THE USE AND EFFECTIVENESS OF BUILDING INFORMATION MODELLING (BIM) IN THE SOUTH AFRICAN CONSTRUCTION INDUSTRY

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Contents

Declaration

I declare that this is my own, unaided work. It is submitted in partial fulfilment of the requirements of the Degree of Master of Science in Building at the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination at any other University.

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Abstract

The South African construction industry has not seen a spike in the implementation and use of Building Information Modelling (BIM) compared to other countries which include amongst others the USA, the UK and Hong Kong. This raises concerns regarding South Africa's competitive advantage and role in the global construction industry.

This research assessed and investigated factors that impacts on the use of BIM in the South African construction industry, using a mixed design approach of both quantitative and qualitative design methods, by which primary data was conducted through questionnaires distributed via the SACPCMP to cover the whole country and secondary data by means of semi-structured interviews with registered construction professionals around the Gauteng Province.

Whilst the responses received did not meet the required sample size, the results indicate that BIM is currently mostly used in the planning and design stages of construction projects in South Africa. Costs and the availability of skills are the two main factors identified that have a high impact on BIM use in South Africa. For South Africa to move towards full BIM implementation, it is necessary that the skills unavailability is addressed including government support as well as client influence on projects. Standards and regulations need to be put in place as currently there is no regulation or legislation for BIM use within the South African construction industry.

Dedication

To my wife Nthabi and my son Nasir, thank you for your support and encouragement.

Acknowledgements

I wish to extend my gratitude to my supervisor Prof. David Root for his guidance and support during the completion of the research.

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List of Acronyms

BIM	Building Information Modelling
CIDB	The Construction Industry Development Board
CIOB	The Chartered Institute of Building
ECSA	The Engineering Council of South Africa
HKIBIM	Hong Kong Institute of Building Information Modelling
IMESA	The Institute of Municipal Engineering of Southern Africa
IPET	The Institute of Professional Engineering Technologists
ISO	International Organization for Standardization
NHBRC	The National Home Builders Registration Council
PMI	The Project Management Institute
PMSA	Project Management South Africa
RICS	The Royal Institution of Chartered Surveyors
SACAP	The South African Council for the Architectural Profession
SACPCMP	The South African Council for the Project and Construction Management Professions
SACQSP	The South African Council for the Quantity Surveying Profession
SAIAT	The South African Institute of Architectural Technologists
SAICE	The South African Institution of Civil Engineering

1. Introduction

The concept of Building Information Modelling (BIM) has been around since the 1970's and has gone on to develop and has been used throughout the 1980s and the 1990s (Wong *et al*, 2011). BIM in the construction industry essentially involves the use of processes that do not only provide for designs to be carried out in 2 dimensions but in addition, it expands these processes to allow for the designs to be carried out in 3-dimensions, 4-dimensions as well as in 5-dimensions. It basically enhances the standard 2-dimension paper designs by using computer programmes to achieve 3, 4 and 5-dimension designs.

BIM use has also further developed and does not only include the design stages of the project but also extends to the construction phase with regards to the management of time, costs and resources as well as to the handover phase regarding the sharing of information related to the building and assets, which can include amongst others maintenance information required by the client or end user of the product (Gleason, 2013). BIM is therefore not only used during the construction phase but can be used for the life-cycle management approach in the construction projects.

A lot of countries around the world have implemented and are successfully using BIM within their construction, engineering and architectural sectors. These include amongst others the United Kingdom (UK), the United States of America (USA), few countries within the European Union (EU) as well as some Asian countries like Singapore and Hong Kong. Africa has not seen a spike in the use of the BIM within the construction industry. Wong *et al*, argues that "the USA is the pioneering country when it comes to the use of BIM around the world and as such the information flow with regards to the developments in the BIM context is therefore generally from the USA to the rest of the world".

Within the South African context, the construction industry development is driven by the Construction Industry Development Board (CIDB); which is a schedule 3a public entity established by the South African government to lead the construction industry (www.cidb.org.za). The CIDB was therefore established in terms of the CIDB Act 38, of 2000 and amongst others, the CIDB must promote:

- Uniformity in construction procurement
- Efficient and effective infrastructure delivery

- Construction industry performance improvement
- Development of the emerging sector, including industry transformation; and
- Skills development.

With regards to the development of the emerging sector, including the industry transformation, one can conclude that this should include implementation and development of technologies that will benefit the construction industry in South Africa and as such should include amongst others BIM.

A few papers have been written about whether BIM is being utilised in South Africa and to what extent does BIM have advantages if implemented within the South African context. South Africa is therefore playing catch up with the rest of the world and as a result the implementation of BIM might end up being too costly if not implemented sooner (Kaber, 2010). Kaber further concludes that "there are certain issues and problems which are hindering the successful implementation of BIM in the South African context". This research therefore further explores the various factors that are stumbling blocks in getting the BIM system fully implemented and utilised in the South African construction industry.

1.1 Problem Statement

The South African construction industry is part of the global construction industry at large and many South African construction companies do business with international clients in the private sector. The South African government also enlists some international organisations in implementing some of the public construction projects that it undertakes as part of the infrastructure drive currently being advocated by the government. It is therefore for this reason that the South African construction industry should move in the same direction as the rest of the world when it comes to construction technologies and advances like BIM.

It has been established that a lot of countries around the world have adopted the BIM concept and that in some countries BIM has been given a lot of attention by the private and public sector in the respective construction industries and there are efforts being made towards the adoption and use of the concept. From the available literature further discussed in Chapter 2, it appears South Africa is still far behind in embracing the concept of BIM. Even though the various professionals in the South African construction industry are familiar with the concept, it seems that there is no push or much interest in the adoption of BIM (www.engineeringnews.co.za).

There seems to be less interest from the various construction governing bodies to develop frameworks and policies regarding the complete adoption of BIM within the industry.

Therefore, whilst BIM is advancing in various countries as indicated above, South Africa is behind with regards to the use and implementation of BIM. It is for this reason that the research was undertaken to investigate what are the factors that impact on the use and implementation of BIM within the South African construction industry. The study is aimed at identifying these factors with the view that further research can be done to address and it is envisaged that the study will benefit the South African construction industry professionals and the industry development at large.

1.2 Research Aims and Objectives

1.2.1 Research Aims

The aim of the research was to assess the use and effectiveness of BIM within the South African construction industry. To achieve this, one needs to target the following:

- Understand the level of awareness of BIM with South African construction professionals;
- Identify if BIM is currently used in South Africa and at which stages of construction projects and this is limited to the planning, design, construction and handover stages of the projects; and
- Identify to what extent is BIM used throughout the whole project in South African construction projects. Operations and maintenance phase were not included in the research.

1.2.2 Specific objectives

From the aim of the research indicated above, the specific objectives of the research can be best summarised as follows:

- Uncover the extent to which BIM is used or implemented in the South African construction industry,
- Identify primary factors that seem to hinder the South African construction industry in successfully adopting and implementing BIM throughout the construction project.

It is therefore envisaged that this research will be of benefit to the various construction professionals which will translate to the benefit of the organisations under which they operate as well as the entire South African construction industry. Due to the limited time afforded to carry out the research, it is envisaged that the findings of the research will open further debate and thus room for further research within the same context.

1.3 Primary Research Question

The research was primarily undertaken to answer the following specific question:

- What are the factors that are impacting the successful use and implementation of BIM within the South African construction industry throughout the project?

1.4 Research Design and Methodology

Before we go into detail on how the research was conducted, it is of importance to first understand what research is. According to Leedy and Ormrod (2005), research is a systematic process of collecting, analysing, and interpreting information (data) in order to increase our understanding of the phenomenon about which we are interested or concerned. The key word to the definition provided is "systematic process". This is also emphasised by Saunders *et al* (2012); where research is defined as "something that people undertake in order to find out things in a systematic way, thereby increasing their knowledge".

The approach for the research was therefore an abductive approach, using a mixed method design, where primary data was collected using questionnaires and secondary data was collected by using semi-structured interviews. The data was then analysed by visual representation on graphs as well statistical analysis using appropriate methods by showing correlations between variables and calculating means and standards deviations to see if there is any common trend or agreement on the research data received from the observed sample. The detailed justification for the chosen method is provided under Chapter 3 of this report.

1.5 Ethical Considerations

The nature of this research was such that it needed at to be collected from individuals who are also part of organisations. This therefore requires a certain degree of ethical consideration when approaching these organisations and the respective individuals to access to request access.

Since the research was carried out for academies purposes, ethics clearance certificate was issued from the University. This assisted in making sure that the participants understood that the research was legitimate and that the data collected was to be used for academic purposes.

In addition, consent forms were issued to willing participants to provide details on the research subject as well to get their consent to participate on the research.

1.6 Limitations and Constraints

The research is for academic purposes as established and was done within the South African context. This therefore means that it was limited to the concept of BIM use within the South African concept whilst the literature reviewed was across the world, this was only done for comparison purposes as well as get data to answer the research question. It should also be noted that the research was only limited to BIM use construction stages in projects and that the in-depth use and maturity levels were not considered for the study or measured for effectiveness. Also, the cultural differences within the various countries for which literature was reviewed was not taken into consideration or viewed as a factor for the purposes of this study.

Time to carry out the research was also limited due to it being for academic purposes as such the data used for the study is based on the amount of data that was collected in the limited period afforded for the study. The research was also limited by the budget available in carrying out the interviews across the country, hence only the Gauteng Province was used for the interviews and the questionnaires only sent out country wide. The limitations and constraints are further detailed in Chapter 3 of this report.

1.7 Assumptions

The following assumptions were made for the purpose of the research:

- The fielding of questionnaires through the SACPCMP would entail enough coverage for the study to be representative of the South African registered CM and CPMs
- The chosen population is regarded as homogeneous by virtue of affiliation to the SACPCMP regardless of qualifications, years of experience, gender, etc.

1.8 Structure of the Research Report

Chapter 1: This chapter introduces the problem, the aim and objectives of the research, the research question, research design and method, ethical considerations, limitations, assumptions as well as the summary of the report structure.

Chapter 2: This chapter discusses all the literature sources that the researcher used in the research in order to supplement the need of why the proposed research had to be undertaken as well as to support the research problem/question stated in Chapter 1.

Chapter 3: This chapter discusses how the research was undertaken with regards to the research philosophy employed, research design, the research methods used in data collection, the ethical considerations, limitations and conclusions.

Chapter 4: This chapter goes into detail about the data that was collected with regards to the data analysis to establish whether it answers the research question. It should be noted that this chapter simply deals with how questions associated with the research were answered and not who answered in line with the ethical considerations.

Chapter 5: This chapter gives a summary of the findings based on the analysis done in Chapter 4 and provides an indication of whether the research question was answered or not as well as what lessons or recommendations the researcher puts forward in relation to the research problem.

2. Literature Review

2.1 Objectives of the Literature Review

The objective of this literature review is to first give a background with regards to BIM to gain a better understanding of the concept. Following the background and understanding of the BIM concept globally, the literature review will also assess to what extent BIM is being used in the South African context, when the BIM concept was introduced in the South African construction industry, whether it has been successfully implemented and effective, which sectors and professionals are currently using the BIM system in South Africa as well as to what extent are the various stakeholders contributing to the promotion, use and implementation of the BIM system in South Africa.

The literature will further establish how BIM is being used and implemented in other parts of the world, more specifically the developing countries like South Africa. As much as the literature will compare the use and implementation of BIM in the developing countries it will also touch on how the developed countries have successfully implemented BIM and how these countries promote and legislate the use of the BIM in their respective construction industries.

2.2 Background

BIM has a lot of definitions in various text, however for the purpose of this research Gu and London's perspective will be adopted. Gu and London (2010, p. 988) as cited by John Rogers, Heap-Yih Chong, Christopher Preece (2015) defines BIM as "an IT enabled approach that involves applying and maintaining an integral digital representation of all building information for different phases of the project in the form of data repository." According to this BIM definition, the information concerned can be geometric or non-geometric. Gu and London further add that "BIM is expected to envision efficient collaboration, improved data integrity, intelligent documentation, distributed access and retrieval of building data and high-quality project outcome through enhanced performance analysis, as well as multidisciplinary planning and coordination." Other definitions extend the use of BIM to the asset management, especially for the government procured construction projects (BIM-Industry-Working-Group, 2011, p.7 cited by Rogers *et al.*, 2015).

The extension of BIM to the asset management as indicated above is very critical to this research. This is because in the South African context, government is currently investing a lot in the infrastructure of the country in the form of buildings infrastructure, housing infrastructure, roads network infrastructure and other civil, electrical and mechanical infrastructure. All this drive is due to an attempt to provide service delivery for the many needs of the South African population, whilst meeting the demands of the developing country. It is therefore imperative to understand whether the South African government in its many infrastructure projects does implement BIM and to what extent if it is implemented.

As stated in the introduction of this report, the Construction Industry Development Board (CIDB) through the Construction Industry Development Board Act No. 38 of 2000, has been created by the South African Government "to implement an integrated strategy for the reconstruction, growth and development of the construction industry and to provide for matters connected therewith" (Construction Industry Development Board, Act No. 38, 2000). It is therefore also of importance to understand what the CIDB is currently doing with regards to the use and implementation of BIM within the South African context.

As already established, BIM has been in existence since the 1970s and has seen great development in the 1980s and 1990s with increased implementation in the construction industry to produce data-rich models of buildings and structures (A. Wong, F. Wong and A. Nadeem, 2011). The USA and the EU countries are the biggest consumers and users of BIM systems and technology, as well as some Asian countries. African countries are not well known to be big users of the BIM concept and this can be attributed to many factors, which are outside of the scope of this research, but the most obvious reason is that many countries in Africa are far behind when it comes to technology and advancement when compared to the rest of the world. The table from a research by Rogers *et al.*, (2015) briefly illustrates some of the countries that are implementing BIM as well as the professionals who are in the forefront of the BIM implementation within the respective countries indicated.

From the Table 2.1 below, it can be seen that BIM is not in full use by the whole construction industry in some parts of the world. BIM is mainly adopted by architects for the various construction or building projects. This can be attributed to the fact that BIM is an IT system which expands the design from 2D and 3D to 4D, 5D, etc; and as such it has been mostly welcome by the architects in bringing forth their designs and visions during the initiation and design phases of the construction projects. However, it should be noted that BIM encompasses

the whole project and therefore the use of BIM only in the design stages of the project cannot be seen as a full implementation and successful use of BIM by a long shot.

Table 2.1: BIM use in other countries

No.	Authors	Country	Description	Architects	Contractors	Quantity Surveyors	Combinations of some/all of them/whole industry
1	Tse et al. (2005)	Hong Kong	Data interfacing and adoption barriers in BIM modelling	X			
2	Howard and Bjork (2008)	Several countries	Expert's views on standardization and industry deployment in BIM				X
3	Gu and London (2010)	Australia	Understanding and facilitating BIM adoption in the AEC industry				X
4	Arayici et al. (2011)	UK	BIM adoption and implementation for architectural practices	X			
5	Keat (2012)	Malaysia	Strategies for adopting BIM for quantity surveyors			X	
6	Khosrowshahi and Arayici (2012)	UK	Roadmap for implementation of BIM in UK				X
7	Arayici et al. (2012)	UK	BIM implementation and remote construction projects: issues, challenges, and critiques	X			
8	Glennon and Brown (2013)	UK	Adoption of BIM Level 2				X
9	Reina (2013)	UK	BIM mandate in UK	X			
10	Shanmuganathan (2013)	Several Countries	BIM – a global consultant's perspective				X
11	Wong et al. (2013)	Several Countries	Successful adoption of BIM within organization				X

12	Eadie et al. (2013)	UK	Drivers for adopting BIM		X	X	
13	Aibinu and Venkatesh (2014)	Australia	BIM adoption and experience of cost consultants in Australia			X	
14	Gardezi et al. (2014)	Malaysia	Challenges for implementation of BIM in Malaysia				X
15	Mohd-Nor and Grant (2014)	Malaysia	Building Information Modelling (BIM) in the Malaysian architecture industry	X			

Note: X Is area of focus of the articles

Source: John Rogers, Heap-Yih Chong, Christopher Preece (2015)

2.3 BIM Practices in Other Countries

2.3.1 Hong Kong

Hong Kong is a small country in Asia which forms part of China. Although it is small in size, Hong Kong has seen a huge spike in the construction industry with several high-rise buildings because of confined space as well as a bustling civil infrastructure. Hong Kong also has a high volume of annual construction output compared to many countries in the world and as a result, the demands for productivity are high on Hong Kong projects due to the tight schedules, space restrictions, high land costs, etc (A. Wong, F. Wong and A. Nadeem, 2011). It is for these reasons that the private sector in Hong Kong has adopted and implemented the use of BIM as illustrated in the table below from the research done by Wong *et al.*, 2011.

Table 2.2: Use of BIM in various Hong Kong Projects

Project Name	Lead BIM Implementer	Scheduled for completion	Building Function	Distinguished Feature	BIM Scope
Building 20, Hong Kong Science Park, New Territories, Hong Kong	Hong Kong Science and Technology Parks Corporation	2010	R & D Office Building	Commercial building with green and Sustainable technologies	Integrated architectural, structural and MEP design

Cathay Pacific Cargo Terminal, Hong Kong International Airport, Hong Kong	InteliBuild BIM + 3D Consultants	2011	Air Cargo Terminal Building	Huge project, first of its type to use BIM	Multi-disciplinary coordination during design and construction
MTR Subways Stations, Hong Kong	MTR Corporation, Hong Kong	2009 onwards	Subway Stations	Visualisation of stations before being built	Design visualisation
One Island East	Gehry Technologies	2008	Office Tower	Tallest building to utilise BIM	Design and construction

Source: Wong *et al.*, 2011

From the table, it can be seen from the last column with regards to the scope of BIM, that as much as BIM is practised in huge construction projects in Hong Kong, it may not be utilised throughout the project. In the projects indicated in the table above, BIM was mainly used in the design and construction stages.

However, Hong Kong has established the Development Bureau (DevB), which regulates and formulates policies for government funded public construction related projects and spearheads the regulation and implementation of BIM even for the public sector (Wong *et al.*, 2011). Over and above the establishment of the DevB, Hong Kong has the Architectural Services Department (ArchSD). The ArchSD is responsible for the development of the government funded construction projects and is the biggest client for these projects with regards to the use and implementation of BIM.

With regards to the private sector funded projects, Hong Kong has also established the Building Department which regulates and controls the buildings in the private sector (20th Anniversary Booklet, Hong Kong: Buildings Department, 2013). When it comes to providing housing for the deserving Hong Kong population, its government has the Hong Kong Housing Authority which also serves to ensure that in such housing construction projects, the use and implementation of BIM is promoted. The Hong Kong Housing Authority has also developed a BIM Standards Manual for their Development and Construction Division which are aimed at implementation throughout the project and extends into the operation and maintenance phases

of the project (Hong Kong Housing Authority, BIM Standards Manual for Development and Construction Division, 2009).

In 2009, the Hong Kong Government started implementing guideline policies to enable the successful implementation of BIM. This was achieved through establishing the Works Project Information Standard (WPIS) which covers the computer-aided design (CAD) standard as well as object-oriented CAD (OOCAD), which Hong Kong considers necessary for the implementation of BIM (Wong *et al.*, 2011). Through the DevB, ArchSD, the Building Department, the Hong Kong Housing Authority and the WPIS, Hong Kong has established work groups which monitor the development of BIM solutions and evaluates its incorporation in the construction industry. The evaluations are done on a continuous basis to formulate strategic plans for a complete BIM implementation.

Hong Kong is the first country in the world to have a professional institute that promotes and facilitates the implementation of BIM. The Hong Kong Institute of Building Information Modelling (HKIBIM) was established in 2009 by a group of corporations, stakeholders and BIM application experts in Hong Kong to ensure the successful implementation and promotion of BIM (Wong *et al.*, 2011). The objectives of the HKIBIM are as follows:

- "to promote and advance the general education, understanding, appreciation and interest of BIM in management for the benefit of the member and the general public;
- to foster general awareness, understanding and concerted efforts in the Hong Kong community towards the advancement of these objectives;
- to establish an identity for the institute within Hong Kong and overseas;
- to establish and maintain standards of building information management practice in Hong Kong;
- to establish links with relevant institutes of tertiary education, government bureaus/departments, statutory bodies and other organisations;
- to research, facilitate and promote the means of better management of building information for improving communication, coordination, management, productivity, delivery time, cost and quality throughout the whole building ;
- to improve understanding of the range of professional competence of fully qualified members;
- to provide guidance on careers in the building information management profession;

- to establish and maintain a code of conduct for practitioners of BIM in Hong Kong."

The objectives of the HKIBIM as set out above are a clear demonstration that the government of Hong Kong is committed to the promotion and implementation of BIM in its construction industry, with an aim to monitor and continuously improve the standards by which BIM is implemented. It is therefore imperative to understand within the South African context if there are any such initiative from both the private and the public sector.

The HKIBIM is a well organised institute with a structure as depicted in the diagram below, from which was outsourced from the HKIBIM website(www.hkibim.org), cited by (Nadeem, et al, 2011):

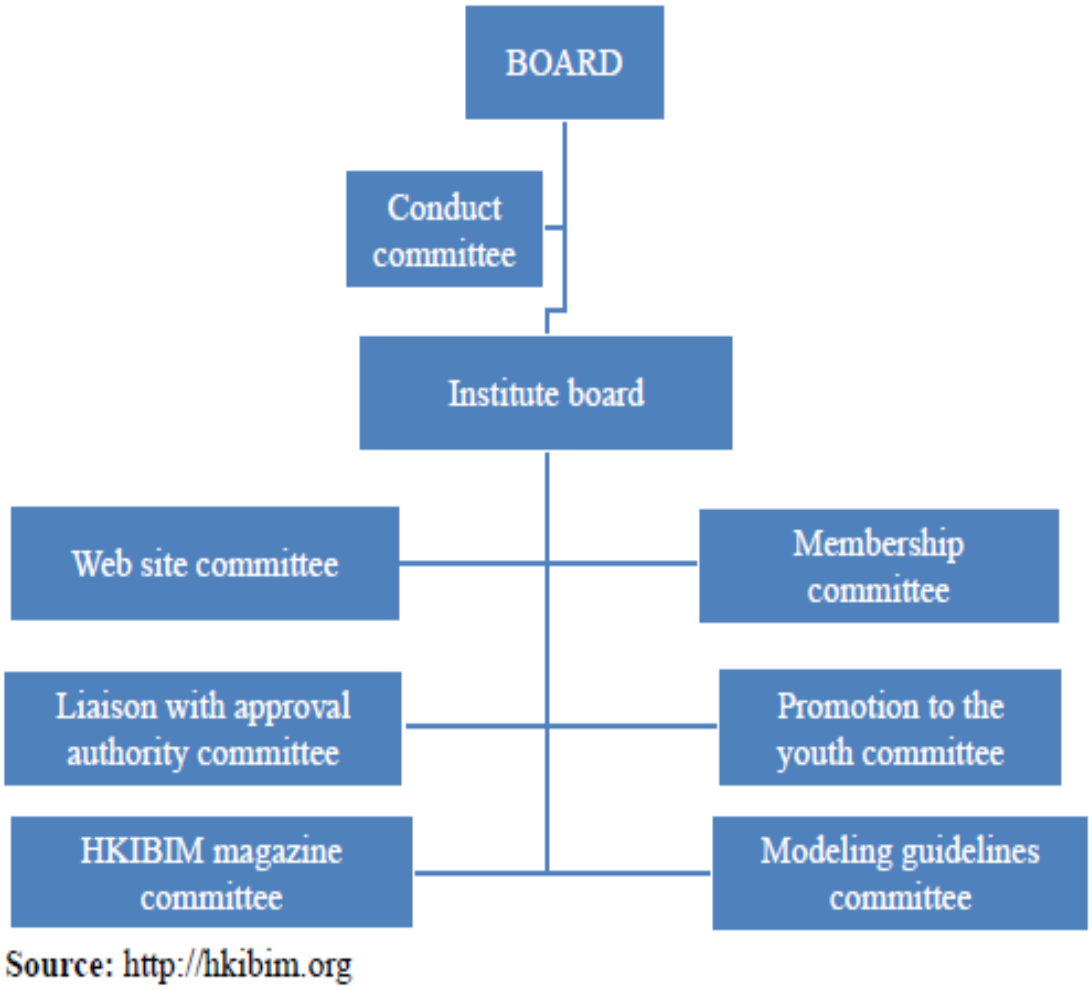

Figure 2.1: HKIBIM organisational structure

As much as Hong Kong is smaller in size compared to South Africa and other countries in the world that practice BIM, it should be commended for the strides that it has made in ensuring that there are institutions that are in place specifically to promote the use and implementation of BIM in that country. In addition to the HKIBIM, Hong Kong also has the Government Property Agency (GPA) created in 2008, which has as its main objectives the acquisition and allocation of projects, the management of property and estate utilisation, whilst ensuring the promotion of BIM (Wong *et al.*, 2011). It can be said that Hong Kong is one of the leading countries outside of the USA, UK and the EU which is in the forefront in the promotion and development of BIM.

2.3.2 The United States of America

The USA is amongst the biggest consumers of BIM and associated technologies as stated in 3.2 above. In the same way that Hong Kong has various agencies or institutions that promote the use of BIM, the USA as the oldest country to adopt the use of BIM has the US General Service Administration (GSA) as a prime agency that actively promotes BIM in that country (Wong *et al.*, 2011). The GSA as the government agency is tasked with proving and maintaining buildings for the various US federal agency workers across the country. The number of buildings involved currently run into thousands, which include government owned as well as leased buildings.

Since the GSA is a government agency it has as its focus the building and maintenance of public facilities, which include amongst others courthouse, office buildings for various government agencies and departments and border stations across the United states. With the USA being a big country in size and volume it is no surprise that in 2007, it undertook projects over US $8 billion, which consisted of new construction projects as well as the renovations and modifications of existing buildings totalling 170 buildings (Wong *et al.*, 2011), which had a combined rentable area of 340 square feet. This was all successfully implemented using BIM as promoted by the GSA.

According to Wong *et al.*, 2011, the chief architect of the GSA's Public Buildings Services (PBS) "was responsible for the implementation of BIM in these projects". This was achieved through the launch of the GSA's national 3D-4D programme in 2003 and it had as its objectives the following:

- "Establishing policy to incrementally adopt 3D, 4D and BIM for all major projects.

- Leading 3D-4D-BIM pilot applications and incentives for current and future capital projects.
- Providing expert support and assessment for ongoing capital projects to incorporate 3D, 4D and BIM technologies.
- Assessing industry readiness and technology maturity.
- Partnering with BIM vendors, professional associations, open standard organisations and academic/research institutions."

The many projects undertaken by the GSA in the USA through the implementation of BIM has seen the GSA being awarded many awards in recognition of its successes in the field of BIM. Amongst these awards are the "Honourable Mention" award in 2005, by the American Institute of Architects – Technology in Architectural Practice (AIA TAP) conference, the BIM Award for the Analysis or Simulation Category at the AIATAP conference in 2006, the jury's choice category at the AIATAP conference in 2007 and three awards in 2008 at the AIA TAP 2008 conference for its projects under categories for (Wong *et al.*, 2011):

"(1) the design/delivery process innovation using BIM;

(2) outstanding sustainable design using BIM; and

(3) support for human use and innovative programme requirements by using BIM."

As part of the fulfilment of the BIM obligations, the USA through the GSA undertook various projects to implement the use of BIM and amongst these projects are the US Courthouse, El Paso, Texas; a total of 300 NLA Federal Building, Los Angeles, California; Border Station Prototype, US-Canadian Border; Eisenhower Executive Office Building, Washington, DC; GSA Regional Office Building, Washington, DC, to name a few (Fallon, 2005 cited by Wong *et al.*, 2011). According to Dakan, 2006, cited by Wong *et al.*, 2011, the key objectives of undertaking these projects were "the laser scanned 3D modelling, early detection of design errors, building space efficiency, 4D schedule modelling, building rehabilitation, 4D cost-time trade-off, building energy analysis, building massing and design-construction integration".

The USA has made tremendous strides in being one of the leading countries which are for and promoting the use and implementation of BIM through its programmes and this can be best summarised by a quote from the AIA's 2005 award note as cited by Wong *et al.*, 2011:

"The first of its kind in the world, this programme earns special mention as a significant event in the development of BIM, challenging design, construction and software providers to improve. It exhibits the advantages of BIM on a variety of projects (AIA, 2005)."

2.3.3 Malaysia

Malaysia just like South Africa is one of the developing countries in the world and some might argue that perhaps it is far developed than South Africa. It is however interesting to note that from a research done in 2015 by John Rogers *et al*.; Malaysia has received BIM very well however has not progressively adopted its use, but plans have been put in place for the use and promotion of BIM by the construction industry.

Rogers *et al.* (2015), carried out a research on the Malaysian construction industry with a specific focus on the adoption and use of BIM by the Consulting Engineering Service (ECS) firms. The objective of this research was to "determine the perceptions, barriers, governmental support and intentions in adopting BIM, and second, to identify the key drivers for adopting BIM within two years" (Rogers *et al.,* 2015). From the findings of the research conducted by Rogers *et al.* (2015) the results showed that "the firms have a concept of BIM that equates to industry authorities' norms; yet the lack of well-trained personnel, guidance and governmental supports were identified as the main barriers to adoption. Nevertheless, the firms were prepared to adopt BIM where market demands and competitive advantage and these were the main drivers to adoption within two years.

In addition, from the research carried by Rogers, other barriers to the adoption of BIM within the Malaysian context were identified as follows:

- "BIM is perceived as a complex, difficult to implement and expensive technology (Eastman *et al*., 2011; Lu and Li, 2011; Roper, 2012);
- expensive, lack of suitably skilled human resource and organizational and process difficulties as barriers to BIM adoption (Teo, 2012);
- technical (interoperability), process, cost, legal, human resource skills as barriers and market demand (Baba, 2010)."

The above barriers require that there should be a relationship with regards to the processes and the human resources interface in gradually implementing BIM as indicated in the figure below

by Bew-Richards endorsed by the UK Government (Cabinet-Office, 2011) as cited by Rogers *et al.*, 2015.

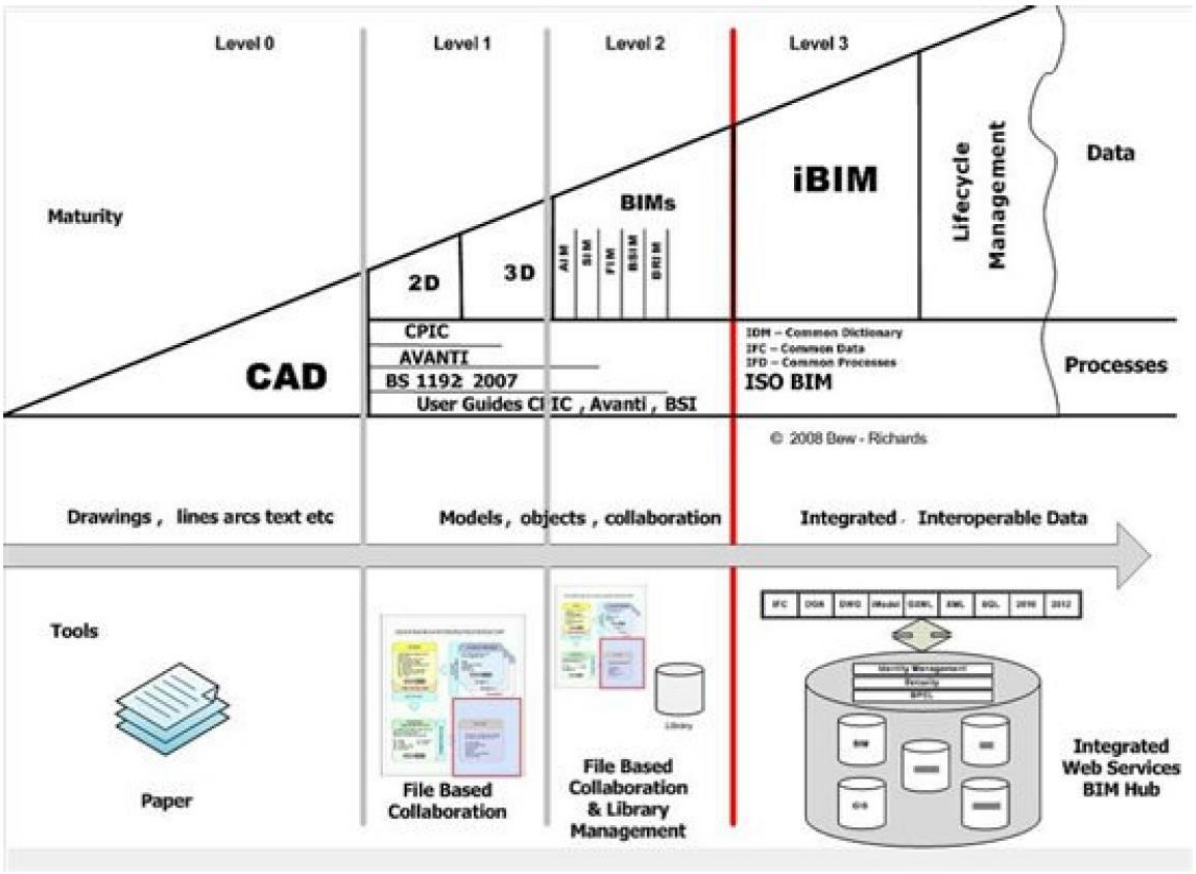

Figure 2.2: Levels of BIM implementation

Source: John Rogers, Heap-Yih Chong, Christopher Preece, (2015)

Rogers *et al.*, (2015) further identifies a few factors within the Malaysian context that have to a certain extent an impact in the adoption and implementation of BIM. These factors are briefly discussed and summarised below.

Financial considerations

Since BIM is software based and as such requires interfacing with other software, it is argued therefore there is a substantial cost component for an organisation and the country at large to adopt and start implementing BIM. Although the interfacing to other construction related software can be done with ease, the costs associated with it does become a factor when considering the move away from the common construction related software to BIM.

Process changes

Within an organisation or a country there are established processes with which it conducts its day to day business and operations. Some would even term this the organisational culture or the policies and regulations for the country. The changes from the established processes and policies in general require commitment from all levels and stakeholders. This also comes with a bit of financial considerations and effort, as such the process changes can also be seen as a factor and barrier in the BIM adoption and implementation.

Human Resources

As indicated above, process changes require commitment from all stakeholders. By nature, stakeholders in many construction projects consists of natural persons as well as organisations. Within said organisations there should be a drive from the decision makers coupled with acceptance and commitment from the workers or employees and other associated bodies. In addition, there should be suitably qualified and trained personnel at all levels to ensure successful migration to new systems, which can also hinder the adoption and implementation of BIM if not available.

Legal Factors

By its nature, BIM requires that there is collaboration between the various teams involved in the construction project. This includes collaboration between the design team and the project team. It is for this reason that some sort of protection from infringements is afforded to retain certain rights to specific individuals and organisations. Though not much research has been done in this aspect it remains a concern and as such a factor in the adoption and implementation of BIM simply because BIM requires information sharing which can be a legal nightmare if not properly legislated and controlled.

Professional Support

Within many countries there are professional bodies established to regulate and continuously improve their respective construction industries. As much as most countries around the world tend to align these bodies and associated regulations to the internationally recognised standards, most countries still tailor these based on the country's specific needs and cultural values. These

specific needs and cultural values in some instances can be a factor or a barrier in adopting and implementing BIM which is a global system suitable for any country in the world.

As much as these barriers have been established in developing countries like Malaysia, it should be noted that from the research conducted by Rogers et al (2015), Malaysia has positioned itself to start implementing BIM in two years i.e. 2017. This commitment was as a result of Rogers' research which included a focus workgroup that consisted of the following groups:

- "four participants from the existing ECS firms that were using BIM;
- the ACEM was also requested to nominate a participant;
- the Construction Industry Development Board (CIDB) of Malaysia, the government agency responsible for construction, were asked to nominate one participant;
- the PAM was also requested to nominate a participant;
- the Chartered Institute of Builders (CIOB) was asked to nominate one participant;
- a Malaysian University providing BIM education modules was asked to nominate an academic familiar with BIM;
- BIM consultants – (one MEP engineer, one strategist); and
- two Architects with BIM experience."

As per the indications above, Malaysia has accepted BIM within its construction industry even though it has not been widely used. The interesting and encouraging part about Malaysia as per Rogers' research, is that strides have been made in getting the construction industry stakeholders in Malaysia to come together with an aim to move towards the use and adoption of BIM by the majority if not the whole industry.

2.3.4 Denmark and Iceland

Denmark and Iceland are two countries that are part of the Nordic countries of Europe. The other countries that form part of the Nordic countries are Sweden, Norway and Finland. All the other countries except for Iceland are commonly referred to as the Scandinavian countries. Iceland is by far the smallest country amongst all these countries with an estimated population of just over 300 000 as at 2013, compared to a population of between 5 and 10 million for the other four countries (Per Anker Jensen, Elvar Ingi Jóhannesson, 2013). It can therefore be

deducted that Iceland's construction industry is a very small industry compared to the other Nordic countries.

Jensen *et al.*, 2013, conducted a research in the use and implementation of BIM in Iceland drawing comparisons to BIM use in Denmark. The research shows that Denmark has "started implementing BIM technology as a part of increased use of information and communication technology (ICT), in a hope that it will lead to better quality buildings and increased productivity in the industry" (Jensen *et al*., 2013). The Denmark construction industry has thus gained some ground with its digital use in construction for the implementation of BIM as compared to Iceland. This is also because Denmark is more technologically advanced than Iceland.

The implementation of BIM in Denmark was mostly due to the digital construction concept which was introduced by the Danish government in 2002 through the launch of a competitive package called "Will to Grow" (Jensen *et al.*, 2013). According to Jensen *et al.*, 2013, "one of the objectives of this package was to increase productivity and competitiveness in the Danish construction industry by means of improved utilization of ICT (EBST, 2005, p. 3)". Therefore, the intensive use of IT by all stakeholders in the project was intended as a drive to move towards the use and implementation of BIM. Coupled with this, the Danish government intended to use this to create IT standards and guidelines to be used throughout the construction industry for best practice purpose (Jensen *et al*., 2013).

In contrast the Icelandic construction industry has not progressed as much in the use and implementation of BIM. Studies like the one conducted by Jensen, do however indicate that the Icelandic construction industry firms are well aware of BIM and are willing to adopt the concept. Even though BIM has not been fully implemented in Iceland, the research conducted has provided recommendations for the use and implementation of BIM both at national level and organisational level. The following are excerpts from Jensen's research with regards to how Iceland can successfully adopt BIM at all levels and this can be applied to any country including South Africa:

"On national level, authorities are recommended to:

- Increase the general knowledge of BIM through public initiatives. Inform the building industry about BIM, its features, its advantages and disadvantages. This must be

introduced in the educational system. Emphasis must also be put on the cultural changes followed by BIM – not only the technical matters.

- Consider that public clients order simple building models of existing buildings (so-called Slim BIM). Such projects could serve as a good introduction of BIM technology to the building industry.
- Enter cooperation with the Nordic countries regarding the development of standards and guidelines. Due to its smallness, the Icelandic market has limited resources to provide all the support needed to facilitate an effective implementation. In a more comprehensive market, this step may not be necessary though.

The individual organizations are recommended to:

- Start the implementation of BIM now – but start slowly. Implementing BIM is much more than just implementing a new software system. A paradigm change will occur in the way people work and it will take a long time for everybody to become comfortable with that. Icelandic companies should try to use the time during an economic recession to rethink their work processes.
- Choose the right pilot projects. Start with simple projects and define a few subjects at a time to work with. It is easy to get lost by including too many details at the early levels of the implementation.
- Find the super-users. They are not necessarily those who are the most experienced CAD users since old working habits can turn out to be a barrier. Seek for those who show interest in finding new, more efficient ways of doing things.
- Seek out cooperation with companies from the Nordic countries. Many companies in Scandinavia have already acquired experience with using BIM technology. Establish connections and widen the horizon."

2.4 BIM in South Africa

Over the last few years the South African construction industry has seen and increasing uptake in the use of BIM on many major construction projects mostly at the design stages of the project and efforts are being made to allow BIM to move into the construction phases of the major construction projects (www.engineeringnews.co.za). A lot of companies, especially consulting engineering firms have taken it upon themselves to drive the adoption and implementation of BIM within their organisations. This is due to the ease with which hardware and software is

becoming increasingly accessible and cheaper to acquire even within the South African market. Even though the use of BIM in South Africa seems to be more at the design stages of construction projects it should be acknowledged that the South African market has to a certain extent embraced BIM (www.engineeringnews.co.za).

As much as the drive seems to be more at the organisational level it is worth looking into what is being done at a national level to support the use and implementation of BIM and perhaps to legislate and possibly make it a compulsory tool within the South African construction industry. For this reason, it is therefore worth considering what organisations like the CIDB are doing in the implementation of BIM at national and organisational level, as an organisation tasked with the development of the construction industry under the Construction Industry Development Board Act No. 38 of 2000. The objectives of the CIDB in terms of the Act are, amongst others, to promote the contribution of the construction industry in meeting national construction industry demand and in advancing industry performance, efficiency, and competitiveness.

In addition, the CIDB is responsible to promote, establish or endorse uniform standards that regulate the actions, practices and procedure of parties engaged in construction contracts. It however appears that the CIDB has not been as involved in the promotion of BIM within the South African construction industry which should be part of its objective in promoting standards. The CIDB as indicated in its objective is therefore also required to engage with stakeholders with regards to the use and the implementation of BIM within the construction industry. The CIDB as indicated in its objective is therefore also required to engage with stakeholders with regards to the use and the implementation of BIM within the construction industry. It is therefore of interest to see that the CIDB is not as involved with BIM implementation.

As indicated in the beginning of this section, the South African construction industry has embraced the BIM concept since its introduction in South Africa around 2004 (Kotze, 2013). Whilst this the research's focus is not on the in-depth use and maturity levels of BIM as stated under limitations in Chapter 1, it should be noted that South Africa is not mature in the adoption and usage of BIM and there is less demand from both the private and public sector to adopt BIM as the mainstream technology (Booyens et al.2013). As established earlier the adoption and use of BIM has mainly been on design organisations and it is done in isolation and not as a collaboration tool amongst design stakeholders (Froise and Shakantu 2014).

The slow pace at which the adoption and use of BIM in South Africa has progressed could be as a result of the lack of involvement of the major role players and stakeholders including amongst others the government, bodies such as the CIDB, the Council for the Built Environment (CBE), etc. The government as well as the regulatory bodies involvement is important and also the most commonly used strategy to impose mandatory requirements for BIM usage on projects in the public and private sectors (McAdam, 2010; Wong et al,2013). Within the South African context, BIM is mostly driven by organisations within the industry with no involvement from the government, regulatory and professional bodies.

Whilst the BIM advanced countries like Hong Kong created an institute like The Hong Kong Institute of Building Information Modelling (HKIBIM) as early as 2009, in contrast, in South Africa the South African BIM Institute was only created in 2015 (BIM Institute of South Africa 2015). The fact that it took as long as ten (10) years to have such an institute in South Africa since the introduction of BIM within the country in 2004, only shows and demonstrates the slow pace at which the South African industry has advanced in the adoption and implementation of BIM in projects.

It should further be noted that whilst the BIM Institute of South Africa does publish documents regarding the use of BIM, these are not standards or regulations. Furthermore, the BIM Institute of South Africa is not affiliated nor endorsed by any of the construction professional bodies. As such, the training provided by the BIM Institute of South Africa to the various construction professionals is not recognised by the various bodies with regards to continuous professional development, aimed at advancing knowledge and development within the construction industry.

In terms of the limitations of the research, it was indicated that the maturity levels of BIM implementation in South Africa do not form part of the research. It is however worth noting that conceptual frameworks have been developed around the world for BIM implementation maturity levels. The following table shows stages and steps for a conceptual framework for BIM implementation maturity levels (Succar, 2009).

Table 2.3: Stages of BIM implementation Maturity Levels

BIM STAGE	NAME	DESCRIPTION	EXAMPLE/APPLICATION
Stage 1	Object-based modelling	Involves single disciplinary modelling expertise	Architect developing and sharing a Revit model with other AEC professionals
Stage 2	Model-based modelling	Multiple disciplines collaborate to produce a model with interoperable interchange.	Sharing of data between an architect and engineer
Stage 3	Network based modelling	The development of interdisciplinary models which are significantly rich in model data and integration through dedicated model server technologies. At this stage models would comprise data.	Examples of data model data at this stage includes data on model intelligence, lean construction principles and, whole life costing, etc.

In summary Table 2.3 above shows characteristics of each stage, where Stage 1shows the fast-tracking form design to construction, Stage 2 involves a need for collaboration between stakeholders and Stage 3 shows the integration of the various professionals which extends to the whole life cycle approach to costing of projects. It is therefore worth noting that there are already established conceptual frameworks which South Africa can use when it comes to the implementation of BIM within the construction industry.

Further to the stages indicated in Table 2.3, Succar further further describes steps that need to be followed for BIM implementation for each stage as indicated in Figure 2.3 (Succar, 2009).

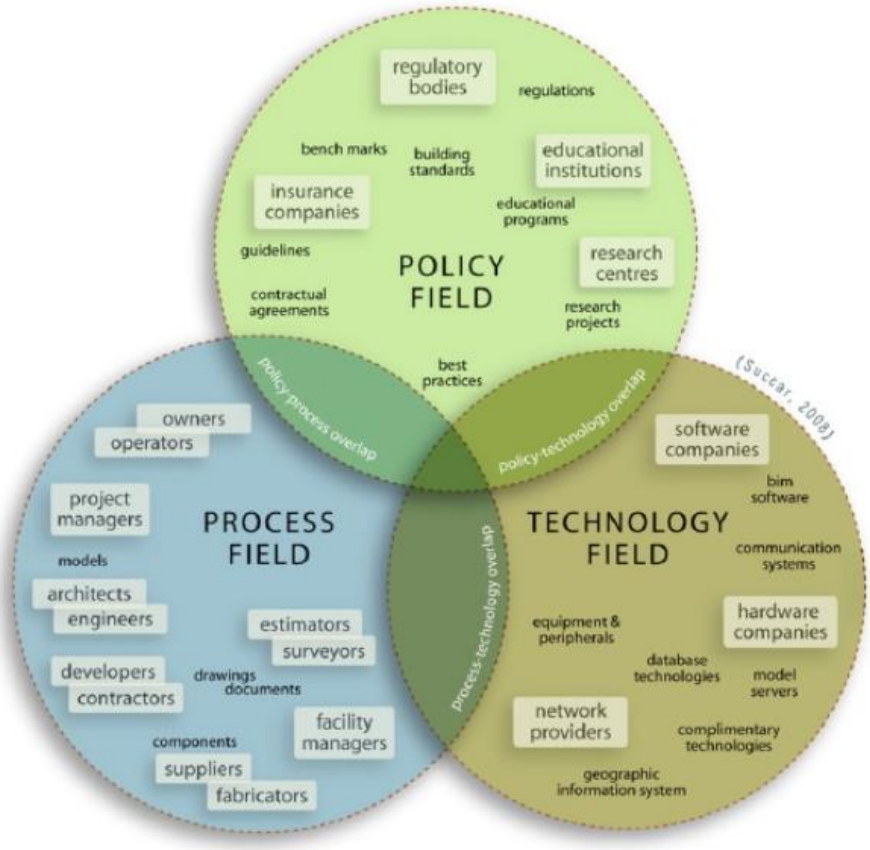

Figure 2.3: Three Interlocking Fields of BIM Activity-Venn Diagram

The figure above indicates steps that need to be taken at each of the stages indicated in Table 2.3 for the implementation of BIM. Each of the items within the specified fields need to be taken into consideration when one considers a conceptual framework for the implementation of BIM. This is therefore applicable in the South African context in order to start with steps towards the implementation of BIM in the construction industry.

2.5 Conclusion

Based on the literature reviewed, one can conclude that BIM is a construction IT tool that expands the traditional approach to construction to more capabilities. BIM can be used at virtually all stages of a construction project. Traditionally, tools like Auto CAD are mostly used for the design on construction projects mostly in 2-dimension and BIM expands this to 3,4,5-dimensions. It is also worth noting that as much as most construction professionals focus

on the design stages for BIM usage, BIM can be used as early as the planning stages of the project. This stage involves gathering information on the project requirements and scope which can be later translated into the design development phase. All this information can be captured as early as planning and can become valuable for the design and construction stages of the project to ensure that the project is delivered in accordance with the client requirements and budget, as well as the allowed time.

From the literature reviewed one can deduce that most construction practitioners and most countries use BIM more at the design and construction phases of the project. This can be attributed the fact that BIM has the capabilities of presenting the building or design information in many dimensions and perhaps this is where the focus tends to be for most projects. Countries like Hong Kong where a lot of big projects had BIM implemented also suggest that the practise is mostly at these stages, however BIM extends further as established earlier. This therefore means that BIM can also be used at the handover stage, where information on the project with regards to asset information and maintenance requirements can be categorise appropriately for the clients and end user. This information would then be of benefit during the operations and maintenance phases of the project. This therefore speaks to the life cycle approach to the application of BIM in projects.

For any country to implement BIM successfully, the literature therefore suggest that collaborations are very important between the various role players within the construction sector. These role player or stakeholders include both the public and the private sector, as evidenced with the advancement made by such countries like the USA and Hong Kong. The role players need to engage regarding the establishment of standards, manuals, regulation and legislation around BIM practise. However, the setting up of the aforementioned items does not automatically translate to successful implementation and requires the necessary skills development and training which include continuous evaluation and improvements, which can only translate to success on various projects where BIM is implemented. This in turn benefits and grows the country's construction sector which later translate to the growth if economies as well.

Whilst there are challenges to be considered, for example, financial considerations, legislative matter, organisation cultures, integration, etc, the advanced countries in the use of BIM have overcome these challenges by establishing institutes that are focused in the research and advancement of BIM within their respective context. The process therefore requires long term

planning and careful consideration of all factors at play in order to successfully navigate these challenges.

In the South African context, there is little to no literature available regarding BIM use and implementation. This begs a question with regards to the role that the various stakeholders are playing in the advancement of technologies to improve how projects are undertaken and delivered. The advancements made in other parts of the world far surpass the South Africa constructions advancement in BIM. South Africa odes not seem to have even scratched the surface when it comes to unlocking the barriers of BIM implementation. No evidence of collaborations between the private sector and the public sector seems to exist where initiatives are being made to develop standards and regulate the use of BIM. The BIM Institute of South Africa does not have the support of other construction stakeholders when compare to other BIM advanced countries. It is therefore a lone voice advocating for a concept that does not seem to resonate with the rest of the South African construction industry.

Therefore, such a research is imperative to be undertaken to identify the contributing factors to this phenomenon. We need to identify the barriers that exist within the South African context, such that we can start unlocking them and begin with the dialogue and collaborative process where standards and regulations can be established, implemented and continuously improved to realise the benefits that technologies and advances like BIM have in the successful delivery of construction projects.

3. Research Design and Methodology

3.1 Introduction

Chapter 1 of this report indicated the research question that the study was concerned with. This section will therefore deal with how the research was conducted as well as the various methods that were used in collecting the data required for the research and how it was analysed to answer the research question. Also, to be dealt with in this chapter will be the ethical issues which were need addressed and considered when collecting and reporting on the data for the proposed research.

Before we go into detail on how the research was conducted, it is of importance to first understand what research is. According to Leedy and Ormrod (2005), research is a systematic process of collecting, analysing, and interpreting information (data) in order to increase our understanding of the phenomenon about which we are interested or concerned. The key word to the definition provided is "systematic process". This is also emphasised by Saunders *et al* (2012); where research is defined as "something that people undertake in order to find out things in a systematic way, thereby increasing their knowledge".

It is for this reason that for any research undertaking, a certain methodology or design is undertaken in order to properly understand and answer a specific research question like the one provided in Section 1.3 of this report. This therefore requires systematic planning, gathering of information as well as analysis of the information or data in order to understand as well as establish correlations and relationships which will assist in answering the research question. This section therefore seeks to clarify how the various research techniques and tools were used to address the stated research question. Each chosen technique and tool is further substantiated for its suitability in relation to the topic and research question as well as ethical issues addressed during the undertaking of the research.

3.2 Research Philosophy

When conducting research, it is critical to note that it is not only the method of collecting data that is important but also the reason as to why that method or a combination of various methods were adopted. The research methods that are normally undertaken are mostly based on the assumptions that are made during the research process (Saunders *et al*, 2012). According to

Saunders, these assumptions are what translates to a research philosophy that researchers adopt during a research process.

The various research philosophies fall within two categories namely ontology and epistemology. Ontology is concerned with nature of reality whilst epistemology concerns what constitutes acceptable knowledge in a field of study (Saunders *et al*, 2012). The four various philosophies within the stated categories are positivism, realism, interpretivism and pragmatism. It should therefore be noted that the research adopted a pragmatism philosophy. Pragmatism asserts that concepts are only relevant where they support action (Kelemen and Rumens 2008 cited by Saunders *et al*, 2012). The reason for this approach is that one should recognise that it is possible to work with different philosophies and that there may be multiple realities. The other reason is that the research was undertaken in a South African context however embedded within the research question is a global concept which may present multiple realities. In addition, the research question deals with factors that affect or hinder the successful use of BIM with the South African context, therefore there may be a variety of issues that might not be applicable to other parts of the world and unique to the South African context.

3.3 Research Approach

The other important aspect to consider when undertaking research is the approach by the researcher. In this regard, the approach can be deductive, inductive or abductive. Saunders *et al*, 2012 defines the three approaches as follows:

- ***Deductive approach*** involves the development of theory that is then subjected to a rigorous test through a series of propositions;
- ***Inductive approach*** involves the collection of data to explore a phenomenon which is then used to generate theory.
- ***Abductive approach*** involves the collection of data to explore a phenomenon, identify themes and explain patterns, to generate a new or modify an existing theory which is subsequently tested through additional data collection.

This research adopted an abductive approach. This is because an abductive approach is in a sense a combination of both the inductive and deductive approaches. By nature of the research question, it is only practical that it necessitated that the research moves back and forth from theory to data as well as data to theory. Therefore, a lot of theory with regards to literature

review in Chapter 2 of this report was used and then primary data collected and analysed to answer the research question. During the data collection process, there was a need to also revisit the existing theory in relation to the research question in a form of more literature review, this to assist in evaluating, analysing and reporting on the primary data collected. This is referred to as secondary data and hence the abductive approach.

3.4 Research Design

Research design by definition is a general plan of how one goes about answering the research question (Saunders *et al*, 2012). The process therefore requires clear objectives, sources for the data collection, method of the data collection, data analysis, ethical considerations as well as any constraints that need to be considered during the research process. This is elaborated upon in the following sections.

3.4.1 Research Methodology

There are mainly two research methods normally used when undertaking a research project namely qualitative research design and quantitative research design. Qualitative research is mostly associated with an interpretive philosophy (Denzin and Lincoln 2005 cited by Saunders *et al*, 2012) whilst quantitative research is normally associated with positivism. It is however common that most researches adopt a multiple method research design which incorporates both qualitative and quantitative research. Due to the nature of the stated research question which is aimed at understanding factors affecting or facilitating the use of BIM, there is a need to identify these factors and also rate their impact with regards to how the affect the use an implementation of BIM within the South African context. The research therefore used a combination of both qualitative and quantitative research thus making it a multiple methods research design. It is important to note that the chosen multiple method design is also divided between multimethod research and mixed methods research.

According to Tashakkori and Teddlie 2010 cited by Saunders et al 2012, in the multimethod research more than one data collection technique is used with associated analysis procedure, but this is restricted within either quantitative or qualitative design. The research was therefore more qualitative than quantitative.

3.4.2 Data Collection

As indicated in the above section, the research adopted a multiple method design. This therefore required that the data collection process also be a mixed approach. The research initially investigated the existing theory in a form of literature. Following the investigation of available theory, primary data was collected using semi-structured interviews. This is because the research is in a form of an explanatory research and this form of data collection is mostly applicable to such research. Also, the fact that whilst the research is a multiple method research, it is more qualitative, and interviews are one form of collecting qualitative data.

In addition to the semi-structured interviews, the data was also collected in a form of questionnaires which were administered to the chosen population without necessarily having face to face interviews. This was mainly because the research also needed to cover a wider population within South Africa. Therefore, due to the available time it was not possible to conduct the interviews face to face, which formed part of the constraints as indicated in section 3.6 of this Chapter.

Since the research entails the use of BIM in the South African construction industry context, it was impossible to collect the necessary data on all the role players or stakeholders through the construction industry in the country. It was therefore necessary that sampling is done to acquire the necessary and relevant data for the research from the available population of the construction industry stakeholders.

Based on the research question and methods of data collection, non-probability sampling was used for the research. Because the research is focused on the construction industry it was logical that non-probability sampling be used as it focused the research on the specific role players within the construction industry, which best suited the aim of the research. It can therefore be concluded that random sampling was adopted for this research.

The random sampling was of a homogeneous nature in that the research itself is concerned with BIM, which is used by the various stakeholders in the construction industry with diverse needs and characteristics. It was envisaged that for the semi-structured interviews a sample of between 30 and 40 interviews would be conducted, with stakeholders and professionals on the construction industry. The sample was split between the various professionals and organisations which included amongst others; contractors, consulting firms, architectural firms,

various engineering and project management professionals operating within the private and public sector, as well as members of the BIM Institute in South Africa, just to name a few.

The rest of the data was then collected by means of questionnaires which were distributed electronically to a large sample of about 70 stakeholders in the construction industry with varying interests and professions like those targeted for the semi structured interviews. It should be noted that the semi-structured interviews were conducted with participants within the Gauteng Province with the questionnaires administered electronically to participants operating in other parts of the country to reach a wider population. Professional bodies were used to assist in getting access to these professionals from their data bases.

Following the collection of primary data through the methods indicated, secondary data was collected based on the data received as well as during the analysis stages of the data. This was done to verify certain facts that were established during the process of primary data collection. The secondary data included more literature review in a form of publications, journals, books, internet, etc.

3.4.3 Data Analysis

As has already been established in the previous section, the research was a mix of qualitative and quantitative nature. It therefore follows that the data collected was partly qualitative and quantitative, as such the method of data analysis chosen was specific for each case.

Since the research was more qualitative it should be noted that there were very few quantitative analyses required as most of the data collected was more nominal or descriptive in nature. Therefore, the method of analysing this quantitative data was the examination of trends. This was done by comparing the trends within the various construction industry stakeholders that the data was collected from in order to establish correlations and relationships that might exists in connection with the research question, answers and information provided during the data collection process.

Most the data collected was more qualitative and qualitative methods were therefore used to analyse this data. Before embarking on the methods used to analyse the data it is important to remember that the research adopted an abductive approach. This therefore means that a combination of a deductive and inductive approach was used in analysing the qualitative data collected.

Since the research is based on already existing literature regarding the BIM use in the South African construction industry context, a deductive approach was used for the research. This was done in order to identify any variables, components, themes as well as issues to be considered in the research (Yin 2009 cited by Saunders et al, 2012). This approach also aided in making sure that the research was directed towards answering the research question and not diluted with other irrelevant questions which do not form part of the research aims and objectives as stated in Chapter 1.

Following the collection of primary data, an inductive approach was used to establish themes and issues which the research needed to focus on in order to answer the stated research question. It is important to note that data collection was only done after the literature review, hence the combination of deductive and inductive approaches which culminated into an abductive research approach as stated.

3.5 Ethical Consideration

When conducting research at any level, there are ethical considerations to be considered. This is mainly due to the fact that in most cases when research is undertaken there are individuals and/or organisations involved as part of the research. It is therefore critical that the researcher conducts the research in an ethical manner such that his or her actions do not bring about harm to the individuals or organisations concerned with the proposed research. The ethical considerations also require that the researcher carries himself in a professional manner when conducting the research, this so as not to appear disrespectful, inconsiderate as well as dishonest toward the individuals or organisations involved in the research. This is more important during the process of requesting access to the individuals or organisations as well as during the process of data collection from the concerned individuals and organisations.

Also, of importance is how the researcher treats the data that has been collected during the research process. To this end it was therefore necessary that ethics were considered during the data collection process with regards to the protection of data such that it is only used for the purpose that it is intended for and that the reporting of the said data does not result in harm to the individuals and organisations involved. The following sections will deal with the aforesaid issues in more detail and should be read in conjunction with the methods indicated for the data collection and analysis process.

3.5.1 Ethics during accessing and reporting of data

The research was conducted in fulfilment of a Masters' Degree and as such was not commissioned by the organisations or individuals that were used for the collection of primary data. The researcher was not part of the organisations for which the individuals that were involved in the research belonged to. This therefore presented some obstacles and difficulties in firstly getting access to the individuals and sources of data.

In order to overcome the difficulties associated with the above-mentioned issue, certain level of ethical behaviour had to be maintained in order to be able to gain access to the sources of the data required for the research. Since the identified methods of data collection involved semi-structure interviews and questionnaires, this meant that the process required to gain access to the sources for primary data collection be that of traditional access. The second method of access for the research was that of Internet-mediated access in the case of questionnaires which could not be administered through the traditional access. This therefore meant a hybrid access method which entailed the combination of traditional and internet mediated access.

In order to overcome rejection in gaining access to individuals and the various organisations that were required for the research, the researcher ensured that ethics clearance had been obtained in accordance with the University guideline before approaching the data sources identified. This went a long way in establishing legitimacy and credibility when approaching the relevant data sources. The participants of the research were also provided with a clear and unambiguous purpose of the research. This was also to ensure that they fully understood what the research entailed as well as to indicate how their participation in the research would be used with regards to data reporting and ensuring that the supplied data is only used for intended purpose.

Consent forms were also issued to the various participants of the research this in order to ensure that their permission had been granted with regards to conducting the required interviews as well as in answering any of the questionnaires that were administered to them through the various media chosen. The consent forms were also to allow that the participants could at any stage withdraw from participating in the research. This was done in order to ensure that the willing participants were at ease when agreeing to be part of the research and would not feel compelled to proceed with the research should they perceive that it might affect them personally or their organisations in one way or another.

The final but most important aspect with regards to the access to data sources was to ensure that confidentiality of data and anonymity is maintained throughout the data collection process. By its nature, the research process is aimed at answering specific questions and it is often not so much concerned about providing information on the individual or organisation providing the data to answer the specific questions. It is for this reason that when requesting access and issuing the concern forms it was specified that the data acquired would remain confidential as well as the individuals and organisations providing the data would also remain anonymous. However, should a need be required to reveal participants' details, written consent and agreement will have to be made with the specific individuals or organisations involved with regards to the reporting of the data collected from them and the inclusion of any of their details.

3.6 Limitations and Constraints

Like with any other research project, this research was aimed at answering a specific question within a particular concept in a systematic fashion. This therefore meant that the research had as its focus a particular filed of interest, individuals, groups or organisations as well as a region in which it was undertaken. This therefore means the research was confined or limited to specific objectives at a particular time period. The following section briefly discusses some for the constraints as well as the limitations of the research.

3.6.1 Context

The aim of the research was to answer the question of what are the factors that are impacting the implementation and effective use of Building Information Modelling (BIM) in the South African construction industry. Therefore, with regards to the context, the following should be noted as limitations to the research:

- Culture was not considered regarding comparison to other countries;
- The research focuses on BIM use from planning to handover stage of the construction project and excludes use in operations and maintenance;
- The research inly deals with the use and does not measure or investigate success factors and maturity levels of BIM implementation;
- The sample was chosen from the registered Pr CM and Pr CPM population of the SACPCMP;

- The results and conclusions are based on the data received from the acquired sample and no inference is made on the population sample.

3.6.2 Time

The research was conducted in fulfilment of a Masters' Degree within the University and as such time was a factor with regards to all the research processes that needed to be followed. Only 8 months was afforded for the research process in order to meet the University deadlines. This meant that the time required for the ethics clearance, gaining access to data sources, collection of data and analysis of data was limited. Time therefore presented a constraint in that it was not possible to collect sufficient data from all of the identified sample or get feedback on time to include in the data analysis. It is for this reason that the focus of most of the interviews were within the Gauteng Province, whilst questionnaires were administered via internet mediated access in order to reach other construction industry role players in other parts of South Africa due to time constraints. The analysis and conclusions were therefore made on the data collected over the available time afforded for the research.

3.6.3 Budget

Any research undertaking needs resources for a successful completion. Amongst these resources are the costs associated with the research activities. The process of research involves interacting with various participants who are of interest to the research for purposes of data collection as well as having to possibly travel to certain areas to access any archived data which might not be possibly accessed over internet media or even to pay to acquire certain information even if it is through the internet i.e. data costs.

In some instances, this might require long trips for which accommodation for a specific period might also be required. This requires a budget to be put in place in order to ensure that this is all made possible for the researcher to undertake the research successfully within the time afforded. The costs of carrying out the research presented limitations and it is for this reason again that the interview process was limited to within the Gauteng province, with only questionnaire distributed nationwide.

4. Data Presentation and Analysis

4.1 Population and Sample Size

The population chosen for the research was the construction professionals affiliated with The South African Council for Project and Construction Management Professions (SACPCMP). Whilst the participants had various backgrounds and qualifications, their affiliation to the SACPCMP renders the population to be of a homogeneous nature and therefore the sample size as well. At the time of the data collection process, the combined total number of registered Professional Construction Project Managers and Construction Managers was 2,310 (Annual Report 2015/2016, SACPCMP). Therefore, when applying a margin of error of 5 and a confidence level of 95%, the required representative sample size for the research was 330 participants.

In order to achieve this required sample and to reach various professionals around the country, the questionnaires for the study were distributed through SACPCMP, however only 44 responses were received. This is a very low sample, as such it needs to be understood that the results of the study were therefore only based on the responses received from this sample and may therefore not be inferred upon as the population results.

The data collection process for the research was in two ways as was indicated in the preceding chapter i.e. through questionnaires and semi-structured interviews. The questionnaires were however the primary research instrument used and the interviews were only conducted with willing participants primarily in the Gauteng province due to the stated time and budget constraints. Therefore, out of the 44 responses, the researcher was only granted interviews with 8 participants.

4.1.1 Qualifications and Professional Affiliation of Participants

As indicated in the above section, the participants of the research were construction professionals all affiliated with the SACPCMP. The participants had various qualifications which included amongst others, Architects, Construction Managers, Quantities Surveyors and Civil Engineers. The various qualifications however do not render the population heterogeneous, in that the participants are all construction professionals registered under the SACPCMP. In addition, and as established under Chapter 1, the gender of the participants was not considered as it has no material bearing on the outcome of the results from the sample.

Further to the participants affiliation with the SACPCMP, the participants were also part of other professional bodies on respect of their qualifications. These bodies include amongst others ECSA, CIOB, SACAP, SAIAT, PMSA, IPET, PMI, NHBRC, SAICE, IMESA, SACQSP, RICS, etc.

4.1.2 Experience of Participants and BIM Exposure

To properly analyse the data received it was imperative to also consider the participants' number of years of experience within the construction industry, in South Africa to be specific. Of the 44 participants, 29, 55% had between 1 to 5 years' experience, 22,73% had 5 to 10 years' experience, 18,18% had 10 to 15 years' experience, 13,64% had 15 to 20 years' experience and 15,90 % had more than 20 years' experience in the South African construction industry as depicted in the graph below. It is clear for the results that just below half of the participants had over 10 years' experience in the South African construction industry.

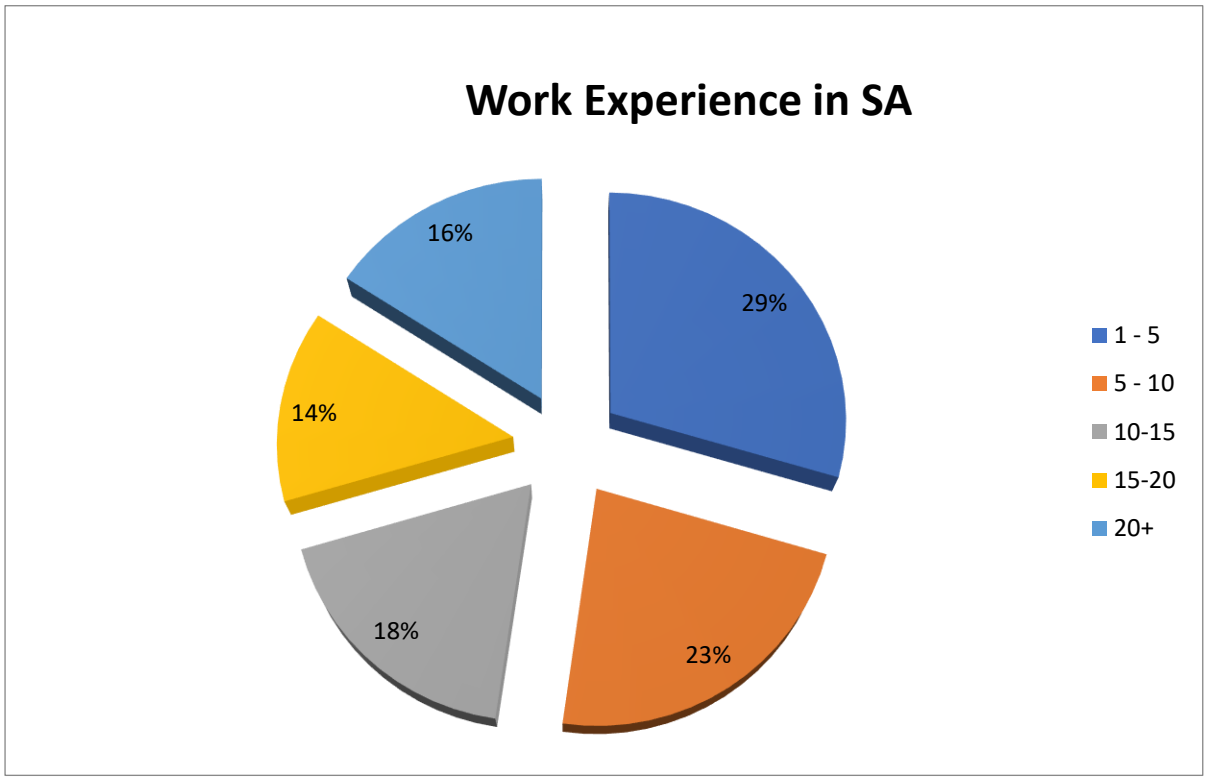

Figure 4.1: Participants' years of experience in SA construction industry

Over and above the number of years within the South African construction industry, it was also necessary to establish whether the participants were familiar with the BIM concept. From the data received, 93,18% of the participants were familiar with the concept of BIM whilst only

6,82% indicated that they were not familiar with the concept. It should also be noted that out of the total requests sent, a few participants indicated that they were not willing to participate in the research as they were not familiar with the concept, as such the 6,82 % is only based on the 44 participants that participated in the research. As indicated previously, the required sample for the population was 330 with only 44 responses received and used as a sample. However, whilst one cannot infer on the results based on the sample obtained, the fact that 93,18 % of the obtained sample were familiar with BIM makes for a strong case that the responses received were from an informed point of view.

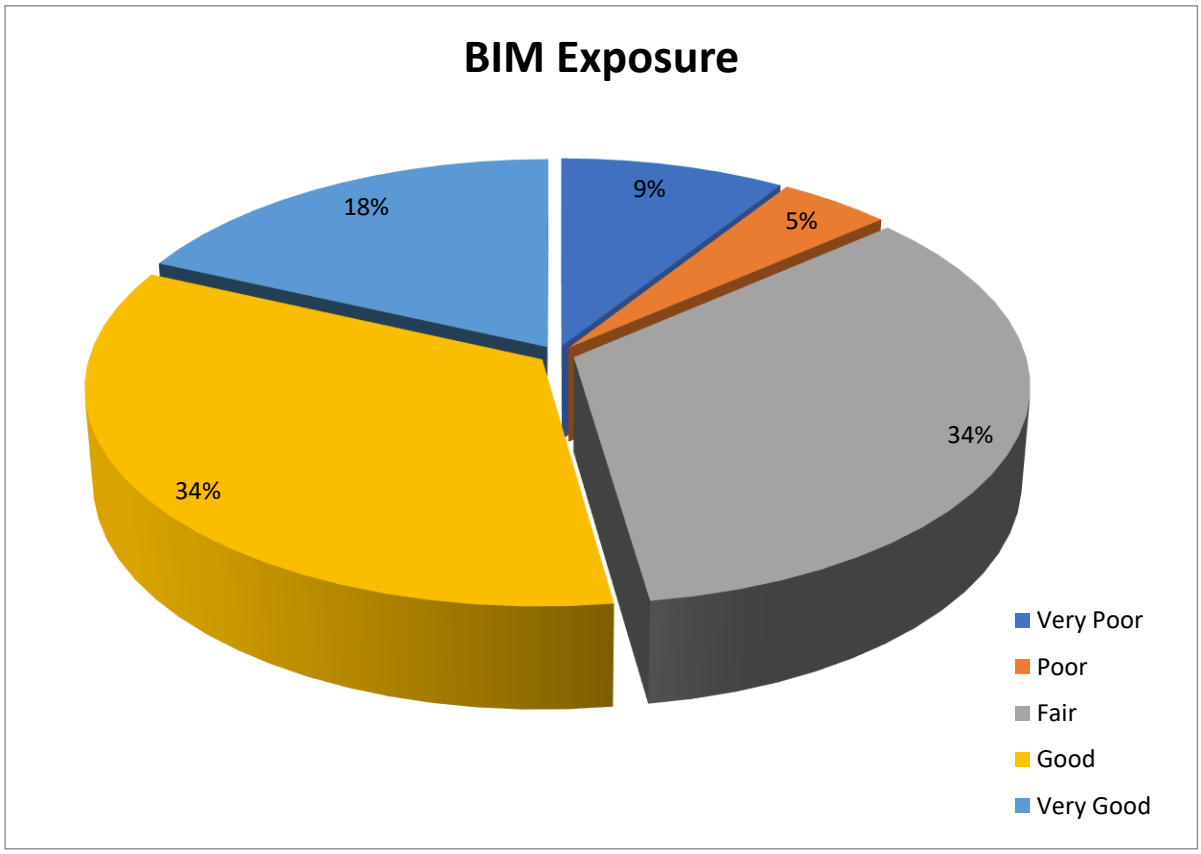

Figure 4.2: Participants' BIM exposure

To be familiar with a concept does not necessarily indicate one's understanding or mastering of the concept and hence it was also necessary to further measure the respondent's exposure and understanding ranging from very poor to very good. The participants were asked to measure themselves and the results show that 9,09% indicated very poor, 4,55% indicated poor, 34,09% indicated fair, 34,09% indicated good and 18,18% indicated very good. It can be noted then that a huge number of participants had a fair or good understanding of the BIM concept.

4.1.3 Participation on projects implementing BIM

To answer the research question and gain confidence on the data received, it was also imperative to establish out of the total number of participants, how many of them have implemented BIM in the various projects they have undertaken over the years that they have been involved in the South African construction industry. From the results, 70,45% had implemented BIM in various projects and only 29,55% indicated they had not implemented BIM before within the South African construction industry. It is interesting to see that whilst 93,18% of the participants were familiar with BIM only 70,45% had actually implemented BIM in practice, within the South African construction industry.

Of the participants that had implemented BIM in practise, 56,82% only did so between 1 and 5 projects, 9,09% between 5 and 10 projects and lowly 4,55% on 10 or more projects. Therefore, the majority of the participants had only implemented BIM on very few projects which indicates a very low usage in the South African construction industry. Whist this cannot be a conclusive inference on the population, an indication is that the levels of BIM implementation are very low. With regards to the respondent's roles in the projects where BIM was implemented, 19,35% implemented it in their capacity as architects, 6,45% as engineers and 74,20% as project managers.

4.2 Use of BIM in SA Construction Projects

The participants were also asked to indicate the total number of projects in which they had used BIM and the results indicated that between the 44 participants, they have undertaken a total of 53 projects where BIM was implemented at some stage of the project.

Of the 53 projects where BIM was used amongst the 44 participants, it was imperative to also understand at what project stages was BIM used, this to answer the question of whether BIM is currently implemented throughout the projects and why not if this is not the case. The graph below represents the respondent's answers with regards to the various stages at which they have used BIM. As per the limitations of the study, it is important to note that issues like specific details of what BIM was used for at each stage as well as maturity levels were not considered for the study.

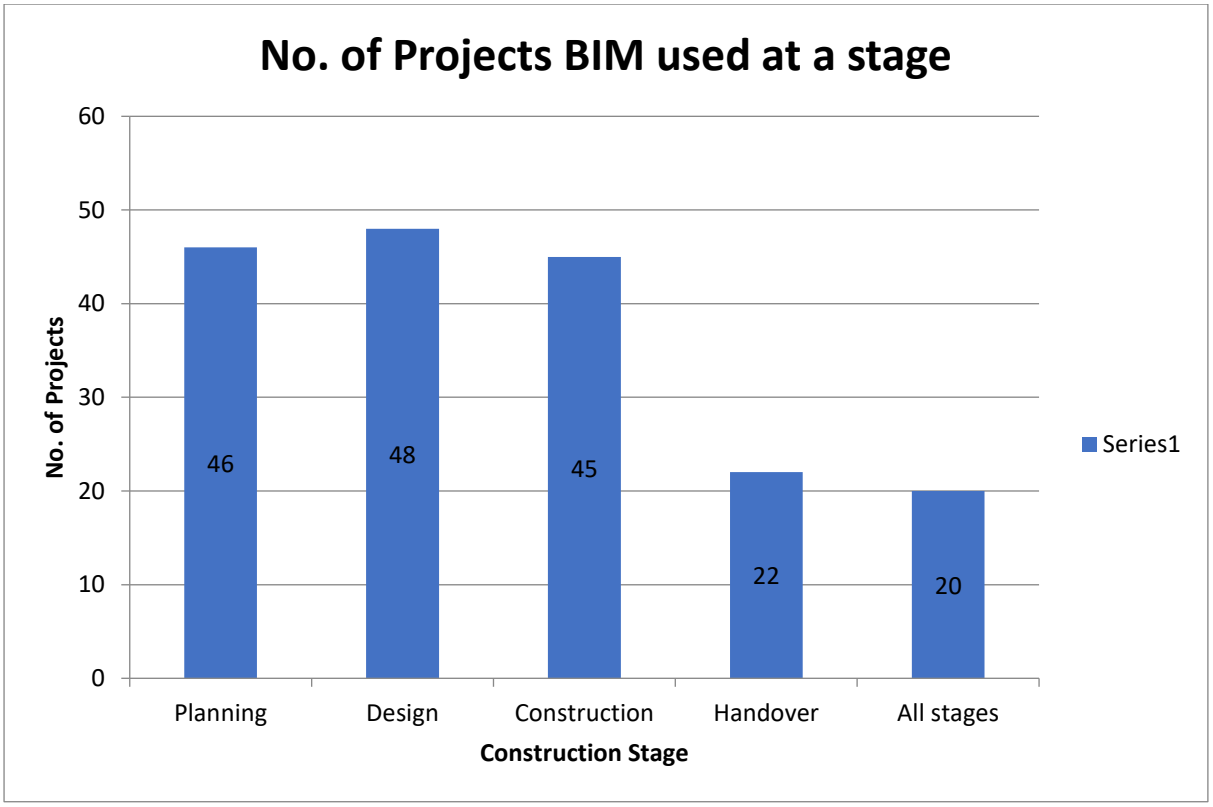

Figure 4.3: BIM implementation in projects

From Figure 4.3 above one can see that of the 53 projects, 86,79% used BIM at the planning stage, 90,57% at the design stage, 84,91% at the construction stage, 41,51% at the handover stage and 37,74% throughout the project. From the obtained sample data, the indication is that there is a low percentage or number of projects in which BIM is currently used throughout project stages in the South African construction industry. Whilst this is not conclusive enough based on the population used in the research it makes for a strong case that the use of BIM in the South African construction industry has not advanced that far and selectively used as supported also by the literature in Chapter 2 of this report.

The other aspect to be considered with regards to the implementation of BIM at the various stages in the construction projects in South Africa, is that the participants were not asked to elaborate as to how BIM was used at each stage. There are many activities during each stage of a construction project and BIM has different applications and uses for the various activities. It should be noted therefore that the research only focused on whether BIM was used or not at a particular stage and not on what activity or even the success achieved through the use of BIM at that particular stage.

The other factor which was considered in regarding the use of BIM at the various construction project stages beside just the number of projects, was to measure the rate at which BIM is used at the various stages. The table below indicates the rating as per the number of responses received.

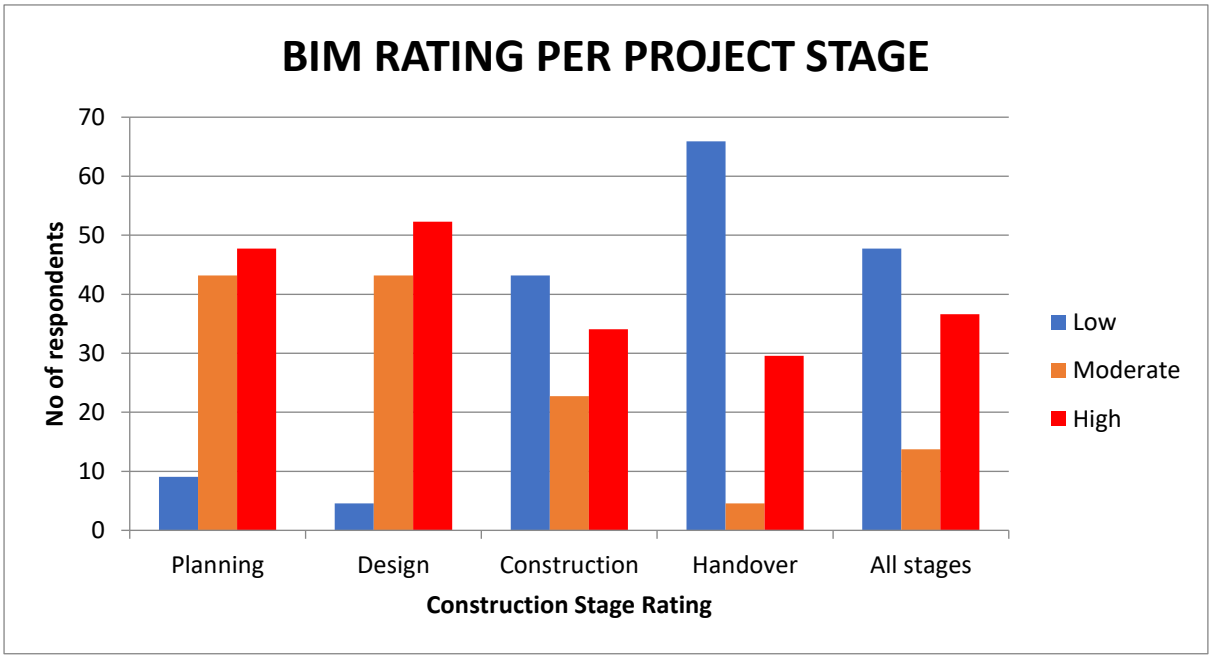

Figure 4.4: BIM rating at project stages

Figure 4.3 is based on the number of projects in which BIM was implemented whilst Figure 4.4 indicates ranking of the rate in which BIM is used the for the various stages in construction projects within the South Africa context.

When one looks at the two figures a clear distinction can be made with regards to the results. Figure 4.3 indicates that a lot of projects from the sample used BIM mostly at the planning, design and construction stages of the projects with a slight decline at the handover stages and the use throughout all the project stages.

Figure 4.4 on the other hand gives a different view in that whilst there may seemingly be a high number of projects in which the various professionals had used BIM, the ratings indicate that BIM is mostly used in the planning and design stages of construction projects in South Africa. 47,73 % of the construction professionals in the sample indicated that BIM is highly used at the planning stage and 52,27% indicated that it is highly used at the design stage. Interestingly 43,18% indicated moderate usage at both stages.

In contrast, the ratings show that 43,18% indicate that the rate at which BIM is used at the construction stage is low and 65,91% indicate a low usage of BIM during the handover stage of the project. This is also a stark contrast when one looks at the number of projects in which BIM was used at the construction stage as per Figure 4.3. The high number of projects indicated to have used BIM at the construction stage can be attributed to the fact that the participants were not asked to specify the level of implementation per stage, so one can conclude that some aspects of BIM are used at this stage but at a very low rate and not through the entire construction stage.

The one aim of the research was to answer the question of whether BIM is currently used throughout the project. From the data 47,73% indicates that the use of BIM through the project is low and 38,64% indicate it is high. Whilst there is no direct relationship between the number of projects in which BIM was used through the whole project as per Figure 4.3 and the ratings in Figure 4.4, one can see that the number of projects indicated to have used BIM throughout the whole project is very close to the high rating of BIM use in the whole project. This could therefore mean that the participants who rated BIM use in the whole project high are the ones who have undertaken projects where BIM was implemented in the whole .

When applying a 3-point Narrative Rating Scale on the data, where 3 represents “high”, 2 represents “moderate” and 1 represents “low”, the researcher calculated the means and standard deviations for the rating of BIM use at the various construction project stages. Table 4.1 below represents the calculated means and standard deviations of the obtained sample.

Table 4.1: Means and Standard Deviations for each stage rating

CONSTRUCTION STAGE	SAMPLE MEAN	SAMPLE STANDARD DEVIATION
Planning	2,39	0,65
Design	2,48	0,59
Construction	1,91	0,88
Handover	1,64	0,92
All stages	1,91	0,94

When looking at Table 4.1, it can be noted that there seems to be agreement amongst the participants that BIM highly implemented during the planning and design stages of construction projects in South Africa. The standard deviation in the results is very small which points to a high level of agreement amongst the participants in the observed sample, bearing in mind however that the sample is not representative of the population. The standard deviations for the other stages are higher and shows that the opinions of the participants vary widely. This tends to agree to the earlier observation on Figure 4.4 where the ratings at the construction, handover and all stage show that the participants opinions varied widely regarding BIM usage.

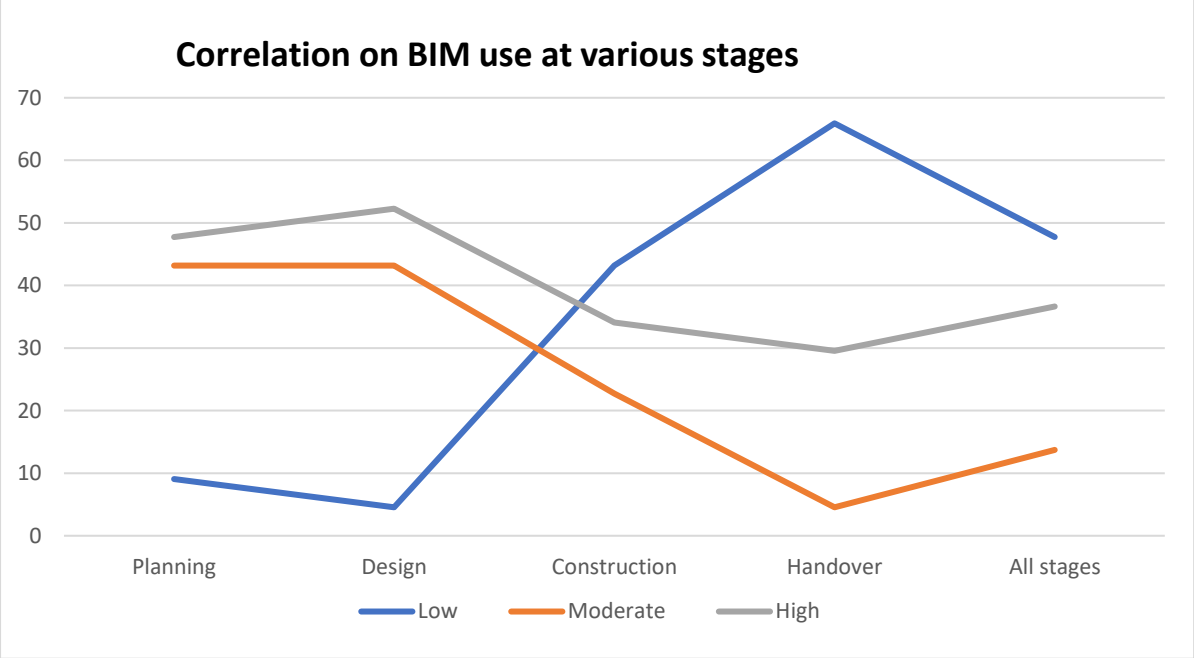

Figure 4.5: Correlation on BIM use at various stages

Further to Table 4.1 where the means and standard deviation were calculated, Figure 4.5 above gives a representation of the data with regards to the use of BIM at the various phases of the construction projects from the sample surveyed. The data shows that there is some correlation with regards to how the participants view the use of BIM in that it shows that the trend seems to agree that BIM is mostly used during the planning stage and more so during the design stage and the level of usage is much lower at the later stages of the construction project. Again, the Figure 4.5 shows that the views of the participants varied a lot regarding the usage at handover and throughout all stages of the project.

The participants' opinions were also sought with regards to how well is BIM understood and embraced in the South African construction industry. 90% of the participants indicated that

BIM is not well understood and embraced in the South African context with only 10% indicating otherwise. Therefore, whilst 70,45% of participants have used BIM in projects before, the consensus is that it is still not understood and embraced in the South African construction industry. The required sample data might show a different trend and this is consensus is only based on the 44 participants received.

4.3 Factors Impacting BIM in South Africa

In the section above, it was pointed out that the one aim of the research was to establish if BIM is used and implemented through the whole project in the South African construction industry. From the data received, it shows that whilst BIM has been implemented in the whole project in certain projects, the rate at which this is done is very low, this when compared to the planning and design stages of the projects. It is therefore necessary to get an understanding of what are the factors or issues that contribute to the low numbers in the implementation of BIM in the whole project within the South African context.

The data received through the literature review in Chapter 2 was used as a measure of comparison to other countries in the world where BIM is currently rapidly used in delivering projects and where plans are underway to standardise and legislate the use of BIM. The primary factors that were considered for the research within the South African context were costs, skills, organisational culture, interoperability and legal aspects all associated with the actual implementation and use of BIM. Figure 4.6 shows the result and answers of the 44 participants with regards to the rating of the influence each of these factors has on the use and implementation of BIM in the construction projects in South Africa.

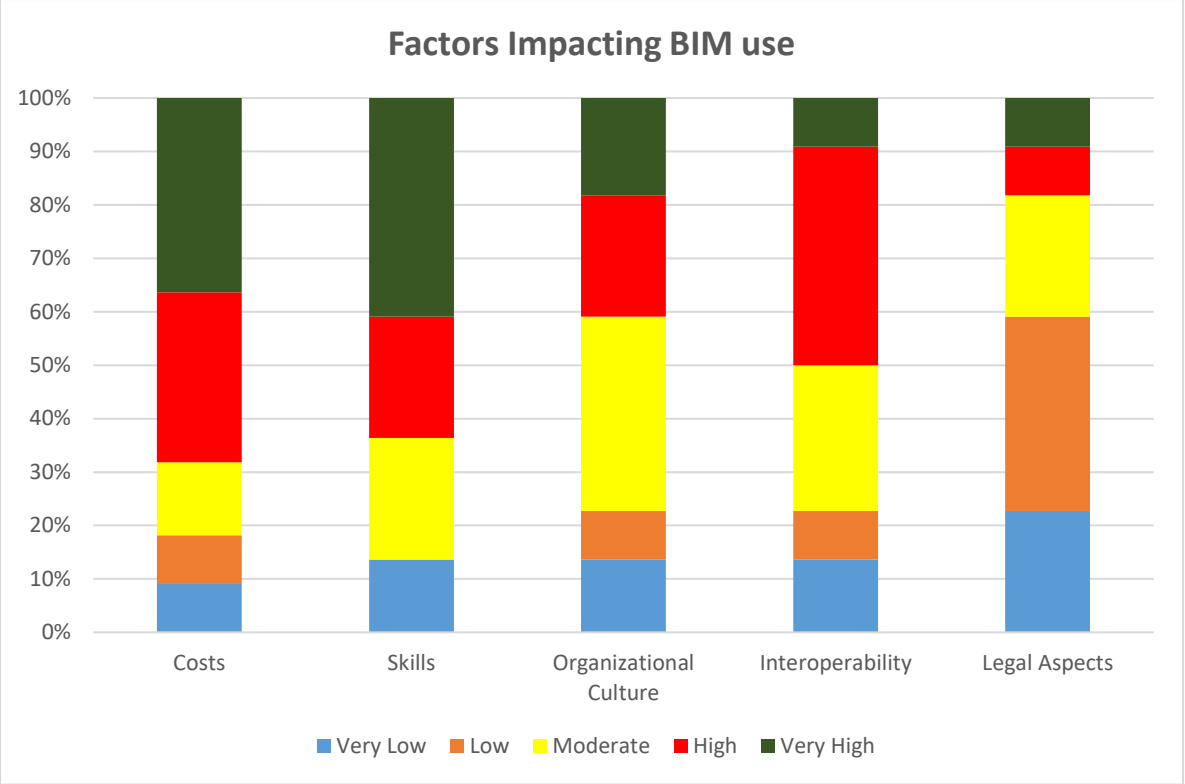

Figure 4.6: Rating of factors impacts on BIM use in SA

BIM is software based as established in Chapter 2 of the research, there is therefore costs associated with the acquiring of the software, training of users, interfacing with other construction software, change implementation, etc, which are all internal to organisations. The costs of adopting, implementing and use of BIM therefore has an impact within the organisation, in projects and also the industry as a whole. Of the 44 participants, 31,82% rated the costs impact as high and another 36,36% rated the costs as very high. The combined 68,18% gives an indication that the observed sample rated the costs as a huge factor for organisations and projects alike to adopt, implement and use BIM.

Similar to costs, for BIM implementation and use, there is a need for suitably skilled personnel who fully comprehend the various aspects and benefits of BIM. There is therefore a link to the costs and the availability of skills for the use and implementation of BIM within the South African context. Considering the participants indications in their understanding and exposure to BIM as per Figure 4.2 of this chapter, only 18,18% showed a very good understanding and exposure to BIM within the South African context. The impact of the availability of suitably skilled professionals within the South African context was rated as very high by 40,91% of the

participants and was rated high by 22,73%. This makes for a combined 63,64% impact rating on skills availability, which is close to the costs rating.

For an organisation to embark on spending and skills training for any change, it requires a change in the processes and adaptation to new processes and a move away from the already established processes, which forms part of the organisational culture. This therefore requires a mindset shift and a cost trade-off in aligning the organisations needs and that of their clients or potential clients. The organisational culture was rated as having a moderate impact by 36,36% of the participants, and 22,73% as high and 18,18% rated the organisational culture as having a very high impact. The data obtained from the observed sample thus indicates that the organisational culture does have an impact to a certain extent in the implementation and use of BIM by various organisations.

BIM is a software-based concept and as established, it also extends already existing concepts to far more capabilities and benefits in a construction project. This therefore requires interfacing with other software and programmes. The question is therefore, how does interoperability with other software and programmes impact on the use and implementation of BIM within the South African construction industry? The impact of interoperability was rated 9,09% very high, 40,91% high and 27,27% as moderate. Compared to the other factors the interoperability does have a high impact on BIM use and it does require serious considerations in decision making on projects and within organisations.

The other aspect that the rest of the world also takes into consideration with regards to the use and implementation of BIM is legal aspects associated with its use. Each organisation and professional normally prefers to retain their rights with regards to the use of their works, namely the intellectual property. BIM entails collaborations and interfacing between different organisations and individual professionals in undertaking construction projects. This presents a different challenge as BIM entails sharing of information in some cases within professionals across the world but working in the same project. So how does legal aspects and legislation impact on BIM use in the whole project? Of the 44 participants, 22,73% rated legal aspect's impact as very low, 36,36% rated it low and 22,73% rated it as moderate. Therefore, whilst legal aspects were not rated very high amongst other aspects impacting on the use of BIM, it is worth considering when it comes to issues of intellectual property.

In order to further analyse the data received, the researcher applied a five-point scale for the rating with 5 representing a “very high” rating, 4 as “high”, 3 as ‘moderate”, 2 as “low” and 1 as “very low”. The means and standard deviations for each factor were then computed and are represented in the table below.

Table 4.2: Means and Standard Deviations for factors impacting BIM use

FACTOR	MEAN	STANDARD DEVIATION
Costs	3,77	1,29
Skills	3,77	1,36
Organisational Culture	3,23	1,26
Interoperability	3,18	1,15
Legal Aspects	2,45	1,21

Based on the calculated means and standard deviations in Table 4.2 above, it can be shown that the costs, skills, organisational culture and interoperability have a huge impact in the implementation and use of BIM in South African construction projects. As evident by the earlier percentages, the costs and skills seem to be the main drivers that impact or facilitate the use of BIM in construction projects within the South African context. The standard deviations of the obtained sample are a bit high and as such it cannot be concluded that the results would be representative of the required sample for the chosen population.

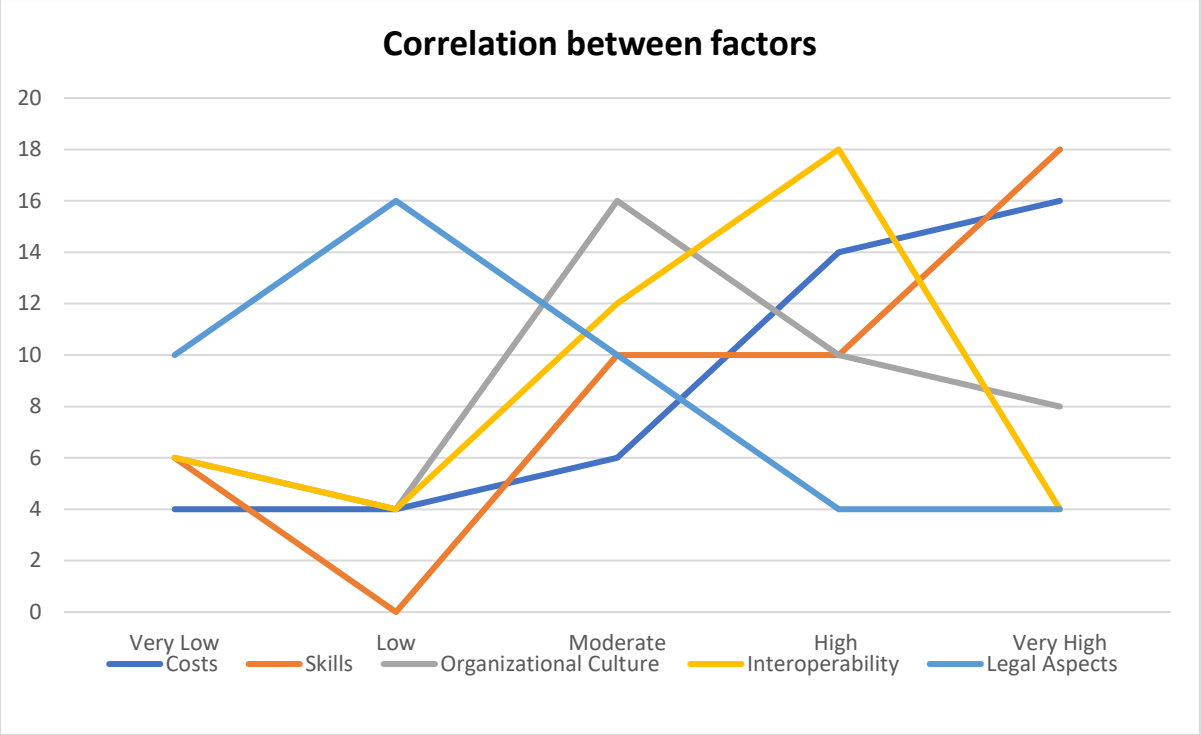

Figure 4.7: Correlation between factors

Figure 4.7 above depicts the results from the surveyed sample and the graph shows that there were varying views from the participants as shown also by the calculated standard deviation in Table 4.2. It should however be noted that costs and skills showed some correlation and were in fact rated as having a very high impact on BIM usage.

4.4 Discussion on Semi-Structured Interviews

During the interviews, which were only limited to 8 participants, other aspects which were not part of the questionnaire, came up in most of the discussions. The one aspect that came up most during the interviews and which is closely linked to costs, is the client's desire to accept and use BIM in projects. It is a known fact that all construction projects are mostly if not entirely funded by clients and therefore the client has very much of a say when it comes to expenditure in projects. The client buy-in is therefore one other aspect that impacts on the use of BIM in construction projects within the South African context. The client is therefore both the facilitator and the hinderance for the use of BIM in construction projects. The clients therefore have a huge role in responsibility in promoting the use of BIM in the South African construction industry. It is therefore advisable that construction professionals get by in and advise the clients on the benefits of BIM which in stances outweigh the costs of implementation on a project.

The other recurring theme during the interview process was the lack of training for BIM use within the South African construction industry. This can also be closely linked to the availability of skilled personnel in the field of BIM which was detailed above and ranked very high by most of the participants. In addition, the age and retention of skilled personnel in the South African construction industry was also mentioned as a factor in that there does not seem to be a sharp increase in the level of skills and qualified personnel in the industry as whole, which in turn results in the lack of many skills personnel, which include amongst other skilled BIM user. Also linked to this factor was the issue of BIM training or education in the higher learning institutes. BIM is currently not offered as part of the construction curriculum in most if not all South African institute of higher learning. It appears that BIM is mentioned but not a core focus course in these institutions.

The issue of government involvement was also questioned in getting involved with the promotion of the use of BIM. This is because the South African government has been advocating infrastructure development to drive the country's economy and create employment. The government is therefore a key client in big projects happening within the country as far as construction is concerned. Only 6,82% of the participants thought that there is enough government involvement in BIM promotion with a staggering 90,91% indicating a lack of government involvement and support for BIM. The rest of the 2,27% believed that there is no need for government involvement and that it is up to the construction industry to push for the use of BIM in South Africa.

To support the fact that there is not much government involvement in the use of BIM, 81,81% of the participants indicated that the limited use of BIM as it is now in South Africa is mostly within the private sector with 13,64 indicating some use in public projects. 4,55% of the participants held a different view and indicated that it is not so much about private or public project but rather the size of the project, and the bigger the project the more BIM is likely to be used in some stage and maybe in the whole project.

5. Conclusions and Recommendations

5.1 Summary of Findings and Conclusion

It was established in the preceding chapter that at the time when the research was undertaken the population of registered Construction and Construction Project Managers was 2,310 (Annual Report 2015/2016, SACPCMP). This required 330 participants for a representative sample, however only 44 responses were received for which the data was used, analysed and upon which the findings and conclusions of this report are based. It should therefore be noted that if a representative sample was obtained, it cannot be inferred that the data would produce the same findings if were to be repeated. This chapter therefore only represents the researcher's findings based on the obtained sample during the research.

The research data collected and analysed shows that most of the professionals and their organisations at large do have an understanding and awareness of the BIM concept. Whilst the research did not go into details in evaluating and measuring the understanding and awareness amongst the various professionals who participated in the research, it did use a self-evaluating format for which the participants indicated their awareness of BIM. About 73% of the participants were aware and familiar with the BIM concept, which is a good sign for the South African construction industry.

Awareness however does not automatically translate to being an expert or skilled in a particular field. This was observed with the number of participants that had participated in projects in which BIM was used at some stage or throughout the project. Most of the participants (56.82%) had only used BIM in most cases on one project in their professional experience. This paints a bleak picture for South Africa regarding the advances and progress made with regards to the use of BIM in the construction industry. As indicated, whilst a lot of the professionals in the South African construction industry are well aware of BIM, they have not really used it in practice and as such it gives an indication that South Africa does not have high skilled personnel in the BIM field.

The research only sought to gain understanding of the level in which BIM is used in the South African context with regards to the stages of the construction project . The research was not concerned with the level of maturity in which BIM is currently implemented as well as the success factors achieved. From the results analysed it was noted that BIM is currently highly

used in the planning and design stages of construction projects within the South African context, this when compared to other countries like Hong Kong, the USA, etc as indicated in Chapter 2 of the report, where these countries deliver the whole project using BIM tools at all the stages of the project. When compared to South Africa, these countries have advanced very far in the implementation and use of BIM, which also included aspects of operations and maintenance as seen in the USA i.e. the use of BIM from a project life-cycle approach. It appears from the data analysed that South Africa is still far behind in relation to these countries and more still needs to be done in the field of BIM implementation on construction projects.

It cannot be denied that South Africa has its own challenges compared to other countries, and therefore one cannot make a one on one comparison with the likes of the USA, UK and other first world countries. However, what comes out of the results is that even these countries experienced challenges when it comes to implementing BIM in their construction industries. These as established in Chapter 2 of the report included amongst others, costs of implementation, skills availability and training, process changes, complexity and interoperability, market demand and legal aspects. From the analysed data it seems in South Africa, the two main factors that seem to be the key drivers (i.e. both inhibitors and facilitators) on the use of BIM are the costs and the lack of skills. The two are also in a way intertwined in that in order to obtain these skills, organisations need to hire these resources or internally train them, which all comes at a cost. The lack of skills can also be attributed to implementation of BIM in practise. Whilst 73% of the participants were well aware of BIM, a few had uses or implemented BI in the projects they have carried.

Whilst the costs and the lack of suitably skilled personnel was ranked as a major factor impacting on the use and implementation of BIM in South African construction projects, the organisational culture and interoperability were also ranked in the top order but below costs and skills amongst factors to be considered in BIM use and implementation. The perception is that organisations find it hard at times and very difficult to implement process changes internally within the organisations. This is partly due to the costs associated with changes, the resistance to change by the management and also the organisation's personnel. Organisational culture was therefore rated as also having a high impact in the use and implementation of BIM even though lower than that of costs and skills. However, it is worth considering as mentioned that change in processes comes at a cost. In addition to the costs of change the organisation or team members sometimes feel threatened by change especially when it comes to technological

changes which makes for reduced human intervention or involvement and as a result push back or reject the change.

BIM is a software-based concept and as a result there are interfaces that are required with other construction software in the market. There is therefore a need to consider integration aspects before using and implementing BIM on projects. With advances in technology, it has become easier and simpler to attain certain software or integrate between different system. From the observed sample, it however seems that within the South African context this is still viewed as a challenge which then becomes an inhibitor for projects to actually use and implement BIM. Whilst the rating if this factor was not as high as costs or skills, it should be noted that it does need to be considered as one of the factors that have a huge impact when deciding to use and implement BIM in construction projects within the South African context.

The last factor measured was legal aspects and from the observed results it seems that the legal aspects do not have as high an influence as the other four factors measured. Although it is worth noting that legal implications with regards to intellectual property are a consideration for organisations when it comes to making decisions around the use and implementation of BIM when undertaking construction projects. This is not an isolated South African case as observed in the literature review chapter but a global view in countries where BIM is being practised.

Besides the factors that have been identified as impacting on the use of BIM within the South African construction industry and based on the findings from the limited interviews held, one gets the sense that there does not seem to be too much drive and support from the government of South Africa to advocate for the implementation and use of BIM within the construction projects. It seems that BIM is currently used in the private sector mostly and not as much in the public sector where government is the sponsor or client for these projects.

Government projects are mostly huge projects related to infrastructure and service delivery and they should be in the forefront in the drive for introduction of new technologies to improve the effective delivery of these projects. Whilst there is a BIM institute established in South Africa, they alone cannot successfully promote and support the BIM use without government support. The successful countries like the USA have been successful in the implementation and use of BIM due to government support received as established in Chapter 2 of the report. This also supports the notion that the client in projects is both an inhibitor as well as the facilitator for

the use and implementation of BIM. This is regardless of whether the projects are in a private sector or a public sector, including the size of the project.

Therefore, in conclusion, the research aimed at investigating the factors affecting the implementation and use of BIM in the South African context and whilst the data received cannot be used to infer on the population, the results show that costs, skills and organisational culture rate high amongst the factors that impact on BIM use in South Africa.

5.2 Recommendations

For the South African construction industry to move forward with the rest of the world, technologies and tools like BIM need to be part and parcel of the industry. For South African organisations to be able to strive and compete with the rest of the world, they need to equip themselves with the necessary skills and tools to play a significant role in a global construction industry. As indicated earlier, the South African government at often times employ services of international companies to deliver huge infrastructure projects. It is then often the case that the South African companies play a secondary or supportive role in the delivery of these projects. One can therefore also argue that South African organisations do not have a competitive advantage over their international counterparts to deliver such projects and that maybe the necessary skills and tools are a reason for this apparent lack of capabilities.

This is where the concept of BIM comes into play, in that it enhances how construction projects are ultimately initiated and successfully delivered. As per the definition adopted for this proposed research, BIM is an IT enabled approach that involves applying and maintaining an integral digital representation of all building information for different phases of the project in the form of data repository. It is no argument that the application of IT within the construction industry can equip the various professionals and organisations in South Africa with the necessary skills to compete within the global market whilst delivering state of the art projects within the country.

In order to address the skills issue, it is therefore recommended that higher learning institutes consider providing BIM a part of their curriculums for the various construction related professions in order to promote, as a start, awareness amongst the construction graduates. The organisations and stakeholders in the work place need to engage with training institutes to provide professionals in the workplace with the necessary training to promote awareness and

skill them on BIM practise and benefits. Furthermore, it is recommended that the training is accompanied by some form of certification for the construction professionals which is recognised by professional bodies like the SACPCMP, amongst others.

It is now normally acceptable that whenever clients call for bids for specific projects, one of the requirements is that the bidding organisations are ISO certified. It should however be noted that ISO certification is not a must have for organisations but a choice and a decision that organisations make to adopt, in order to improve their systems and remain competitive in the market. The clients, whether in the private or public sector, are both inhibitors and facilitators of BIM implementation in projects as established in Chapter 4, and as such they are in a position to drive it in a similar way organisations are increasingly getting ISO certified to remain competitive in the market. This will also result in organisations being able to overcome the change resistance within and BIM will become a part of the organisations' competitive advantage. This addresses in a long term the organisational culture factor discussed in Chapter.

The lack of skills and organisational factors were rated high amongst factors impacting the use and implementation of BIM in projects. If the above recommendations are further pursued and implemented, it is the researcher's view that the benefits of BIM to the organisations and the South African industry as a whole will, in long term, far outweigh the cost factor, which was rated very high from the sample observed. These include not just the costs for the training and change management, but also include the cost for operability in the form of software and other applications that need to be considered for BIM as indicated in the conceptual framework for BIM implementation that was discussed under Chapter 2.

Much like ordinary clients in the private sector, the government plays a huge role in the promotion and implementation of regulations and legislation across various industries. Within the construction space the government is therefore also required to be in the forefront when it come to promoting, legislating and regulating the use BIM. The government is however effective only through the various departments and agencies that are tasked with overseeing these industries. There is therefore a requirement for collaboration amongst the various stakeholder's in both the private and the public sector to move towards the implementation of BIM and start to develop a conceptual framework for regulations and legislation for such an implementation.

Given time, one can also consider further research with regards to the various activities within each construction project stage where BIM was used to assess at what level was it used and how effective was it in the delivery of the project. This will assist in understanding why it seems that there is a low interest from clients in using BIM in projects within the South African construction industry. Is this only a cost decision or are the other complexities associated with BIM which seems to turn the clients against its use? Such a research is necessary to get a client perspective but will require more time as well as studying each project in which BIM was used to get a complete assessment of the client's decision based on the various factors within each project. The client as indicated could be in both the private and public sector.

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6. APPENDIX A

RESEARCH QUESTIONNAIRE

The use and effectiveness of Building Information Modelling (BIM) in the South African construction industry

Dear Sir/Madam

Thank you for your willingness to participate in this research. The purpose of the research is to assess the use of BIM in the South African construction industry, specifically to investigate what are the factors that prevent the implementation of BIM throughout the project. The questionnaire should not take more than 5 minutes and the information provided will remain confidential. You will not be identified through the answers that you will provide, and these will be only used to understand your perception with regards to the use and factors affecting BIM in the South African construction industry.

Please answer all questions by either placing a tick (√) in the appropriate box or filling in the required data.

1. **What is your professional qualification?**

2. **Which professional body are you affiliated to?**

3. **How many years' experience do you have in the SA construction industry?**

4. **Are you familiar with the concept of Building Information Modelling (BIM)?**

YES	NO

5. **If answered yes in 4 above, please indicate your exposure and understanding of the BIM concept on a scale of 1 to 5**

1. Very Poor	2. Poor	3. Fair	4. Good	5. Very Good

6. **Have you implemented BIM in any of the construction projects you have undertaken in SA?**

YES	NO

7. **If answered yes in 6 above, please indicate how many projects**

8. **On the above indicated project please indicate at what capacity/role were you involved in the BIM implementation e.g. client, PM, Engineer, Architect, vendor, software support, etc.**

Project No	**Role/Capacity**
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	
11	
12	
13	
14	

9. **Please indicate the number of projects in which BIM was implemented at the various stages of the project**

Project Stage	**No of projects**
1. Planning	

2. Design	
3. Construction	
4. Handover	
5. Whole project	

10. On a scale of 1 to 3, at which stage is BIM currently mostly implemented in the South African construction industry

Stage	**1. Low**	**2. Moderate**	**3. High**
1. Planning			
2. Design			
3. Construction			
4. Handover			
5. Whole Project			

11. In your opinion do you think BIM is well understood and embraced within the South African context?

YES	**NO**

12. Please rate the factors identified below on a scale of 1 to 5 with regards to the impact they have in the use of BIM in South Africa throughout the project

Factor	1. Very Low	2. Low	3. Moderate	4. High	5. Very High
1. Costs					
2. Skills					
3. Organizational Culture					
4. Interoperability					
5. Legal aspects					

13. Please indicate in your opinion other factor not identified in 12 above and their level of impact on the use of BIM in South Africa

Factor	1. Very Low	2. Low	3. Moderate	4. High	5. Very High

14. In your opinion, do you think there is enough government involvement through e.g. CIDB, etc. in promoting and legislating the use of BIM in the construction industry

YES	NO

15. In which projects would you say there is a drive in the promotion and use of BIM

Public sector	Private Sector

Comments/Discussion: