36**	4	4	**0.64**	4	4	**0.64**	4	4	**0.64**	4	4	**0.64**	3	3	**0.36**
14	3	3	**0.36**	4	4	**0.64**	4	4	**0.64**	3	3	**0.36**	4	4	**0.64**	2	2	**0.16**
15	2	2	**0.16**	4	4	**0.64**	4	4	**0.64**	3	3	**0.36**	4	4	**0.64**	3	3	**0.36**
16	3	3	**0.36**	4	4	**0.64**	4	4	**0.64**	3	3	**0.36**	4	4	**0.64**	1	1	**0.04**
17	3	3	**0.36**	4	4	**0.64**	4	4	**0.64**	3	3	**0.36**	3	3	**0.36**	2	2	**0.16**
18	3	3	**0.36**	4	4	**0.64**	5	5	**1.00**	4	4	**0.64**	3	3	**0.36**	2	2	**0.16**
19	2	2	**0.16**	4	4	**0.64**	4	4	**0.64**	3	3	**0.36**	3	3	**0.36**	2	2	**0.16**
20	2	2	**0.16**	4	4	**0.64**	5	5	**1.00**	4	4	**0.64**	2	2	**0.16**	1	1	**0.04**
21	2	2	**0.16**	4	4	**0.64**	5	5	**1.00**	4	4	**0.64**	2	2	**0.16**	2	2	**0.16**
22	2	2	**0.16**	4	4	**0.64**	4	4	**0.64**	3	3	**0.36**	2	2	**0.16**	2	2	**0.16**
23	4	4	**0.64**	5	5	**1.00**	5	5	**1.00**	5	5	**1.00**	4	4	**0.64**	4	4	**0.64**
24	4	4	**0.64**	4	4	**0.64**	4	4	**0.64**	4	4	**0.64**	2	2	**0.16**	2	2	**0.16**
25	5	5	**1.00**	4	4	**0.64**	5	5	**1.00**	4	4	**0.64**	5	5	**1.00**	4	4	**0.64**
26	3	3	**0.36**	4	4	**0.64**	4	4	**0.64**	3	3	**0.36**	3	3	**0.36**	3	3	**0.36**
27	3	3	**0.36**	4	4	**0.64**	4	4	**0.64**	3	3	**0.36**	3	3	**0.36**	2	2	**0.16**
28	3	3	**0.36**	4	4	**0.64**	5	5	**1.00**	3	4	**0.48**	2	2	**0.16**	3	3	**0.36**
29	3	3	**0.36**	4	4	**0.64**	4	4	**0.64**	3	3	**0.36**	3	3	**0.36**	3	3	**0.36**
30	4	4	**0.64**	4	4	**0.64**	4	4	**0.64**	2	2	**0.16**	2	2	**0.16**	2	2	**0.16**
31	4	4	**0.64**	4	4	**0.64**	4	4	**0.64**	2	2	**0.16**	2	2	**0.16**	3	3	**0.36**

Table 15: Legal Risks Analysis (continued)

Respondent	Legal (C)					
	C13			C14		
	P	I	RS	P	I	RS
1	4	2	**0.32**	4	2	**0.32**
2	4	3	**0.48**	5	3	**0.60**
3	4	2	**0.32**	5	2	**0.40**
4	1	3	**0.12**	3	4	**0.48**
5	4	4	**0.64**	5	5	**1.00**
6	4	4	**0.64**	4	4	**0.64**
7	4	4	**0.64**	4	4	**0.64**
8	2	2	**0.16**	4	4	**0.64**
9	2	2	**0.16**	4	4	**0.64**
10	3	3	**0.36**	4	4	**0.64**
11	3	3	**0.36**	4	4	**0.64**
12	2	2	**0.16**	4	4	**0.64**
13	2	2	**0.16**	4	4	**0.64**
14	3	3	**0.36**	4	4	**0.64**
15	3	3	**0.36**	4	4	**0.64**
16	2	2	**0.16**	4	4	**0.64**
17	3	3	**0.36**	4	4	**0.64**
18	3	3	**0.36**	5	5	**1.00**
19	3	3	**0.36**	4	4	**0.64**
20	4	4	**0.64**	4	4	**0.64**
21	4	4	**0.64**	4	4	**0.64**
22	1	1	**0.04**	4	4	**0.64**
23	4	4	**0.64**	4	4	**0.64**
24	3	3	**0.36**	4	4	**0.64**
25	5	5	**1.00**	5	5	**1.00**
26	4	4	**0.64**	4	4	**0.64**
27	3	3	**0.36**	4	4	**0.64**
28	4	4	**0.64**	4	4	**0.64**
29	2	2	**0.16**	4	4	**0.64**
30	4	4	**0.64**	4	4	**0.64**
31	4	4	**0.64**	4	4	**0.64**

4.3.2.4 Management Risks Analysis

In Table 16, risks D1, D2, D4 and D8 are regarded as the riskiest after the analysis hence the recommendations of managing them will be provided in the following section. Risks D3, D5, D6, D7, D9, D10 and D11 are not included in the research due to their low RS.

Table 16: Management Risks Analysis

Respondent	Management (D)																	
	D1			D2			D3			D4			D5			D6		
	P	I	RS	P	I	RS	P	I	RS	P	I	RS	P	I	RS	P	I	RS
1	3	4	0.48	4	4	0.64	4	2	0.32	4	4	0.64	5	4	0.80	4	4	0.64
2	4	3	0.48	4	2	0.32	1	2	0.08	4	4	0.64	2	1	0.08	5	5	1.00
3	5	5	1.00	5	5	1.00	3	5	0.60	2	5	0.40	3	4	0.48	3	4	0.48
4	4	5	0.80	4	4	0.64	2	5	0.40	4	4	0.64	4	4	0.64	4	3	0.48
5	5	5	1.00	5	5	1.00	3	3	0.36	4	4	0.64	4	4	0.64	3	3	0.36
6	5	5	1.00	4	4	0.64	2	2	0.16	4	4	0.64	3	3	0.36	3	3	0.36
7	5	5	1.00	4	4	0.64	2	2	0.16	4	4	0.64	3	3	0.36	2	2	0.16
8	5	5	1.00	4	4	0.64	2	2	0.16	4	4	0.64	2	2	0.16	1	1	0.04
9	5	5	1.00	2	2	0.16	2	2	0.16	2	2	0.16	3	3	0.36	2	2	0.16
10	5	5	1.00	4	4	0.64	1	1	0.04	4	4	0.64	2	2	0.16	2	2	0.16
11	5	5	1.00	4	2	0.32	1	1	0.04	4	4	0.64	2	2	0.16	2	2	0.16
12	5	5	1.00	3	3	0.36	2	2	0.16	3	3	0.36	2	2	0.16	2	2	0.16
13	4	4	0.64	4	4	0.64	2	2	0.16	4	4	0.64	2	2	0.16	2	2	0.16
14	5	5	1.00	4	4	0.64	1	1	0.04	4	4	0.64	2	2	0.16	3	3	0.36
15	5	5	1.00	4	4	0.64	1	1	0.04	4	4	0.64	1	1	0.04	3	3	0.36
16	5	5	1.00	2	2	0.16	1	1	0.04	3	3	0.36	1	1	0.04	1	1	0.04
17	5	5	1.00	3	3	0.36	2	2	0.16	3	3	0.36	2	2	0.16	2	2	0.16
18	5	5	1.00	4	4	0.64	2	2	0.16	4	4	0.64	2	2	0.16	2	2	0.16
19	5	5	1.00	4	4	0.64	2	2	0.16	4	4	0.64	2	2	0.16	2	2	0.16
20	5	5	1.00	3	3	0.36	1	1	0.04	4	4	0.64	2	2	0.16	2	2	0.16
21	5	5	1.00	3	3	0.36	1	1	0.04	3	3	0.36	2	2	0.16	2	2	0.16
22	5	5	1.00	4	4	0.64	2	2	0.16	4	4	0.64	2	2	0.16	2	2	0.16
23	5	5	1.00	5	5	1.00	4	4	0.64	5	5	1.00	3	3	0.36	4	4	0.64
24	4	4	0.64	4	4	0.64	2	2	0.16	4	4	0.64	2	2	0.16	2	2	0.16
25	5	5	1.00	5	5	1.00	4	4	0.64	5	5	1.00	4	4	0.64	4	4	0.64
26	5	5	1.00	4	4	0.64	2	2	0.16	4	4	0.64	2	2	0.16	2	2	0.16
27	5	5	1.00	4	4	0.64	2	2	0.16	4	4	0.64	2	2	0.16	2	2	0.16
28	5	5	1.00	4	4	0.64	2	2	0.16	4	4	0.64	3	3	0.36	3	3	0.36
29	5	5	1.00	4	4	0.64	2	2	0.16	4	4	0.64	3	3	0.36	3	3	0.36
30	5	5	1.00	4	4	0.64	2	2	0.16	4	4	0.64	2	2	0.16	2	2	0.16
31	5	5	1.00	4	4	0.64	2	2	0.16	4	4	0.64	3	3	0.36	2	2	0.16

Table 16: Management Risks Analysis (continued)

Respondent	Management (D)														
	D7			D8			D9			D10			D11		
	P	I	RS	P	I	RS	P	I	RS	P	I	RS	P	I	RS
1	4	4	**0.64**	4	4	**0.64**	5	5	**1.00**	5	5	**1.00**	3	3	**0.36**
2	5	5	**1.00**	3	5	**0.60**	5	5	**1.00**	5	5	**1.00**	5	5	**1.00**
3	5	5	**1.00**	5	4	**0.80**	5	5	**1.00**	4	5	**0.80**	2	4	**0.32**
4	5	4	**0.80**	5	3	**0.60**	5	4	**0.80**	5	4	**0.80**	2	4	**0.32**
5	4	4	**0.64**	5	5	**1.00**	4	4	**0.64**	5	5	**1.00**	5	5	**1.00**
6	3	3	**0.36**	5	5	**1.00**	3	3	**0.36**	3	3	**0.36**	3	3	**0.36**
7	2	2	**0.16**	4	4	**0.64**	3	3	**0.36**	2	2	**0.16**	2	2	**0.16**
8	1	1	**0.04**	4	4	**0.64**	3	3	**0.36**	2	2	**0.16**	2	2	**0.16**
9	2	2	**0.16**	5	5	**1.00**	3	3	**0.36**	3	3	**0.36**	2	2	**0.16**
10	2	2	**0.16**	5	5	**1.00**	3	3	**0.36**	2	2	**0.16**	3	3	**0.36**
11	2	2	**0.16**	5	5	**1.00**	3	3	**0.36**	2	2	**0.16**	1	1	**0.04**
12	2	2	**0.16**	5	5	**1.00**	2	2	**0.16**	2	2	**0.16**	2	2	**0.16**
13	2	2	**0.16**	4	4	**0.64**	2	2	**0.16**	2	2	**0.16**	2	2	**0.16**
14	2	2	**0.16**	4	4	**0.64**	2	2	**0.16**	1	1	**0.04**	2	2	**0.16**
15	3	3	**0.36**	5	5	**1.00**	2	2	**0.16**	1	1	**0.04**	2	2	**0.16**
16	1	1	**0.04**	5	5	**1.00**	1	1	**0.04**	1	1	**0.04**	1	1	**0.04**
17	1	1	**0.04**	4	4	**0.64**	2	2	**0.16**	3	3	**0.36**	2	2	**0.16**
18	2	2	**0.16**	5	5	**1.00**	2	2	**0.16**	2	2	**0.16**	3	3	**0.36**
19	2	2	**0.16**	5	5	**1.00**	2	2	**0.16**	1	1	**0.04**	4	4	**0.64**
20	2	2	**0.16**	5	5	**1.00**	1	1	**0.04**	1	1	**0.04**	4	4	**0.64**
21	2	2	**0.16**	4	4	**0.64**	2	2	**0.16**	1	1	**0.04**	4	4	**0.64**
22	2	2	**0.16**	4	4	**0.64**	2	2	**0.16**	2	2	**0.16**	4	4	**0.64**
23	3	3	**0.36**	4	4	**0.64**	4	4	**0.64**	3	3	**0.36**	4	4	**0.64**
24	2	2	**0.16**	4	4	**0.64**	2	2	**0.16**	2	2	**0.16**	3	3	**0.36**
25	4	4	**0.64**	4	4	**0.64**	4	4	**0.64**	4	4	**0.64**	4	4	**0.64**
26	2	2	**0.16**	4	4	**0.64**	2	2	**0.16**	1	1	**0.04**	4	4	**0.64**
27	2	2	**0.16**	3	4	**0.48**	2	2	**0.16**	2	2	**0.16**	4	4	**0.64**
28	3	3	**0.36**	5	5	**1.00**	3	3	**0.36**	2	2	**0.16**	4	4	**0.64**
29	3	3	**0.36**	4	4	**0.64**	3	3	**0.36**	2	2	**0.16**	4	4	**0.64**
30	2	2	**0.16**	4	4	**0.64**	2	2	**0.16**	2	2	**0.16**	4	4	**0.64**
31	2	2	**0.16**	4	4	**0.64**	2	2	**0.16**	2	2	**0.16**	4	4	**0.64**

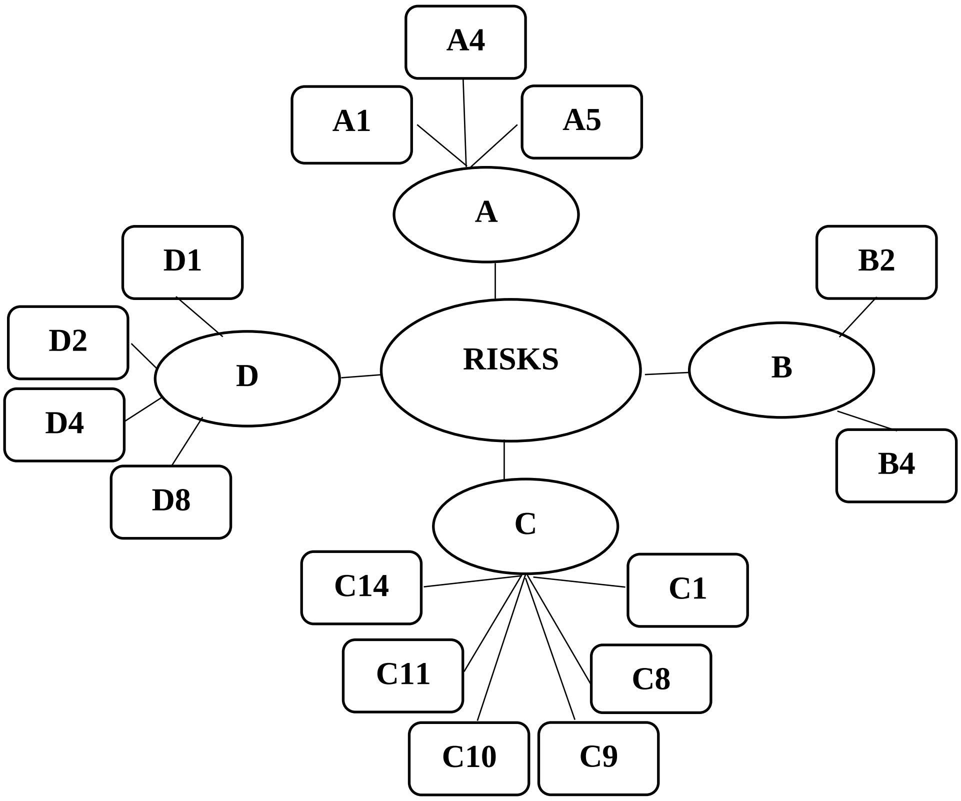
In brief, the risks that have been identified from the risk analysis process which are most critical and will require attention in the implementation of BIM in maintenance of buildings are as follows;

- ***Critical Technical Risks*** (refer to Table 13)
    1. Insufficient or incorrect building information (A1)
    2. Poor adoption of BIM technologies (A4)
    3. Data loss during BIM-IFC file exchange (A5)
- ***Critical Financial/Economic Risks*** (refer to Table 14)
    1. Labour cost increase in training (B2)
    2. High initial investment costs (B4)
- ***Critical Legal Risks*** (refer to Table 15)
    1. Illegal changes in the model (C1)
    2. Coordination and amendment of the BIM model (C8)
    3. Ownership conflicts among stakeholders (C9)
    4. Intellectual property protection (C10)
    5. Damages caused by human errors (C11)
    6. Lack of established case law (C14)
- ***Critical Management Risks*** (refer to Table 16)
    1. Lack of skilled personnel/BIM expertise (D1)
    2. Unclear specifications (D2)
    3. Poor coordination (D4)
    4. Lack of knowledge of BIM implementation (D8)

Figure 22 provides a graphical summary of the critical risks identified from the risk analysis process. As mentioned in Chapter 3, the main motivation for carrying out risk analysis is to estimate the potential impacts of the risks, determine ways of responding to such risks as well as to decide what risks to retain and what risks to transfer to other parties who can better manage them.

Following the risk management cycle illustrated in Figure 6, the risk identification stage was dealt with in subsection 4.2. This section followed up with the risk analysis process which involves risk estimation and risk evaluation. This resulted in the identification of 15 risks that are regarded as the riskiest in the implementation of BIM in maintenance of buildings. However, the risk management process cannot be complete without some form of controlling through proper response measures and monitoring to ensure that the risk environment is managed.

Figure 22: Summary of Critical BIM Related Risks in Buildings Maintenance



The following section provides recommendations on various ways of dealing with such risks. Information contained in this section has been gathered through interviews from a purposefully selected case study.

4.4 Recommendations for Dealing with BIM Risks

There are various ways of responding to risks which include elimination, transfer, retention (active or passive) and reduction as noted in chapter 2 (subsection 2.5.3). The case study approach is adopted in this research (as mentioned in Chapter 3) to provide recommendations for the risks identified in the previous section. However, due to the dearth of cases were BIM has been implemented for building maintenance purposes not only in Gauteng but the republic of South Africa at large, the researcher opts for a case which has adopted 3D and is on its way to adopt BIM.

In an email discussion with a BIM expert, the researcher asked about the possibility of getting a proper case study of a commercial building that has implemented BIM beyond the construction phase. The response from the expert was;

"There is not much research done and I have to disappoint you here. The best call is to look abroad for proper case studies."

Without any reservation, this response clearly supports the case study choice made by the researcher. As mentioned earlier, the case study is for a large commercial (retail) building in Gauteng. The motivation for opting for such a building is twofold, first is the issue to do with the massive advancement made to incorporate BIM in maintenance and secondly the building is located at a very busy junction and as a result receives high volumes of traffic in the form of customers and suppliers thus requires regular maintenance and upkeep to retain the high volumes of traffic. The two interviewees are employed as Asset manager and Building manager respectively and have been strongly advocating for the adoption of BIM to allow for the better management of the Centre.

The analysis of data gathered from the interviews is done through descriptive and pattern coding with the support of NVivo software. For each risk identified under section 4.3.2, the various response options are pattern coded and summarized into a paragraph. The findings from the analysis are as follows;

Recommendations for Responding to Key Technical Risks (A)

Risk A1 – From the meeting outcome, it is vital to understand that this risk can arise due to two factors. The first one is the failure by the project team to handover adequate building information during commissioning and handover while the second factor is the failure by building owners and managers to protect the information. Two recommendations were made on how best to respond to such a risk.

First Recommendation - The first recommendation for dealing with this risk is the early involvement of the asset and or building managers especially during commissioning of the buildings for information and processes compliance checks.

Second Recommendation - Secondly, there is a strong need for all the stakeholders who are involved in the life of the building beyond its construction phase to have a clear understanding of the roles of each party in order to minimize misunderstandings that may result in the loss of some of the building information.

Risk A4 – As has been noted in the first Chapter, it is common for the Real Estate sector to be reluctant in adopting new technologies. Thus, the interview discussions pointed to the fact that, when the industry eventually adopts a technology, chances are that the adoption may be done poorly, partly because of the perceptions towards new technologies. Without reservation, three recommendations were made as best response measures.

First Recommendation – The first recommendation points to the need for extensive research on how BIM has been implemented elsewhere. This according to the first interviewee, allows the implementing organization to gain extensive knowledge on how to effectively implement BIM.

Second Recommendation – Secondly, all the stakeholders involved in the implementation process should hold open discussions on how best they can implement BIM to achieve high success rates.

Third Recommendation – Lastly, regular meetings with the BIM implementing agent for updates and stakeholder training was the recommendation made for responding to this risk during the interviews.

Risk A5 – Both interviewees were of the view that data loss can result in time loss and sometimes monetary costs. Critical to note here is the fact that, although building developers usually keep information about the buildings they would have developed, chances are the information might take time to be retrieved depending on building age and the number of buildings that were developed after the building in question. Monetary costs on the other hand could be incurred when a tenanted building encounters an electrical fault, but the electrical information is missing to enable the fixing of the problem. Thus, depending on the severity of the fault, the building owner can be sued for loss of business by the tenant(s). Two recommendations were made as potentials for responding to this risk.

First Recommendation - The response measure includes obtaining appropriate insurance cover for BIM electronic deliverables including models and data loss. This helps to transfer the risk to a third party thereby allowing the stakeholders to focus on other risks.

Second Recommendation – Secondly, both interviewees also mentioned stakeholder training as a possible response to this risk as it will empower the stakeholders in terms of know-how and decision making.

Recommendations for Responding to Key Financial/Economic Risks (B)

Risk B2 – The implementation of a new technology or concept calls for more staff training costs for that technology on top of the existing staff development costs within the organization. In other instances, this might also include costs associated with hiring experienced employees. One key recommendation for dealing with this risk was made during the interviews.

Recommendation - Both interviewees agreed that this is an unavoidable risk which must be actively retained within an organization. This, they said, is due to the obvious fact that the successful implementation of BIM does not only require general human resources but human resources that are experienced with the BIM concept or technology.

Risk B4 – The findings from the risk analysis ranked initial investment costs as another key risk due to the costs associated with development of the BIM model. During the interviews, one key recommendation for responding to this risk was made.

Recommendation - The best response to this risk according to the interviewees would be for the building owner(s) to transfer this risk to finance lending institutions but this has to be done after cost-benefit considerations have been made.

Recommendations for Responding to Key Legal Risks (C)

Risk C1 and C8 – According to the interviewee's responses, these two risks can be dealt with in a more similar way. As such, only one key recommendation was made as a possible response to these two risks.

Recommendation - This involves ensuring that all stakeholders involved understand their roles in ensuring that the performance of the building is maintained at optimal level. This according to their views, helps to avoid confusions that may result in illegal changes, coordination and amendment issues that distort the model and lead to improper maintenance of buildings.

Risk C9 – The views of the interviewees point to the fact that, Asset/Facilities managers and Building Owners are the main stakeholders that are likely to have such conflicts. One key risk response recommendation was made.

First Recommendation - The best response identified during interviews will be for the building owners to provide clear contract terms and clarity of relationship between the two stakeholders. Therefore, this response is preventive in nature is it seeks to solve the risk before it occurs.

Risk C10 – Intellectual property protection is very key in the successful implementation of BIM in maintenance of buildings. Two key recommendations were suggested as possible response measures to this risk.

First Recommendation – Firstly, in-house measures such as seeking clarification on who is responsible for the protection of such information and having strict and binding contract terms that do not allow anyone other than those allowed by organization policy to access such information.

Second Recommendation – Secondly, outsourcing of insurance services was also recommended as a way of protecting intellectual property.

Risk C11 – According to both interviewees, no matter how much effort can be made to respond to this risk, the effectiveness of the response measures entirely depends on the care applied by the human factors involved in the implementation process. A single recommendation was made as the best response measure to this risk.

Recommendation - Since human errors are inevitable the interview respondents generally agreed that the best way to deal with such a risk would be to provide BIM education and training to employees within every department.

Risk C14 – The first interviewee was of the view that, established legal cases help with the decision-making processes because from a legal standpoint, the stakeholders will be aware of the consequences of certain decisions based on the judgments that were previously passed. One recommendation was made as a best response measure to this risk.

***Recommendation* -** The major response recommendation for this risk is for the stakeholders to study the events that have happened beyond borders in countries were BIM court rulings have been passed. This, according to the interviewees, would allow the stakeholders to make educated decisions though the legal environments in which such decisions were made might be different from the South African legal environment.

Recommendations for Responding to Key Management Risks (D)

Risk D1 and D8 – Again the interviewees agreed that, the suggestion for dealing with both these risks is more similar and thus should be combined. As a result, a single recommendation was suggested on how best to deal with both these risks.

Recommendation - The major suggestion for dealing with these risks is the provision of education and training within every department before, during and after the implementation of BIM.

Risk D2 – According to the interviewees, unclear specifications are detrimental to the successful implementation of BIM. The interviewees made one key recommendation on the best response to this risk.

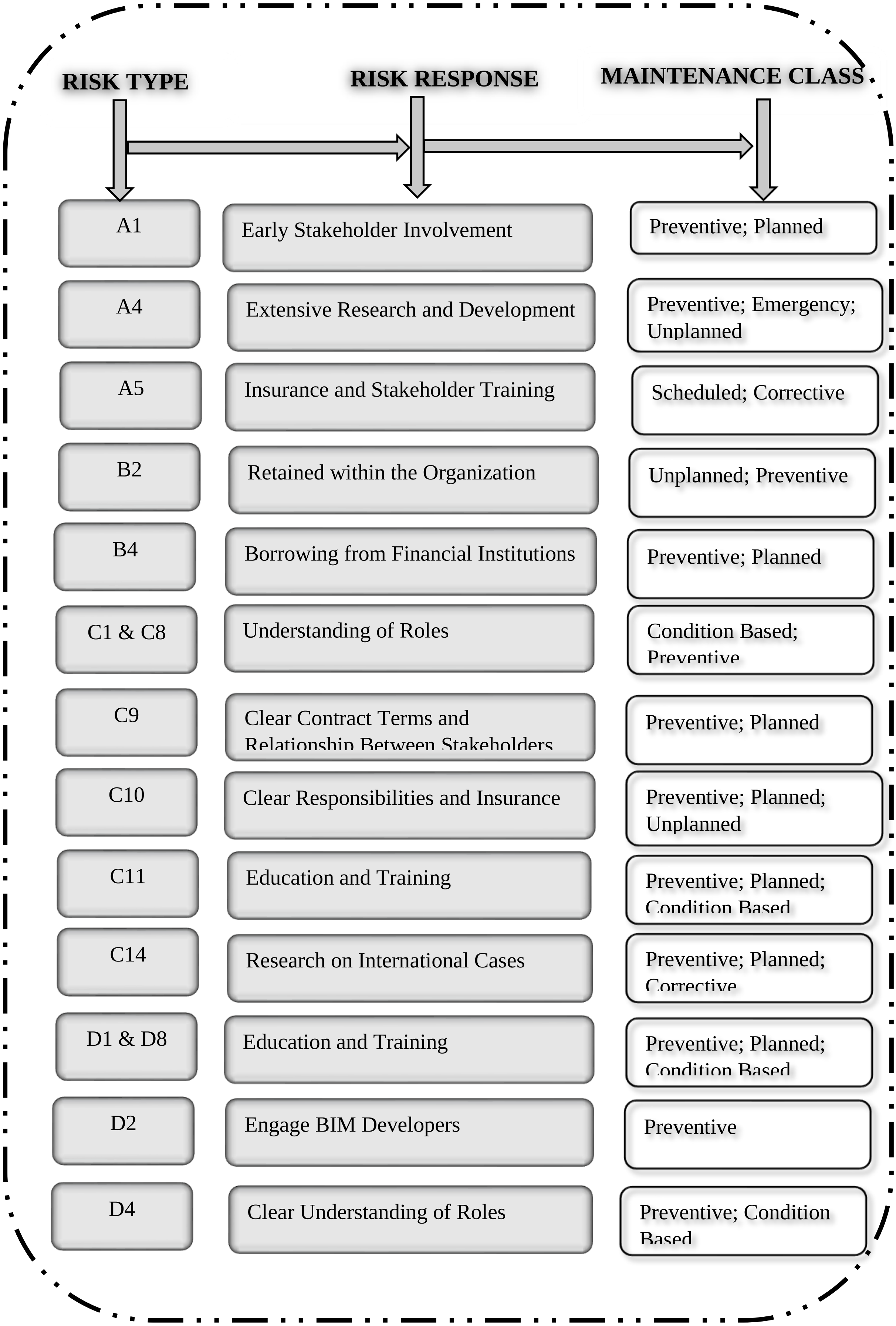
Recommendation - The suggestion for best dealing with such a risk according to the interviewees is to engage with the BIM model developer and ensure that both parties are at the same level in terms of understanding the model specifications.

Risk D4 – The second interviewee was of the view that, like many other risks, poor coordination tends to affect the successful implementation of BIM for the maintenance of buildings. As such a single recommendation was made as the best response measure.

Recommendation – The suggestion for dealing with this risk was for both parties to have a clear understanding of roles to minimize any misunderstandings.

Figure 23 summarizes the link between the risk recommendations and the classes of maintenance that were discussed in chapter two (Table 1). The classification process took into consideration the responses from the case study (interviews). The goal here is to assist the Building Manager with the necessary information which can assist in the decision-making process with regards to the choice of maintenance to choose when implementing BIM for building maintenance purposes.

Figure 23: Link between Risk Recommendations and Maintenance Classes



From Figure 23 most of the recommended risk response measures are linked to preventive maintenance. The reason for such a scenario is that every stakeholder wants as much as possible to prevent risks from occurring since they are undesirable in nature. This calls for maintenance options that are preventive and planned in nature.

4.5 Summary

In brief, this chapter answered and achieved the research questions and objectives respectively. Data collected from Metasynthesis, questionnaires and interviews were presented and analysed to create insightful meaning. A link to reach the research conclusion and suggestions was 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.

5.0 DISCUSSIONS, CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction

The study provided suggestions of dealing with major risks associated with implementing BIM in maintenance of commercial buildings in Gauteng, South Africa. As was mentioned throughout this research, the greatest cost in a building life cycle is experienced in the operation and maintenance stage. Subsequently, research has shown that BIM has significant potential to reduce these costs. However, all these potential benefits can accrue to nothing if there is no BIM risk management process in place. Identification and assessment of the various risks associated with the implementation of BIM in maintenance of buildings is therefore necessary in the success of BIM.

5.2 Discussion

The research provided recommendations of dealing with various BIM risks that have been identified. 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 findings presented under the risk analysis section 4.3.2 that risks 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.

Again, the works of Doumbouya *et al.,* (2016); Garbryk and Scott, (2016) and Aziz *et al.,* (2016) concerning the facilitative benefits of BIM in a building life cycle have been positively validated by the findings of this research. Most of the respondents as shown in Figure 19 and 20 strongly agree that savings or value can be achieved through BIM as it will ensure effective building maintenance.

As earlier noted in Chapter 2, studies by Chanter and Swallow, (2007); Azhar, (2011) and Bortolini *et al*., (2016) emphatically support the need for proper management of buildings. In addition, McKinsey and Company, (2016) and Arcadis, (2016) also share the same sentiments by suggesting that O and M practices require strategic planning if the management of buildings is going to be a success. The research findings of this study supports the notion of all these scholars since most of the respondents agree that there is a need to impart BIM knowledge to all built environment students in the Republic of South Africa since their views are that, BIM will be extensively used in the maintenance of infrastructure within the next 10 years.

According to Ashcraft, (2008); Araszkiewicz, (2015) and Alizadeh *et al*, (2016), the need for the identification and analysis of risks as well as the recommendation of response measures to such risks cannot be overemphasised. This research aimed at identifying, categorising and analysing risks associated with the implementation of BIM in maintenance of buildings. A total of 15 risks categorised into Technical, Financial/Economic, Legal and Management are identified in this research to be the most critical during the implementation of BIM in the maintenance of buildings.

There is no doubt that the findings of this research are in tandem with the findings of many other researchers. It is now common knowledge that BIM has the various benefits throughout the construction process and beyond. However, care must be taken to ensure that proper risk management practices are carried out before, during and after the implementation of BIM. This research has provided several risks that are associated with the implementation of BIM for maintenance purposes.

5.3 Conclusions

The property industry has a lot to benefit from the BIM process. In fact, they are the biggest beneficiary from all the stakeholders. It is therefore crucial that each BIM process be underpinned by a BIM Brief or an EIR to ensure that the content will be developed in line with the Asset Manager's requirements. Unfortunately, there are very few Asset Managers if any in South Africa that are actively utilizing this option since the large BIM projects are mainly using BIM for the benefit of the construction process.

Therefore, the challenges to the implementation of BIM throughout the building lifecycle include the following:

a) Building Economics

Cost of design through the payments made to professional consultants. *Will BIM cost more?* Cost of construction that is lean construction, reduction of waste, less rework, fewer RFI's, resolved clashes between structure and services. Operational costs incurred in obtaining all relevant building information at handover, maintenance repairs scheduling, locating imbedded services etc.

b) Building Performance

Environmental costs impact on neighboring facilities as a result of vehicular movement, excavation, blocking of light etc. Energy use through testing a virtual building to determine the projected lifecycle performance. Deep retrofit through applying new technologies to old buildings and consequently will the building's performance increase and by how much?

c) Building Quality

Compliance with standards such as national building regulations, fire, disabled accessibility etc. and the safety issues to do with stairs, handrails, ramps etc. as well as personal loss/danger of falling from heights and electrical shock etc. when applying maintenance.

d) Building Procurement

Transparent administration with immediate access to information and less paperwork. Better management, reduction/elimination of delays as well as less variations and clear understanding of resolved building. Lastly, the achievement of less disputes as a result of transparency.

Applying the BIM process will reduce risks on all the above fields. However, in the researcher's view Asset Managers do not realize 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 property industries such as the Irish industry that recognized 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. Unfortunately, the future adoption of BIM by Asset and Facility Managers looks bleak unless the education of this sector is boosted.

Again, in an email conversation with the previously mentioned BIM expert, he mentioned that some of the client bodies that he deals with are not in the BIM process and had the attitude of;

'*…we don't care how you do it, just give us our building…*'

This attitude is unfortunately not uncommon in South Africa. However, the client was eventually convinced to accept a CDE (Common Data Environment), which is a cloud based repository for all the building information as they have no intention to manage the facility with intelligent FM software and as such the only information deposited onto the CDE is 2D PDF drawings. It is therefore up to BIM researchers and experts to lead the industry into the right direction as there are plenty layers of BIM yet to be explored by the industry.

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 emphasizes the need for risk management practice within the property sector. This is meant to encourage all property practitioners, building owners and managers, to make effective decisions that are based on risk analysis.

Secondly, the research presents property industry practitioners, building owners, with risk information that they need to consider when making decisions on BIM implementation.

Since risks are identified through techniques such as brainstorming, having a standard check list and through past archival data or standard documents, the last contribution of this research to practice is that it creates a standard checklist for risks associated with BIM implementation in maintenance of commercial buildings in South Africa. Pivotal to note though is the fact that the list of risks compiled in this report can always be updated with new risks as and when they are encountered.

Contribution to the Academic Field

The research firstly provides a deeper academic understanding of the issues to do with BIM risk management in maintenance of buildings particularly with commercial buildings which require frequent maintenance due to the high amount of traffic which makes use of such facilities.

Furthermore, the research presents a foundation upon which future BIM implementation risk researches in the operation phase of buildings can be carried out.

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 risks. However, due to the lack of buildings fully utilizing BIM in maintenance, the respondents lacked adequate practical experience to provide in-depth responses. In addressing this limitation, the researcher reviewed international cases to support the responses provided by the respondents.

Due to the timeframe and submission deadlines, the findings from the case study were limited to Gauteng province. This limited the contributions from the rest of potential respondents throughout South Africa. Nevertheless, the viewpoints gained from international cases helped to support the findings of this study resulting in the suggestions made for future researches.

This research entirely relied on sources of data that have been published in English or those that have been translated into English. As such, this could have possibly left some important work which is published in languages other than 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 organizations such as the BIM Institute. It is still largely unknown in the construction and property industry more so when it comes to the benefits of using the concept in the maintenance of buildings. 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, especially during the operation and maintenance stages.

Moreover, once BIM becomes mandatory in South Africa, research on the assessment of the risk response measures suggested in this research will be required to establish their effectiveness and efficiency through risk monitoring processes.

Since it is not a question of if, but simply when BIM technology will become too great to be ignored. There is a strong need therefore to research on why Asset Managers and Building Owners in South Africa are seemingly not interested in adopting BIM despite all the benefits.

Currently there is no case law (legal precedent) dealing with BIM, therefore when groundbreaking judicial rulings related to BIM technology are ruled on these same rulings must be evaluated and analyzed in depth to align BIM and the project delivery methods it supports with legislation.

Lastly, 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.

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Appendix A - CRAAP Test

EVALUATING INFORMATION (Reliability and Validity)

CURRENCY – timeliness of information

- When was the information published?
- Is the information current and up to date?
- Has it been revised or updated? When? Should it have been updated?
- If online: are the links functional?

RELEVANCE – uniqueness of information and importance to research needs

- Does the information relate to your topic?
- Who is the intended audience?
- Is the information at an appropriate level (i.e. too elementary or too advanced)?
- Can you find the same or better information in another source?

AUTHORITY – source of information

- Who is the author/publisher/source/sponsor?
- What are the author's credentials? Any organizational affiliations?
- Is this author qualified to write on the topic?
- If online: examine the domain (.gov, .edu, or .com). Can you find the author's contact information?

ACCURACY – reliability and correctness of information

- Is the information supported by evidence? Can you verify it from another source?
- Has the information been peer reviewed or refereed?
- Does the language seem biased? Is the tone free of emotion?
- Are there any typos, spelling, or grammatical errors?

PURPOSE – presence of bias, reason the information exists

- What is the purpose of the information: to inform, teach, sell, entertain, etc.?
- Is the information fact, opinion, or propaganda?
- Is the point-of-view objective and impartial?
- Do the authors make their intentions or purpose clear?

(Adapted from Meriam Library, California State University, Chico)

Appendix B - Questionnaire

I am an MSc candidate at the University of the Witwatersrand (www.wits.ac.za). I am carrying out a research on risks associated with implementation of Building Information Modelling in maintenance of commercial buildings in Gauteng, South Africa. Please note that the questionnaire will take about 15 - 20 minutes to complete and is to be returned within two working weeks from receipt. Please be assured that anonymity and confidentiality of returned information will be maintained.

For any further information on this study, please contact me via 1609591@students.wits.ac.za

Thank you.

Yours sincerely,

Ernest Mutingwende
MSc Candidate

Cc. Dr. Ehsan Saghatforoush (Supervisor) ehsan.saghatforoush@wits.ac.za

Section A

Please indicate your gender.

- ○ Male
- ○ Female
- ○ Prefer not to say

Please indicate your highest level of education attained.

- ○ Matric
- ○ Certificate
- ○ Undergraduate Degree/Diploma
- ○ Honors/Post-graduate Diploma
- ○ Masters
- ○ Doctorate
- ○ Other____________________________

Which of the following best describes your profession?

- ○ Asset Manager
- ○ BIM Practitioner
- ○ Academic
- ○ Other____________________________

How many years of experience do you have?

- <2 Years
- 2<Years<5
- 5<Years<10
- 10 Years<

Section B

Please indicate how familiar you are with Building Information Modelling.

- Not familiar at all
- Slightly familiar
- Somewhat familiar
- Moderately familiar
- Extremely familiar

Please indicate your response to each of the following statements.

	Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree
BIM is revolutionizing the Built environment.					
BIM will be a priority in the maintenance of buildings within the next 10 years.					
BIM should form part of the curriculum for students studying a course relating to the built environment.					
Savings/Value can be achieved through the use of BIM in maintenance of buildings.					
BIM is important in ensuring proper maintenance of buildings.					

In your opinion, what is the likelihood of occurrence and impact of the following BIM risks?
(For each of the risks, select one option under likelihood and impact)

Likelihood

5 – Extremely Likely

4 - Likely

3 - Neutral

2 - Unlikely

1 – Extremely Unlikely

Impact

5 – Very High

4 – Above Average

3 – Average

2 – Below Average

1 – Very Low

Risk Category	Risk Type	Likelihood					Impact				
		1	2	3	4	5	1	2	3	4	5
Technical (**A**)	Insufficient or incorrect building information (**A1**)										
	Imperfect BIM software (**A2**)										
	Rapid update of BIM technologies (**A3**)										
	Poor adoption of BIM technologies (**A4**)										
	Data loss during BIM-IFC file exchange (**A5**)										
Financial/ Economic (**B**)	Illusion of maintenance cost estimation (**B1**)										
	Labour cost increase in training (**B2**)										
	Long period of BIM return on/of investment (**B3**)										
	High initial investment costs (**B4**)										
Legal (**C**)	Illegal changes in the model (**C1**)										
	Duty of care/data security (**C2**)										
	Professional terms of engagement (**C3**)										
	Information and reliance (**C4**)										
	Different BIM models (**C5**)										
	Duplication and the risk of ambiguity (**C6**)										
	Standardize the BIM process (**C7**)										
	Coordination and amendment of the BIM model (**C8**)										
	Ownership conflicts among stakeholders (**C9**)										
	Intellectual property protection (**C10**)										
	Damages caused by human errors (**C11**)										
	Changes in laws and regulations (**C12**)										
	Nonstandard contract form (**C13**)										
	Lack of established case law (**C14**)										
Management (**D**)	Lack of skilled personnel/BIM expertise (**D1**)										
	Unclear specifications (**D2**)										
	Theft and vandalism of BIM information (**D3**)										
	Poor coordination (**D4**)										
	Cultural barriers towards adopting new technology (**D5**)										
	The difficult transition of business procedures (**D6**)										
	The difficult transition of management pattern (**D7**)										
	Lack of knowledge of BIM implementation (**D8**)										
	Resistance to change from people (**D9**)										
	Insufficient commitment of top management (**D10**)										
	No Research and Development unit for new technology (**D11**)										

Thank You.

Appendix C - Interview Guide and Protocol

1. MATERIALS (Ensure the following items are available)
   - Audio Recorder (fully charged)
   - Notepad and Pens
   - Copy of Research
   - Watch or Clock
   - Participant's Contact Information
2. PREPARATORY TASKS
   - Make firm arrangement for time and place of interview with participant
   - Contact the participant 7 days to agreed date for interview to confirm the date
   - A day before scheduled date:
     - ❖ Ensure all of the above materials are available
     - ❖ Ensure all electronic materials are working
     - ❖ Send an email reminder to participant
3. MANAGING THE INTERVIEW SESSION
   - Arrive early according to schedule
   - Give a brief introduction as in the next section
   - Give consent form to participant to read and complete
   - Begin interview
4. CONCLUDING THE SESSION
   - Thank the participant
   - Check all notes and audio recordings. Thereafter, reflect on contextual information for some time.

Time Schedule

Task	Estimated Time Required
Setting up time	30 Minutes
Actual interview	20 – 30 Minutes
Rounding up time	10 Minutes
De-briefing (May not be done at interview venue)	30 Minutes
Total:	**90 to 100 Minutes**

PART 1: PREAMBLE

Name: ____ Date: ____________________

Position: ____ Time: ____________________

Good morning (afternoon). Thank you for your time. My name is Ernest Mutingwende, a research student at the University of the Witwatersrand, Johannesburg, South Africa. The purpose of this interview is to get your recommendations on dealing with a few BIM risks that have been determined as the riskiest in this research, based on your experience. There are no right or wrong or desirable or undesirable answers and please base your answers to questions on a BIM project in which you participated or provided professional services. I would like you to feel comfortable with saying what you really think and how you really feel is the best way of dealing with such risks.

If it is okay with you, I will be recording our conversation. The purpose of this is so that I can get all the details but at the same time be able to carry on an attentive conversation with you. I assure you that all your comments will remain confidential. I will be compiling a report which will contain all students' comments without any reference to individuals. Please note that there are no risks involved in participating in this research other than those involved in ordinary everyday life

Before we get started, please take a few minutes to read this consent form and sign if you are in agreement.

Do you have any questions before we begin?

PART 11:

a. **In your opinion based on your experience with BIM, how best can the following Building Information Modelling Risks be managed during the maintenance of buildings?**

❖ **Technical Risks (A)**

i. Insufficient or incorrect building information (**A1**)

ii. Poor adoption of BIM technologies (**A4**)

iii. Data loss during BIM-IFC file exchange (**A5**)

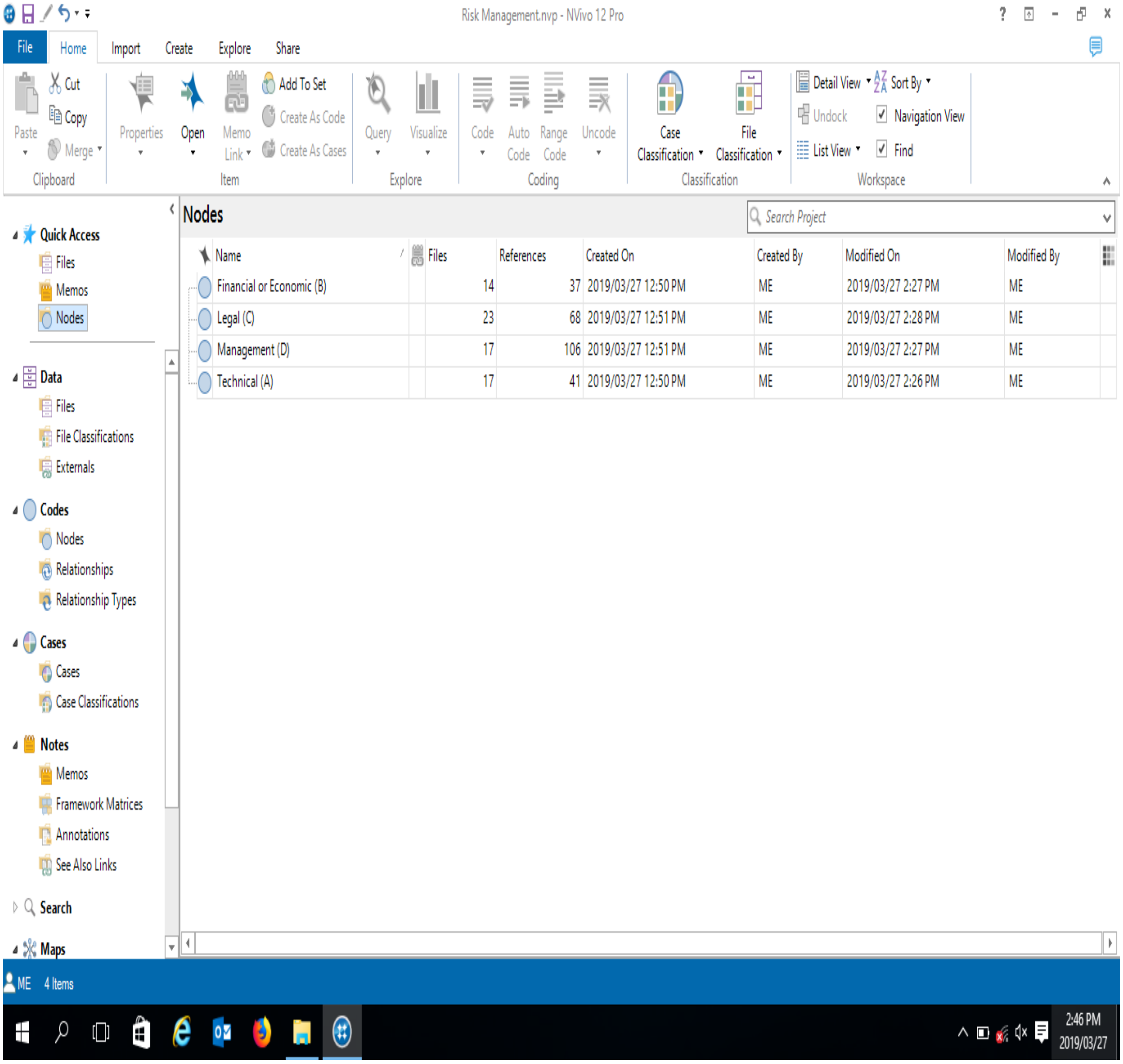
- **Financial/Economic Risks (B)**
    - i. Labour cost increase in training (**B2**)
    - ii. High initial investment costs (**B4**)
- **Legal Risks (C)**
    - i. Illegal changes in the model (**C1**)
    - ii. Coordination and amendment of the BIM model (**C8**)
    - iii. Ownership conflicts among stakeholders (**C9**)
    - iv. Intellectual property protection (**C10**)
    - v. Damages caused by human errors (**C11**)
    - vi. Lack of established case law (**C14**)
- **Management Risks (D)**
    - i. Lack of skilled personnel/BIM expertise (**D1**)
    - ii. Unclear specifications (**D2**)
    - iii. Poor coordination (**D4**)
    - iv. Lack of knowledge of BIM implementation (**D8**)

Thank You for Your Time.

CONCLUSION OF THE INTERVIEW

Once the interview is concluded, all notes and audio recordings should be checked.

Appendix D – NVivo Snapshot



Appendix E – Code Summary Report

Code Summary
Risk Management
2019/03/27 2:29 PM

File Type	Number of Files	Number of Coding References	Number of Words Coded	Number of Paragraphs Coded	Duration Coded

Node

Nodes\\Financial or Economic (B)

Nickname:

Classification:

Aggregated: No

PDF	14	37	124	37	

Nodes\\Legal (C)

Nickname:

Classification:

Aggregated: No

PDF	23	68	388	70	

Nodes\\Management (D)

Nickname:

Classification:

Aggregated: No

PDF	17	106	542	106	

Nodes\\Technical (A)

Nickname:

Classification:

Aggregated: No

PDF	17	41	177	41	

Appendix F – Ethics Clearance Certificate

SCHOOL OF CONSTRUCTION ECONOMICS AND MANAGEMENT RESEARCH ETHICS COMMITTEE

CLEARANCE CERTIFICATE	**PROTOCOL NUMBER** CEM/18/12/EM/MSC
PROJECT TITLE	Assessment of risks associated with BIM IN Maintenance OF commercial buildings in Gauteng
INVESTIGATOR	**Ernest Mutingwende** 1609591
SCHOOL/DEPARTMENT	SCHOOL OF CONSTRUCTION ECONOMICS AND MANAGEMENT
DATE CONSIDERED	7/12/2018
DECISION OF THE COMMITTEE	
EXPIRY DATE	8th December 2019
DATE	8th December 2018
CHAIRPERSON	Dr. Kola Ijasan
cc: Supervisor:	Dr. Ehsan Saghatforoush

DECLARATION OF INVESTIGATOR

To be completed in duplicate and **ONE COPY** returned to the Secretary Mrs. M. Sithole at the CEM reception desk.

I fully understand the conditions under which I am authorized to carry out the abovementioned research and I 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**