**An Investigation on Building Information Modelling In Project Management: *Challenges, Strategies and Prospects in the Gauteng Construction Industry, South Africa.***

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A research report submitted to the Faculty of Engineering and the Built Environment, University of the Witwatersrand, Johannesburg, in partial fulfilment of the requirements for the degree of Master of Science in Building.

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**DECLARATION**

I declare that this research report is my own work. It is being submitted to the Degree of Master of Science in Building to the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination to any other University.

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**ABSTRACT**

The modern Architectural, Engineering and Construction (AEC) industry is characterized by its fragmented, complex and multidisciplinary nature. Hence, the project success is heavily pivoted on its effective collaboration among the stakeholders during various project phases. The exchange and management of massive project information under various project delivery methods are cumbersome in modern day's projects. Information Technology applications are playing a vital role in overcoming this difficulty; however the technological adoption and its full utilisation has always been slow in the emerging economies. Among these technologies, Building Information Modelling (BIM) dominates the AEC sector in developed countries; these countries are still experiencing the transition from 3D technologies to BIM in AEC industry.

In South Africa, Building Information Modelling (BIM) is becoming the prime means of information exchange between various stakeholders involved in construction projects. Various aspects of BIM are explored and tools are developed continuously in order to make BIM more and more efficient for the whole life cycle of the construction projects. Nevertheless, in most implementations, BIM services are widely utilized in schematic design, design development and working drawings for both Engineering and Architecture as a graphical modelling and clash detection tool. But the developers of various BIM tools have listed many Project Management related benefits in their product portfolio.

Nonetheless, it's utilization in various project management knowledge areas according to PMBOK such as Integration, Scope, Time, Cost, Resource, Procurement, Communication, Quality, Risk, Safety, Environmental, Financial and Claim Management are not fully realized in South Africa. This paper investigates the BIM's utilization on the above said Project Management knowledge areas and identifies its challenges towards project management utilisation and strategies to overcome the identified challenges. The research

philosophy adopted in this study follows positivism and a deductive research approach is used to unwind the truth about BIM's utilization for project management, challenges and the strategies among the South African AEC industry. A survey research strategy is used in this research; data are collected through questionnaires and interviews.

Questionnaire responses were obtained from a sample of 34 BIM adopters, the sample includes architectural, engineering, contracting, quantity surveying and construction management firms, questions related to the project management applications, implementation challenges and effective utilization strategies of BIM were asked. The obtained non parametric responses data through the questionnaire are analysed using appropriate statistical tests. The questionnaire results are triangulated through 3 open ended interviews data. Conclusions from this study help the South African AEC sectors to realize and expand their utilization of BIM in project management processes. Further, the identified challenges and strategies in this study assist the AEC industry to plan for the effective utilization of BIM in their future projects.

## DEDICATION

I dedicate this work to my Parents and siblings for their care, love and support; To Robert and his family; for their support in Johannesburg, South Africa. To Lydia for her patience and love even being away from home.

**ACKNOWLEDGEMENTS**

This work would not have been possible without the kind support, patience and assistance from my supervisor Dr. Senthilkumar Venkatachalam, who dedicated a lot of his time to assist me. To Chama, for her continuous support and encouragement. I would also like to thank the school of construction economics and management for their assistance throughout the research process. Finally thank all the professionals of the Gauteng construction sector for taking their time from their busy schedule to provide data for this crucial research.

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**LIST OF ACRONYMS**

**2D -**Two Dimensional: An image represented by height and width but no depth.

**3D -**Three Dimensional: An image that has the appearance of depth and field.

**AEC** - Architectural, Engineering and Construction.

**BIM** - Building Information Modelling.

**CAD** - Computer Aided Design.

**ICT** - Information Communication and Technology.

**BRICS –** Brazil, Russia, India, China, South Africa. Association of five major emerging economies.

## 1.0 INTRODUCTION

The success of a modern multi-disciplinary complex and fragmented infrastructure projects is dependent upon effective collaboration among the various stakeholders. Many of the project information are communicated to assist thousands of decisions during the project through various project delivery methods. Information technology applications are playing a vital role in the project collaboration. However the utilisation of these technologies has always been slow and incomplete in emerging economies such as in BRICS. These countries are still experiencing the transitioning from 3D technologies to Building Information Modelling (BIM). South Africa's economy which falls under BRICS is experiencing a paradigm shift, anticipating Building Information Modelling (BIM) to become the key means of information exchange between various stakeholders involved in construction projects.

Several features of BIM are explored and tools are developed continuously in order to make BIM more efficient for the whole life cycle of the construction project. Conversely, despite the many listed project management-related benefits in most implementations, BIM services are mostly utilised as a graphical modelling tool in Engineering and Architectural firms. In South Africa, utilisation of various BIM aspects on various Project Management knowledge areas is not fully realised. This study investigates BIM's utilisation on Project Management knowledge areas and identifies its challenges towards Project Management utilisation and strategies to overcome the identified challenges. Study conclusions will help the South African and other AEC sectors to realise and expand their utilisation of BIM in Project Management processes. Further, the identified challenges and strategies in this study may also assist the AEC industry to plan for the effective utilisation of BIM in future projects.

## 1.1 The Construction Industry and Project Management

The modern construction industry keeps changing from time to time. One major change is the use of technology and advancement of responsibilities of AEC consultants. Over the last decade, several new roles and professions have emerged to complement the existing construction industry. Among these new roles are the project and construction management profession which have been given distinction in the $20^{th}$ century. While conventionally the Architect, Engineers and Quantity Surveyors are responsible for delivery of a project in a construction cycle including design, detailing, cost analysis and supervision, the project manager has emerged to facilitate the effective delivery of projects (PMBoK, 2010) and several tools such as Gantt charts, network diagrams and related construction management software (Microsoft Projects, etc.) at his or her disposal for planning, coordination and control of a construction project process.

### 1.1.1 The need for ICT in construction

As identified previously that the construction industry is ever changing, with evolution in new technology, materials and ways of transacting business, the ICT sector has subsequently evolved and given birth to customised technologies and applications that suite the AEC industry. It is with this evolution that the uses of computers and technologies have increased in the building and design industry. Ozumba & Shakantu's (2008) stated that recent developments have put forth the myriad advantages of modelling not only the graphical aspect but also the non-graphical aspect of building design life cycle. Design professionals and firms are now being faced with the exciting and quantifiable advantages of this revolutionary technology. The realtimes webpage state that the objective of implementing information technology in the construction industry seems to improve user productivity by making building design and project planning and execution faster, cheaper and more efficient. (Realtimes, 2011)

### 1.1.2 The Construction Industry and BIM

By definition, BIM entails the development of integrated, parametric models of buildings. The process of developing BIM enables better design integration, constructability review, co-ordination for construction, building performance analysis and also facility management**.** (Eastman *et al*, 2008). Building Information Models (BIMs) are 3D parametric, virtual representations of the built environment. These models are capable of representing specific details to facilitate extended analysis as needed ahead of construction. (Stephen and Robert, 2007).

### 1.1.3 Benefits of BIM

Hergunsel (2011) concluded that BIM enhances the use of "design to build" and "built to design" concepts in which coordination, construction planning and prefabrication have been proven through various studies that BIM makes construction more efficient. The application of BIM starts in the *predesign phase* where the building programme and site/design analysis are crucial, BIM has been used as a database for information gathering and sharing among project team on the early stage of design process. BIM has several beneficial uses apart from visualisation such as 3D renderings which can be easily generated in-house with little additional effort. According to Azhar, Hein and Sketo (2011) in the *design phase* it is used as a "Conflict, interference and collision detection: because BIM models are created, to scale, in 3D space, all major systems can be visually checked for physical and technical interferences". For example the process can verify that a service such as plumbing does not interfere with each other or with structural components such as beams.

Further it can be used for *construction sequencing*: a BIM model is effectively used for procurement, delivery programmes and assist in fabrication of building components. In addition, BIM can be used in forensic analysis; where a BIM model is used to represent potential weakness (failures and leaks) in structure of a building and design an evacuation or renovation plan. The programme can be used for *facilities management and operations*: facilities management departments can use BIM for renovations, space planning, and maintenance operations. (Azhar, Hein and Sketo, 2011) The authors' further stated that outside of the construction cycle; building inspection units in city/urban planning and development control can utilise BIM for building code reviews: in which planning officials like fire inspectors can review models to scrutinise fire plans during approval stage of designs.

### 1.1.4 Challenges of BIM

ICT is a core factor in the adoption of BIM, without the effective use of ICT in the construction industry, BIM use cannot be fully realised. A report by Kajewski and Weippert (2001) state, ICT is used to improve efficiency; transform the supply chain and increase total value. They further argue the barriers associated with ICT implementation and successive BIM adoption includes lack of top management buy-in, lack of training, lack of financial resources to implement ICT and lack of ICT/BIM Specialists to assist in implementation. A survey conducted in the US by the National Institute of Building Sciences found other challenges affecting BIM adoption are Lack of interest among other project stakeholders, lack of Technical support for interoperability, and Lack of Awareness on the application of BIM on the Specific Area of Project Management. (NIBS, 2007)

With successful adoption, BIM is not spared from risks associated with its utilisation. One of the risks associated with BIM is increased liability of contractors and designers. A Study by Katz and Crandall (2010) states contractors are worried that BIM will blur the line between design and build. Generally in construction Law, contractors are not liable for consultant/client defects in their own documentation as long as the specifications and designs are monitored during construction. This protection is known as the *Spearin doctrine* (US Supreme Court, 1918). "The protection afforded contractors under the

*Spearin doctrine* is based on the implied warranty from the party providing the design documents and specifications (typically, the owner) that those documents and specifications are free from defects. There is concern among contractors that active collaboration by the contractor in the design process through BIM will undercut the implied warranty behind the design documents and lead to weakened protection for contractors under the *Spearin doctrine*." (Katz and Crandall, 2010)

Another possible drawback is the risk in ownership of intellectual property. BIM is a collaborating tool; therefore any of the teams assigned to the project can access and edit it which can bring conflict in rights ownership. Fundamentally, AEC consultants may claim ownership of the BIM models and the project owner may do so being the employer. A risk common in such case is determining the owner of the data and to the extent of application of copyright. Thompson, (2001) underlines that if the owner is paying for the design, then the owner may feel entitled to own it, but if team members are providing proprietary information for use on the project, their propriety information needs to be protected as well. Therefore no direct solution is available in the cases above; the issues need to be dealt with uniquely as per project characteristics and to ensure the stakeholders are getting the full potential of BIM.

## 1.2 BIM in South Africa

### 1.2.1 Adoption in South Africa

The South African construction sector has for a long time utilised various CAD systems but in the recent times, BIM has had an increased use in the structural and civil engineering sector. Autodesk BIM and Tekla software packages have made a big impact in the construction scene especially in the construction of the stadiums for the 2010 FIFA World Cup and Power Stations such as Medupi Station. The adoption was mainly for the 3D modelling and interface management for clash detection. However, the full spectrum of BIM usage was not realised during these projects.

## 1.3 Need for the study

Project Management is an important aspect of the South African construction industry and with that this study is important to find out how BIM has an effect on its knowledge areas. With BIM's benefits and challenges identified in studies world-wide, the following study investigates the utilisation of BIM in the Project Management processes thus identifying its abilities, challenges and the strategies that need to be put in place for BIM to have a maximum effect.

## 1.4 Problem Statement

The South African construction industry has started implementing BIM in projects of various magnitudes. With its increased potential and challenges alike, it provides an untapped tool to assist in construction project management. However, the industry faces a wide range of challenges that the Project Management profession provides a pool of solutions which have to be assisted with the use of technology as discussed under the use of ICT in the industry. What is required is the increased use of BIM to complement the project management discipline as recommended by Broquetas (2010) that further studies should focus on how to improve BIM and aspects of BIM implementation, rather than trying to prove if BIM should be used or not.

## 1.5 Research Questions

i) What impact has BIM brought in the construction industry's Project Management discipline in South Africa?
ii) How has BIM implementation been done with comparison to project planning in the AEC sector in South Africa?

iii) What are the lessons learned from existing projects that have used BIM and future strategies that can assist in wider use of this application?
iv) What mechanisms are required to implement BIM within Project Management in South Africa?

## 1.6 Aims of the Study

The aim of this study is to investigate the current state of the BIM adaption on the Project Management applications in the South African AEC industry and check on strategies required for its full adoption.

## 1.7 Objectives of the Study

a) To identify the various Project Management applications of BIM as well as its challenges and strategies.
b) To investigate the current status of the BIM adaptions on various Project Management applications among the South African AEC industry.
c) To identify the challenges and strategies to overcome the challenges enhancing its effective adaption.

## 1.8 Scope of the study

The study will concentrate on the AEC professionals of the Gauteng Province construction industry; including Architects, Engineers, Quantity Surveyors and Project Management consultants.

## 1.9 Limitations of the Study

The study was limited to data collection in the Gauteng Province in South Africa. Gauteng Province recorded an economic growth rate of 5.7% during 2010, and it has by far the largest economy in South Africa, valued at R668.9 billion and contributing 33.5% to South Africa's GDP. (Stats-SA, 2011). Consequently, Stats-

SA (2011), stated Gauteng's largest industry is finance, real estate and business services (22% in 2007), followed by manufacturing (19.6%). This provides an enormous access to AEC sector data beneficial to the study with opportunities for case studies on the World Cup venue projects, the Gautrain transportation project and several commercial buildings that have utilised BIM in project planning and execution.

## 1.10 Methodology

The research philosophy adopted follows positivism and a deductive research approach to unwind the truth about BIM utilisation for project management as depicted by Saunders et al (2007). This approach has uncovered the challenges BIM faces and the strategies required for the successful implementation of BIM. A survey research method was used for purposes of collecting data and triangulated using open ended interviews for purposes of validity.

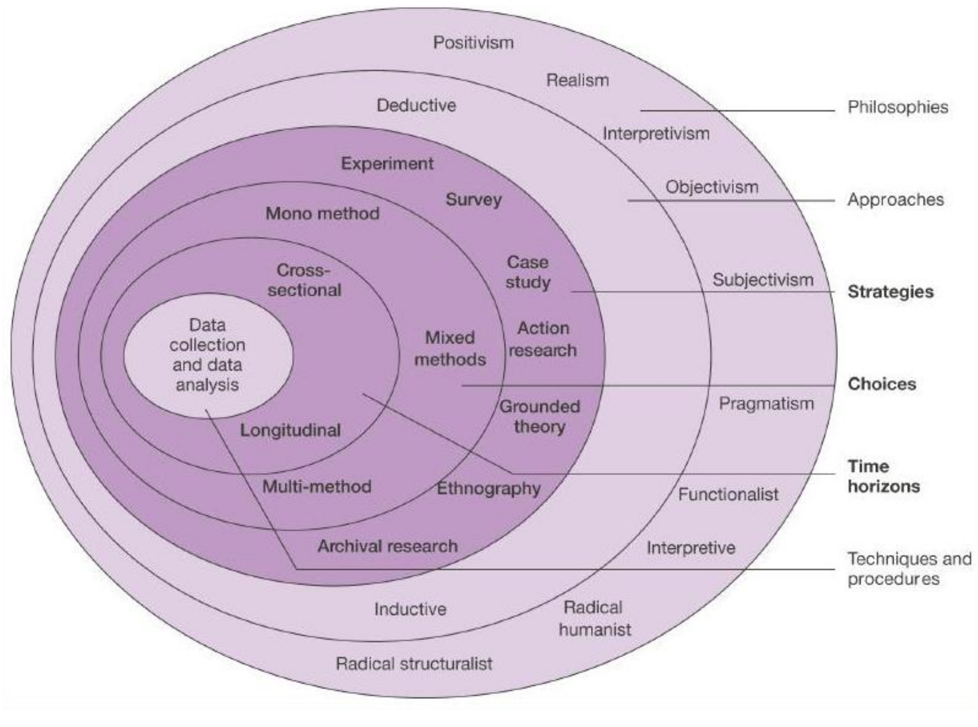


**Fig 1.0: Saunders (2006)**: Research Onion on
the description, explanation and justification
of methods of research methodology

## 1.11 Thesis Structure

The study is divided into the following sections:

***Chapter one***: are the introduction and an overview of the problem statement, aims and objectives of the study.

***Chapter two***: entails the literature review where BIM is introduced, its applications in the predesign, design, construction and maintenance phase. Finally, check the use of BIM as a graphical tool and the adoption strategies in the South African construction industry.

***Chapter three:*** covers the research methodology to be followed. It explains the justification for the research design to be followed and an overview of the type of analysis used.

***Chapter four:*** presents the data collected in an analysed format using the SPSS application. It explains what each result means and relevant conclusions made.

***Chapter five:*** are the result interpretations and conclusions to the study from the data collected.

## 1.12 Ethics in Research Study

The study endeavoured to apply the relevant procedure of ethics as laid down by the University of the Witwatersrand. Care was taken to ensure there is complete *voluntary participation* for all respondents. With this in mind, *informed consent* of all project participants was carried out to ensure respondents understand the risks and procedures (if any) that may be in undertaking this research. This study further guaranteed participants *confidentiality* and strict principle of *anonymity* in all aspects of gathering and analysis of data.

## 2.0 LITERATURE REVIEW

### 2.1 Introduction

This chapter reviews Building Information Modelling applicability in the building and construction sphere; as such it will investigate its use in Pre-Design, Design, Construction, Maintenance. Secondly review BIM as a graphic tool in which bares its origin from; thirdly review BIM as a Project Management tool and South African BIM adoption status. It should be noted that limited literature exists on the adoption, use and research of BIM in South Africa. As seen in the previous chapter, BIM applicability in the construction industry relates to its back bone of ICT in the professions related. ICT has had major role to play in the introduction of BIM; countries that are considered emerging markets such as India have embraced the concept of Virtual Design and Construction to facilitate work processes and organisation of design-construction-operation team which has evolved to Building Information Modelling. These emerging markets are now embracing the need for this tool and research well established on this new concept.

### 2.2 ICT: A CAD perspective

Computer Aided Design can be traced back in time and connected to Euclid of Alexandria, a Greek mathematician, often referred to as the "Father of Geometry". His works have been influential in the fields of perspective, conic sections, spherical geometry, number theory and rigor. (Joyce, 1994) In his famous writing, "The Elements" in 350 B.C. Euclid expounded many of the postulates and axioms that are the foundations of the Euclidian geometry upon which today's CAD software systems are built.(CADDAZZ, 2004) After more than two thousand years Ivan Sutherland in 1963 as part of his PhD thesis at MIT developed “Sketchpad”. This innovation enabled the designer interact with the computer graphically by using a light pen to draw on the computer's monitor. After forty years, ideas introduced in Sketchpad have forged a better understanding for 3D visualisation in computing. It made essential contributions in the area of human-computer interaction, being one of the first graphical user interfaces (Sutherland, 2003).

Initially due to the high cost of early computers and to the unique mechanical engineering requirements of aircraft and automobiles in the 60s and 70s, large aerospace and automotive companies were the earliest commercial users of CAD software. (CADDAZZ, 2004). The construction industry seldom used any CAD inputs in their everyday work; this is also further attributed to the fact that the Architect was able to handle all the design and implementation of projects as they were not complex as today. CAD software has evolved from research to commercial use in the 1970s and its development slowly turned into individual groups. (CADDAZZ, 2004) These groups will be highlighted in subsequent review.

To understand why 3D visualisation and CAD was important at this stage, the elements of calculations were imperative to computer virtual design; in the 1960s these kinds of tests were used in the design of aircrafts. Some of the mathematical description work on curves was developed in the early 1940s by Isaac Jacob Schoenberg, Apalatequi (Douglas Aircraft) and Roy Liming (North American Aircraft), however probably the most important work on polynomial curves and sculptured surface was done by Steven Anson Coons (MIT, Ford), Pierre Bezier (Renault), Birkhoff (GM) Paul de Casteljau (Citroen), Carl de Boor (GM), James Ferguson (Boeing), and Garabedian (GM) in the 1960s and W. Gordon (GM) (Raj, 2007) all largely motor industry based.

Most CAD software programmes in the 60s and 70s were still 2D replacements for drafting. Some of the advantages realised by manufacturers included reduced drawing errors and with more accuracy, drawings became more reliable in the long run. The Lockheed aircraft company developed CADAM (Computer Augmented Drafting and Manufacturing) system where in 1975 the French aerospace company, Avions Marcel Dassault, purchased a source-code license of CADAM from Lockheed and in 1977 began developing a 3D CAD software program named CATIA (Computer Aided Three Dimensional Interactive Application) being a successful and widely utilised CAD programme to date. (Aakanksha, 2010)

The development and expansion of CAD software can be attributed to the affordability of computers over the years. The construction industry evolved to the use of CAD as now a universal application in the industry. The groups responsible for CAD development as mentioned earlier include GRAPHISOFT and AUTODESK.Inc who were at the time at the forefront of commercial extension of these programmes. Graphisoft claims to be an initial Building Information Modelling tool as due to its 3D drafting capability. Both organisations are now a leading developer in BIM.

The American company Autodesk was founded in 1982 by John Walker, starting with the 2D CAD edition called AutoCAD. Not long after, the company released Pro/ENGINEER in 1988, which signalled greater usage of feature-based modelling methods and parametric linking of the parameters of features. Ian Braid then continuously developed programmes that had B-rep solid kernels which were engines for manipulating geometrically and topologically consistent 3D objects; all sources of today's 3D visualisation capabilities of most CAD programmes. (Autodesk, 2012)

According to ArchicadBIM centre webpages (2012) Graphisoft on the other hand was also founded in 1982 by István Gábor and Tari Bojar Headquartered in Budapest, Hungary. Graphisoft was founded with the objective of developing 3D modelling software for PC. In 1984 cooperation between Graphisoft and Apple Computer was established and the first ArchiCAD 1.0 was released as the first 3D CAD software for Apple Macintosh. With now over 125 000 users world-wide, ArchiCAD is now a leader in 3D BIM technology.

Sarshar and Isikdag (2004) further state that ICT is an enabler for integration through the use of 3D modelling and visualisations, virtual reality (VR) applications, object-based product models, four-dimensional computer aided design, and construction process simulation applications. They further state that ICT assists in enabling collaboration and knowledge management which are systems set up for the engineering teams to coordinate various tasks and activities in a project life cycle. Jafaar et al (2007) also notes in their publication that the complexities of projects especially of large scale in nature have advanced the increased use of CAD. The study further state that "innovation in construction procurement for example design, building and operation requires contractors to equip themselves with new knowledge on technologies".

## 2.3 BIM Applicability in the Construction Life Cycle

### 2.3.1 Use of BIM in Pre Design Phase

The key to the success of any project stands with clear understanding of the facility or project to be constructed and problem to be addressed. The pre-design phase involves issues as project start-up, project work plans, data/documentation collection, site surveys/tests, confirmation of existing site conditions and confirmation of space design. (AIA, 2012) These vital information guides the professionals to solve issues related to the project in a timely and cost effective manner. A study by Chen and Kamara, (2011) highlighted that the AEC industry is information dependent, and there is an extensive amount of information generated and exchanged in a project lifetime.

In the term BIM, the "Information" part will generally mean any piece of information tied to the model elements in the BIM which could for example be dimensional, locational, cost, schedules, energy calculations and responsibilities. As illustrated by Smith and Tardif (2012), during the pre-design phase a lot of the information is either in written/text form or in spread sheets used for alphabetic building data. All data gathered and generated in this phase is then recorded into the BIM software and is readily available for all project consultants. As Ham *et al* (2008) state that traditionally in this phase of the construction cycle, the data gathered was dependent upon experience and intuition, however due to projects becoming more complex, the amount of data to be analysed increases tremendously, therefore the necessity arises for a plan that could directly support the pre-design phase. BIM thus provides for a rich base of information which can easily be retrieved; this in turn increases speed of information exchange and delivery heading towards the design process through process review and assessment capability and strategy development.

### 2.3.2 Use of BIM in Design Phase

As stated in the previous chapter, BIM's major benefit is the aspect of 3D visualisation where the project is built virtually with all components, fittings, fixtures, services and details applied. This gives the design team a clear picture to ascertain they have achieved the deliverables of the project in the design phase. Characteristics such as building simulation, data management and checking the building operations can be done at this stage with collaboration with other project stakeholders as this stage is mainly the architect's role to input the design and later involve the MEP, Structural and Quantity Surveyors to action their respective roles.

Once the 3D virtual construction is completed as shown in figure 2.1 by the design team, the opportunity arises to all frontline project stakeholders to visualise the project; giving increased understanding of the complex sections of the project; which immediately has positive impact in giving inputs to improve design both cost effectively and in time. Additionally, at this stage creation of a 4D model (Time) is established and aspects such as project schedule, sequenced animated video of construction, immediate high level of understanding by the key stakeholders and front line staff with awareness of complexities prior to works starting is achieved.

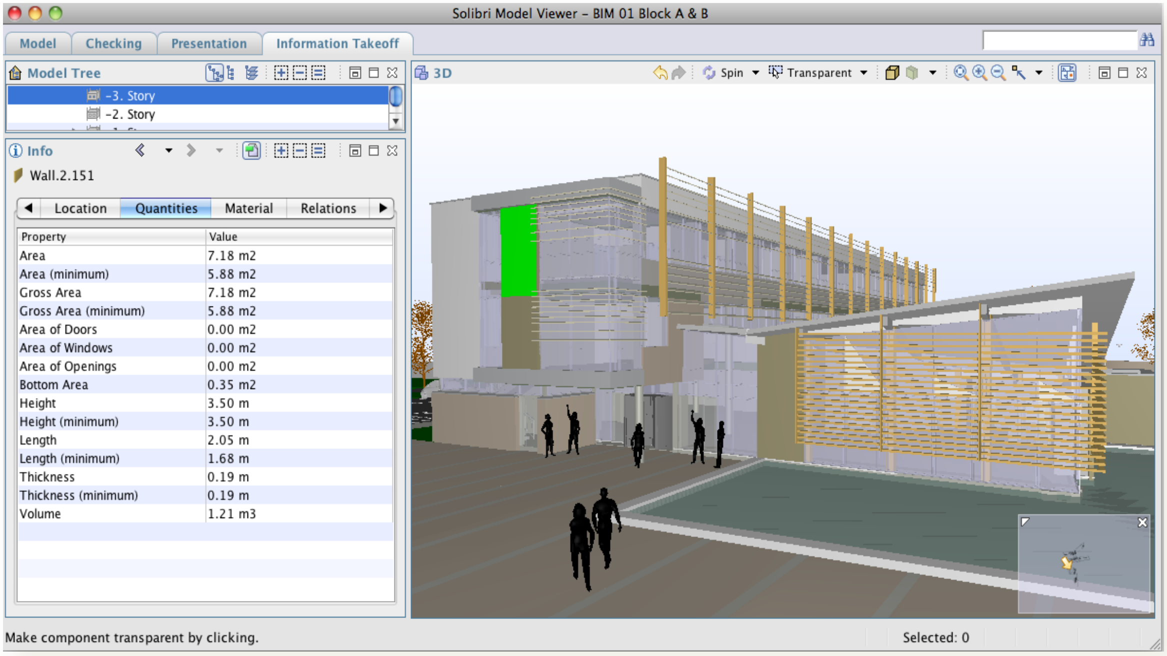


**Figure 2.1: Solibri (2012):** BIM 3D visualisation
and data input-output such as quantity take offs

### 2.3.3 Use of BIM in Construction Phase

During the design phase some issues may not be captured by the design team and will require them to proceed to the next stage to engage with builders on a more practical level. BIM's ability to plan and engage the building and services consultants/contractors has immense benefit by creating an environment for issues such as Logistics, Existing Conditions, Mobilization, Truck Routes, Excavation, Foundations, Steel Erection, Exterior Envelope, MEP Equipment / Systems, Interior Finishes, Site Improvements (Bond, 2010). With improved planning of the construction sites, safety of these sites can be assessed accordingly making BIM a tool for site safety analysis. Further, at this stage; the 3D visualisation simulates various cost accounting scenarios and can be used to forecast the cash budget in turn assisting in analysis or estimation for all models or different parts of models contributes to the decision-making process based on "what if" scenarios by extracting quantity information. (Intelibuild, 2013)

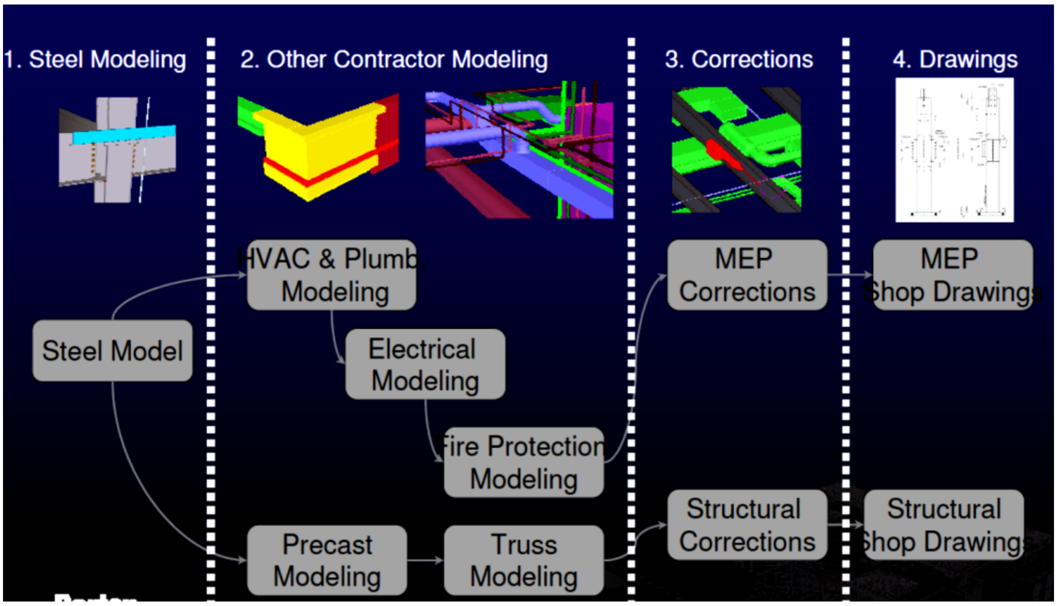


**Figure 2.2: Barton Marlow (2011):** BIM workflow sequencing by Main Contractors

In the construction phase, adequate sequencing of work avoids issues like rework, duplications and increases the effectiveness of current information as the BIM model is continuously updated with new data by the stakeholders. As shown above in figure 2.2, the main contractor involves the sub-contractors in the modelling and sequencing of works to be carried out and eventual production of shop drawings. This process reduces risk through better field visualisation by enabling tracking of challenges at an element by element level by communicating and accurately managing the fabrication and construction process.

### 2.3.4 Use of BIM in Maintenance Phase

Research suggests that more than ten billion dollars is annually lost in the United States due to insufficient close out and as built information for the process of facility management and operation; while 85% of the lifecycle cost of a facility occurs after construction is completed and approximately (Newton, 2004). In the traditional handover process, the disparity between the information transferred from the design documentation or construction documentation to the building owner is a major disconnect in what many aspire to see as a fully integrated digital process (Rudge, 2012). Therefore for maintenance to be effective this information from the construction phase; mainly as built drawings and data from fit out procedures can be easily done in BIM to assist operators to put measures in place for the asset and installation maintenance. This avoids the previous handing over of cumbersome and numerous manuals to facility managers for record keeping and streamlining the information/data recording in this phase.

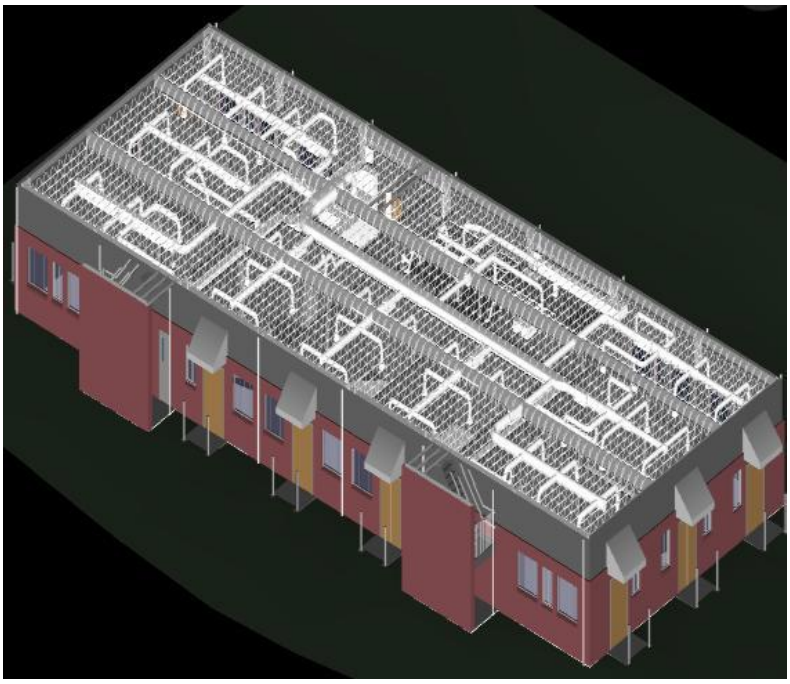

**Figure 2.3: Philips and Azhar (2011):** HVAC system installation for completed building

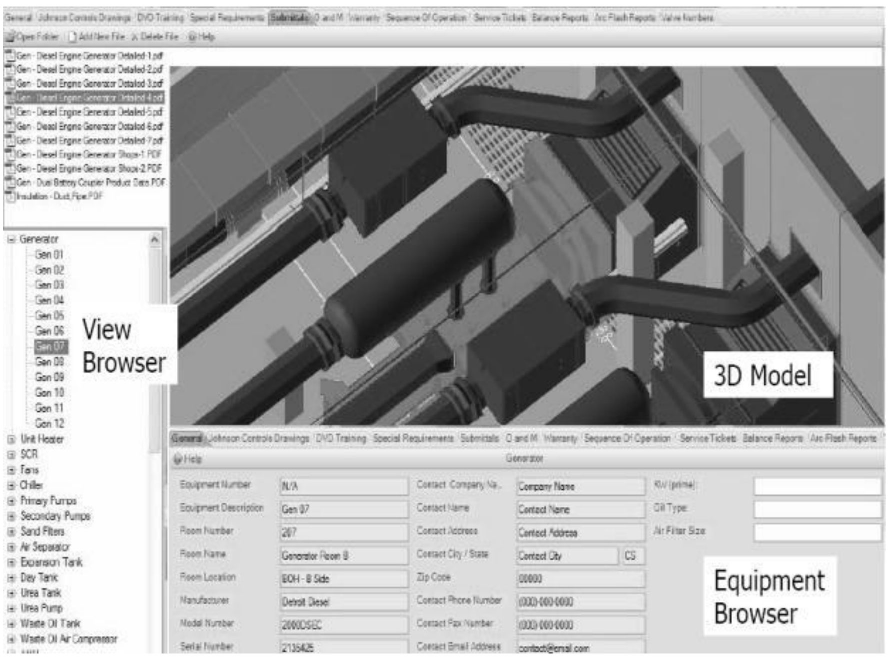


**Figure 2.4: Philips and Azhar (2011):** HVAC system installation data and outfit specification

As shown in figure 2.3 and figure 2.4, BIM provides information about a building and its spaces, systems and components. This information can assist Facility Managers to pin point the location, name, model number, product type, operation and maintenance manuals, commissioning information and performance data (Philips and Azhar, 2011). Further this stage of BIM will contribute to aspects of maintenance such as maintenance work order management; emergency service request management; space planning and management; inventory management and inspections; move management; and real estate portfolio management. (Philips & Azhar, 2011). Below is a summary of the application BIM in the construction lifecycle.

**Figure 2.5: Summary of BIM application (Philips & Azhar, 2011).**

| BIM APPLICATION | OWNER | DESIGNER | CONTRACTOR | FACILITY MANAGER |
|---|---|---|---|---|
| Visualization | ● | ● | ● | ● |
| Options Analysis | ● | ● | ● | |
| Sustainability Analyses | ● | ● | | |
| Quantity Survey | | ● | ● | |
| Cost Estimation | ● | ● | ● | |
| Site Logistics | ● | | ● | |
| Phasing and 4D scheduling | | ● | ● | |
| Constructability Analysis | | ● | ● | |
| Building Performance Analysis | ● | ● | ● | ● |
| Building Management | ● | | | ● |

## 2.4 BIM as a Graphical Tool and its Benefits

As highlighted in section 2.2, BIM evolved from CAD software and has become a tool for digital simulation of design and construction; a drafting tool for spatial simulation of complex conditions and processes; a comprehensive simulator for measuring performance indicators. As a graphics tool, BIM is used by designers and contractors to communicate design intentions (Figure 2.6) within a project team and to the project owners. This 3D graphical representation has in turn as stated previously assisted the design team see a project in reality within the design office making rapid design decisions rapidly at the stage at which changes do not impact the total cost of construction.

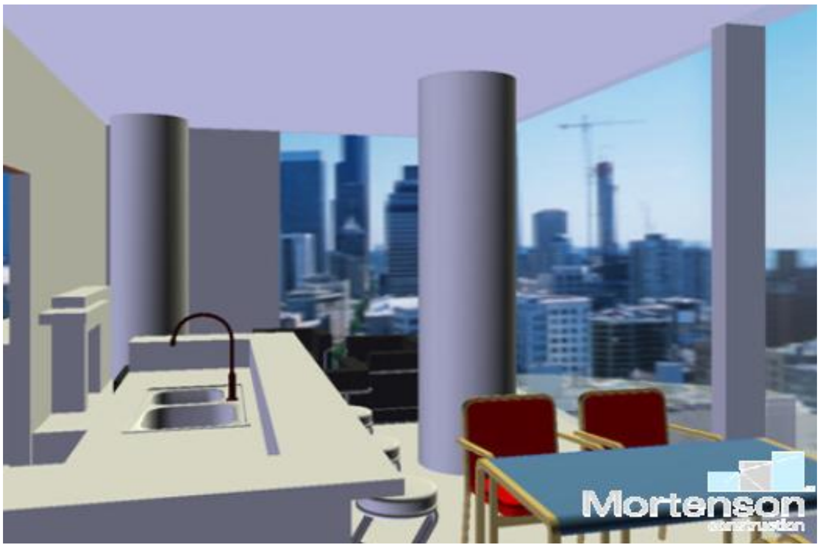


**Figure 2.6: Mortenson (2007):** Simulation of office design interior

BIM is also a design assistant and can review the constructability of components or elements in a building. As Azhar et al (2012) states, in the traditional CAD software where the drawings are graphical entities only, such as lines, arcs and circles, the BIM software represents each element as a model, where objects are defined in terms of building elements and systems such as spaces, walls, beams and columns. As such, if each element, component and fixture can be represented, estimations are more accurate and the project owner can assess the design more consciously with assistance of the design team.

### 2.4.1 BIM Benefits in the Design Phase

During any construction design phase, an Architect or Engineer, depending on the scope of the project, typically has to balance between the project costs, scope and time. The ability to check cost and time consequences is difficult in traditional methods where changes are made and passed on to relevant consultants to assess the result. The principal agent whether an Architect or Engineer has access to only the geometric data and design necessary for any change at one particular time due to the time and effort used in creating the design (Autodesk, 2003) The end result being tracking of the scope and time becoming a challenge to the design team. BIM provides better 3D visualisation, both at a macro and micro level, a feature vital for cost analysis where all construction elements, fittings and fixtures are analysed, specified and priced adding a fourth dimension (4D) to the programme.

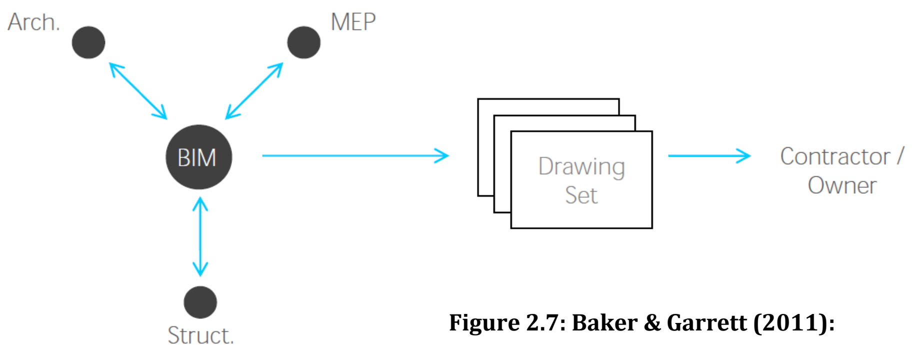


**Figure 2.7: Baker & Garrett (2011):**
BIM Interlink process.

On the contrary, with use of BIM, project changes during design phase can be monitored in terms of scope and time without spending extensive effort and time as compared to the traditional method as shown in figure 2.8. Hardin (2009) states that processes can be monitored in real time as changes are automatically updated both in the 3D model and the data base that has the relevant data such as pricing and model numbers. In addition if the BIM programme is connected to the internet, these changes are reflected to be seen by all consultants and users involved in the project. Arayici et al. (2011) further validates this notion by stating information exchange in BIM through company data bases provide linkages to the originally fragmented databases ensuring comparison and coordination.

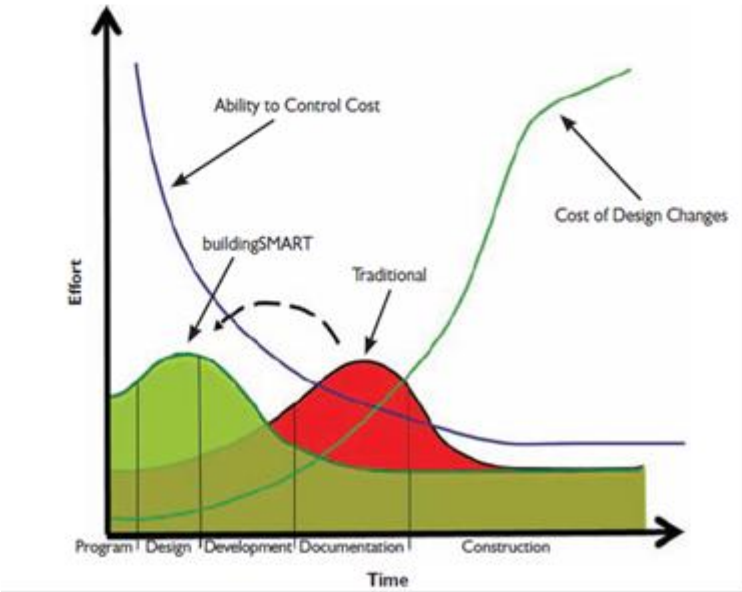


**Figure 2.8: Hardin (2009):** Effort vs. Time and cost comparison

Boon (2009) argues that BIM during design phase has the ability to model the technical performance of the building which can assist consultants in computational based analysis and simulation to be undertaken. Eastman et al. (2008) further expresses that such analysis can be performed in areas such as Structural analysis, energy analysis, mechanical equipment simulation, lighting analysis / simulation, acoustic analysis, airflow computational fluid dynamics and building function analysis. According to Autodesk (2012), the company released the *"Ecotect™ Analysis 2010"* suite which claims can assist designers in the simulation of building energy analysis, day lighting/shading design, thermal performance, carbon emissions, natural ventilation, wind energy photovoltaic collection, solar radiation, visual impact shadows and reflections, acoustic analysis services usage such as electricity, gas and water with cost estimates.

### 2.4.2 BIM Benefits in the Construction Phase

With increased information by the time a project goes to the construction phase, consultants and contractors are able to make refined decisions about projects. Better estimates, clash detection, quality and time controls are more accurate and defined. Boon (2009) identifies that Quantity surveyors are able to advise the design team much efficiently due to this rich data base of information. Solutions such as alternate forms of construction and better estimate evaluation helps both a contractor and design team reach competitive estimates and easy access to options in a problem.

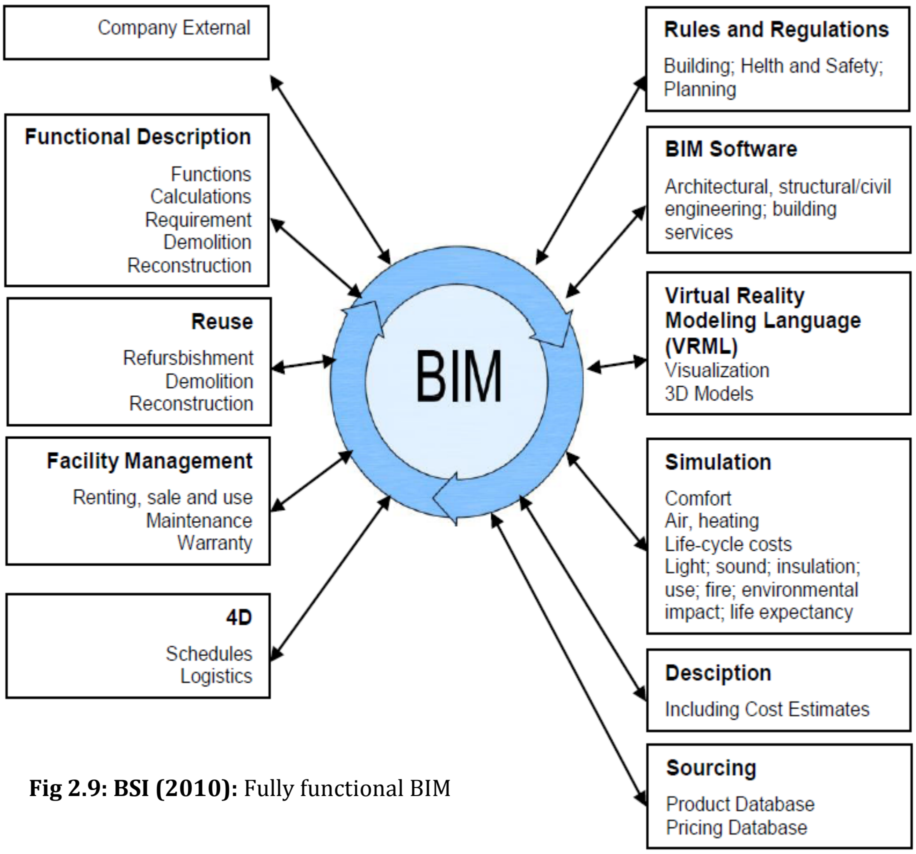


**Fig 2.9: BSI (2010):** Fully functional BIM

JBIM (2007) highlights the fact that with BIM, the site is safer due to fewer materials and fabrications on site due to the accuracy of virtual design. Prefabrication is done off site and whatever is needed is delivered on site on time keeping on-sire trades to a minimum. Ultimately increase workflow within a project is realised and better team work achieved due to reduced inventories of "engineered to order" components. Another benefit in this phase is that BIM provides lean construction, which is having impeccable alignment and holistic pursuit of concurrent and continuous improvements in all dimensions of the built and natural environment: design, construction, activation, maintenance, salvaging, and recycling (Abdelhamid et al. 2008) Enhanced management of these processes reduces the waste of overproduction; waste of waiting; waste of transportation; waste of inappropriate processing; waste of unnecessary inventory and waste of unnecessary movement.

### 2.4.3 BIM Benefits in the Management Phase

In the management phase of the building lifecycle, BIM provides concurrent information on the use and performance of a building; its occupants and contents; the life of the building over time; and the financial aspects of the building. During a renovation process, all the instalments and fittings are recorded for use by facility management to assist in eased replacement or procurement process. BIM provides also physical information about the building such as finishes, tenant logs, furniture or inventory logs, leasable space area and vacancy. It can assist in the design of standard buildings that need to be constructed on several locations or sites to give information on conditions for business. Consistent access to these types of information improves both revenue and cost management in the operation of the building. (Autodesk, 2003)

## 2.5 Challenges of BIM in Practise

As BIM is widely utilised and continuously integrated into the AEC industry, it is not immune to the fact that it may cause certain challenges to traditional project management practises. In addition, a few studies have shown that implementing BIM has hit a snag due to issues such as the fear of change by AEC professionals, legal issues, ownership issues, cost issue and training issues just to mention a few. No great idea is perfect, but the challenges BIM faces should be taken as a step to learn and improve on this idea.

a) ***Lack of interest among AEC professions:*** Bengtson (2010) describes that it is the attitude towards BIM that is the greatest challenge and has to become better in order to develop the utilisation of BIM. Surveys conducted by McGraw Hill construction in 2009 suggest that 52% of AEC professionals which are Architects derive better value for BIM, This is attributed to BIM evolving from the architectural profession, and many still see its value emerging from its use in the design phases McGraw (2009). Most in the design community, along with many contractors (43%) and owners (41%), say that architects experience a high level of value. The investigation finds that with majority of architects finding BIM beneficial and a higher return on investment on BIM, convincing the rest of the AEC professionals becomes a challenge.

**a)** ***Lack of BIM specialists and technical support in software:*** BIM can hold as much information as possible, but it is not uncommon for BIM to experience extensive projects that may require more expertise to extend its ability and capture all data. Despite faster and faster computers and more efficient software, the model slows down as it enlarges. Howell and Batcheler (2009) have also argued that size and complexity of the files that BIM systems create – For complex projects, the scalability and manageability of a fully loaded central BIM project database represents a major challenge which requires more BIM experts in hand to assist in this process.

b) ***Lack of technical support in interoperability:*** With multiple consultants, contractors and construction managers, the project manager will succumb to mismanagement of a project if not tracked efficiently. In this case interoperability between stakeholders is frustrated without technical support. It is hard to share data between Autodesk's Constructware, e-Builder and Meridian's Prolog. The same problem exists with BIM software. But improvements are being realised by BIM developers such as Autodesk and ArchiCAD, and have now integrated

Project Management software such as MS Projects with certain BIM programmes to alleviate the challenge stated. (Crandall & Katz, 2010)

c) ***Legal Issues associated with ownership of BIM document:*** As stated in the first chapter, contractors are sceptical of BIM creating problems and not presenting clearly the line between design and build. Contractors will often follow drawing specifications and instructions from clients/consultants and assume these documents are free of error without being liable if any occur. This protection is known as the *Spearin doctrine*, The protection afforded contractors under the *Spearin doctrine* is based on the implied warranty from the party providing the design documents and specifications (typically, the owner) that those documents and specifications are free from defects.(US Supreme Court, 1918) Concern is widespread by contactors that the doctrine will be weakened and not serve as a protection as BIM allows collaboration of information with contractors during design and build *.*

d) ***Intellectual Ownership:*** In the age of interoperability as discussed above, the issue of the ownership of data generated and gathered into one by various stakeholders comes into question. Crandall and Katz (2010) have identified the fact that BIM models can be opened and edited by other parties and used by other parties to derive new models, both of which can blur a model's ownership. This challenge has however been remedied over the course of the past few years and has in turn changed contracts used as BIM is now being integrated and agreements reached on how the data is handled and owned.

e) ***Lack of organisational support:*** Any organisation adopts new strategies in place to bring efficiency and reduce time to perform tasks. These strategies mainly originate from the top level management; without this level of decision making, BIM's adoption is hindered.

f) ***No client insistence:*** A study by Suermann and Issa (2007) investigated the impact of BIM on construction processes and through a survey to respondents of National BIM standards committee who were asked to rate their perception of BIM's impact on six Key Performance Indicators

(KPI). Client insistence was scored 82% as a factor of increasing the use of BIM; therefore project owners must be encouraged to include new technology as advised by like-minded professionals.

g) ***No regulatory mandate on BIM use***: In countries such as the United Kingdom, BIM is required in projects over £ 5 Million. These government mandates has encouraged the use of BIM in most developed countries.

## 2.6 Possible BIM adoption strategies

The fragmented nature and contextual problems associated with the construction industry challenge new technology constantly; with this in mind BIM can only be successfully adopted through widespread research and sensitisation. Its benefits are well known and numerous studies have acknowledged the claims of BIM developers. It is such that a few organisations such as the National Building Specification (NBS) of the United Kingdom have established completed strategies for the adoption of BIM in AEC organisations. NBS produces annual reports that conduct surveys on the usage of BIM. The equivalent in the United States, the McGraw-Hill Construction performs equal surveys on the utilisation of BIM in the United States and some strategies that are portrayed as possible measures for the adoption of BIM include:

a) ***Deployment of BIM Manager:*** This is vital in ensuring the proper structuring and management of BIM information processes and to track the object-oriented BIM against predicted and measured performance objectives, supporting multi-disciplinary building information models that drive analysis, schedules, take-off and logistics. (GSA, 2012)

b) ***Deployment of BIM Specialists on Appropriate Areas***: In recent times, BIM has been adopted by AEC professions and has changed to BIM consulting firms. Such firms are few and not easily accessed especially in developing countries. BIM developers and sellers must take the responsibility to assist professionals in such areas. (Muthumanickam *et al*, 2011)

c) ***Training and Development on BIM:*** Training is vital in any introduction of new systems. Top level management and BIM developers should assist in training staff for efficiency of use. (Ashcraft, 2007)

d) ***Government and Regulatory Actions/ Mandate:*** As stated earlier, the UK adopted BIM in projects exceeding £5 Million, BIM is now a part of construction contracts and widely utilised. (NBS, 2013)

e) ***Project BIM Management Plan/ BIM Guidelines:*** This can be done as seen in the developed countries; BIM guidelines established by professional bodies in conjunction with government. (NBS, 2013)

***f)*** ***Top Management/ Client's Support***: through client insistence and management. (McGraw, 2007)

g) ***Abundant BIM Element Library:*** The NBS has set up an online elemental library for all professions to access and maintain a national standard.

h) ***Incentives for Utilising BIM:*** Government through the respective professional registration councils and bodies can encourage the use of BIM by giving AEC professions tax incentives. (GSA, 2012)

i) ***New staffing with BIM knowledge:*** Use of BIM trained personnel; this may be a challenge due to firms reluctant to hire new staff.

***j)*** ***Business Process changes according to Collaborative Work:*** Through interoperability and management decisions. (Howell & Batcheler, 2009)

k) ***Better Interoperability through Appropriate Technical Support:*** McGraw (2007) defines interoperability as the ability to manage and communicate electronic product and project data among collaborating firms. Without this concept BIM adoption is challenged due to lack of information sharing and coordination.

## 2.7 BIM in Project Management Practice

Project Management is the overall planning, coordination and control of a construction project from inception to completion, involving multi-disciplinary stakeholders from architects, engineers, quantity surveyors, town planners, interior designers to contractors. According to Haughey (2011a), the project manager has the overall responsibility for delivering a successful project. Industry observers and regulators have argued that BIM is apparent in Project Management. This study aims was to focus on the application of BIM in the Project Management discipline and investigate whether BIM has a role to play in the South African construction sector. An important factor to note is that the study will evaluate the how BIM affects disciplines and sub disciplines of Project Management as shown below in figure 2.10.

| **Project Management Knowledge Areas** | **Project Management Processes** |
|---|---|
| **Project Integration Management** | Project Plan Development |
| | Project Plan Execution |
| | Integrated Change Control |
| **Project Scope Management** | Initiation and Planning |
| | Scope Verification |
| | Change Control in Project Scope |
| **Project Time Management** | Activity Definition, Sequencing & Duration Estimation |
| | Schedule Development Control |
| | Progress Monitoring |
| **Project Quality Management** | Quality Planning |
| | Quality Assurance |
| | Quality Control |

| Project Management Knowledge Areas | Project Management Processes |
|---|---|
| Project Risk Management | Risk Identification |
| | Risk Analysis |
| | Risk Monitoring and Control |
| Project Cost Management | Resource Planning |
| | Cost Estimating |
| | Cost Budgeting & Control |
| Project Communications Management | Communication Planning |
| | Information Distribution |
| | Performance Reporting & Administrative Closure |
| Project Human Resource Management | Organizational Planning |
| | Staff Acquisition & Team Development |
| | Project Team closeout |
| Project Safety Management | Safety Planning |
| | Safety Plan Execution |
| | Safety Administration and Records |
| Project Environmental Management | Environmental Planning |
| | Environmental Assurance |
| | Environmental Control |
| Project Financial Management | Financial Planning |
| | Financial Control |
| | Financial Administration and Records |
| Project Claim Management | Claim Identification & Quantification |
| | Claim Prevention |
| | Claim Resolution |
| Project Procurement Management | Procurement Planning |
| | Solicitation Planning |
| | Contract Administration, Contract Closeout |

**Fig 2.10: Author (2013):** Construction Project Management Knowledge

In line with the South African context, as the Project Manager is mainly the team leader in most construction projects, Broquestas (2010) survey suggested that the Project Manager should be BIM proficient and 24% of respondents highlighted the Project manager should take lead in the BIM management. BIM's positive attributes According to various studies and white papers reviewed a summary of the benefits of BIM are highlighted in figure 2.10 below. The benefits can be linked to the various stages of the construction life cycle which have been highlighted in section 2.3. It is evident that BIM plays a crucial role in the discipline of Project Management. The study aimed to investigate if the same applies to South Africa. In Figure 2.12, a cross reference shows the benefits that BIM has in the Project Management discipline.

| Benefits / Sources | Enhanced project collaboration and control among stakeholders | Improved productivity (less re-work, conflicts and changes) | Better project quality and performance | Faster project delivery | Reduced wastages | Reduced construction costs | New revenue and business opportunities |
|---|---|---|---|---|---|---|---|
| (ASHRAE, 2009) | √ | √ | √ | √ | √ | | √ |
| (Azhar, Hein, & Sketo, 2008) | √ | | √ | √ | | | √ |
| (Becerik-Gerber & Rice, 2009) | | | | √ | √ | √ | |
| (Beck, 2011) | √ | | | √ | √ | √ | |
| (buildingSMART, 2010) | | | | √ | √ | √ | √ |
| (El Dado, 2011) | √ | √ | √ | √ | | √ | √ |
| (Giel & Issa, 2010) | | √ | √ | √ | | | |
| (Han & Damian, 2008) | | | √ | √ | √ | √ | |
| (Hardin, 2009) | √ | √ | √ | √ | | | √ |
| (Hergunsel, 2011) | √ | √ | | √ | √ | √ | √ |
| (Hurley, 2008) | | | | √ | √ | √ | |
| (Rodriguez, 2011) | √ | √ | | √ | √ | √ | √ |
| (Underwood & Isikdaq, 2009) | √ | √ | √ | √ | √ | √ | √ |

**Fig 2.11: Qian (2012):** Key benefits of BIM identified by various sources. The list is not exhaustive; most commonly mentioned benefits shown according to literature reviewed

| **Figure 2.12: Author (2013) Cross check of BIM & PM Application** | | |
|---|---|---|
| **Stage of Construction Project** | **BIM Benefits** | **Type of Project Management Application** |
| **Pre-Design** | Feasibility study | Scope, Integration, Human Resource, Environmental |
| | Virtual design of complete project | Risk, Time, Financial |
| **Design Stage** | Earlier and more accurate visualizations of Design with 3D model | Risk, Cost, Safety |
| | Automated corrections (low-level) when design changes are made | Communication, Risk, Time, Scope |
| | Early collaborate and simultaneous work by multiple design disciplines | Scope, Time, Human Resource, Quality, Integration |
| | Increased accuracy and consistency of 2D drawings from early stages and at any stage of the design production phase | Risk, Time, Procurement, Cost Management |
| | Extraction of bill of quantities for cost estimation | Cost, Financial Management |
| | Design intent checks using 3D visualizations as well as quantification of the space areas | Time, Risk, Integration and Procurement Management |
| **Construction Stage** | Synchronisation of design and construction | Integration, Time |
| | Clash detection | Risk Management |
| | Cross System updates | Risk, Time Management |
| | Fabrication | Time, Procurement, Quality |
| | Reduce wastage | Risk, Cost |
| **Maintenance Stage** | As built documentation | Quality, Risk, Financial Procurement |
| | Fit out documentation | Quality, Risk, Financial Procurement |

## 2.8 South Africa's BIM adoption

Although not widely used as will be confirmed in the data analysis chapter, BIM in South Africa has been in the limelight since the turn of the new millennium. BIM software packages such as "TEKLA", "AUTODESK REVIT" and "ARCHICAD BIMx" have so far been used in various construction projects. The qualification to host the FIFA 2010 World Cup in South Africa gave the AEC sector an exclusive opportunity to implement and examine BIM. Two of the five newly venues built for the quadrennial event were modelled using BIM techniques and software, thus giving South Africa a distinctive chance in Africa to experience the advantages of BIM. (Constructdigital, 2010)

According to Constructdigital web page (2010) to design the steel roof structure of Nelson Mandela Bay Stadium in Port Elizabeth, CadMax of Boisbriand specialising in steel detailing, used Tekla Structures software of Espoo, Finland, to model the roof. The roof comprises of Teflon-coated fibreglass, held up with 36 steel girders and a total weight of 2,500 tons of futuristic curved beams. Daniel Barbeau of CadMax stated *"One of the most interesting parts of the project was the compression ring. To make the 3D model, we had to duplicate the model and simulate the deflection so the compression ring could be fitted properly after the girders erection."*

Additionally, the existing Royal Bafokeng stadium and the new Mbombela Stadium in the city of Nelspruit in Mpumalanga Province was produced by the same TEKLA software; in both projects, visualisation 3D imaging was used to create shop drawings, timelines and delivery schedules which was much needed for a hosting country. Risto Räty of TEKLA in 2010 further acknowledged that "Building the stadiums without the help of 3D BIM software would have been very difficult in an environment in which time was a critical element to the countdown to the opening of the first game".

# 3.0 RESEARCH METHODOLOGY

## 3.1 Introduction

This chapter accounts for the research design and method to be employed for this study. Since this study was an exploratory one by virtue that Building Information Modelling is a relatively new concept in South Africa; the study aims to find first-hand experience from AEC professions in this context. Exploratory research does not aim at the population in general but is specific to the samples related to the AEC industry. The effect of adopting this type of research is to deduce and find the challenges and impact of BIM in Project Management and suggest strategies for the conclusions to the study. This chapter will ultimately be guided by the research questions formulated and stated in chapter one of this report to design the methodology to be used.

### 3.1.2 Unit of Analysis

The unit of analysis of any study is the main basis or entity of which the research is focusing on. It mainly consists of the 'what' or 'who' that is being studied. Units of analysis are essentially the things we examine in order to create summary descriptions of them and explain differences among them (Trochim, 2006) In this study, the main entities are BIM and Project Management, the players of the South African construction industry owe the two disciplines to the success of most of their projects. Therefore the interactions of these industry players with the above mentioned disciplines provide an essential source to derive what our unit of analysis would be.

## 3.2 Appropriateness of the Research Design

All research approaches have underlying philosophical assumptions that guide the inquirer. Exploratory research is able to provide important outlook of a particular issue, this type of qualitative research only gives the "why", "how" and "when" something occurs, it cannot tell us "how often" or "how many"(Diether, 1998) The study requires the establishment of the reasons for why BIM is not widely used, not extensively known and the challenges it faces in the South African market. Consequently the study is interested in knowing what are some of the issues pertaining successful implementation of BIM in Project Management and how can BIM be fostered in this market with appropriate strategies

Alternatively, since the study is also investigating the strategies and challenges of BIM in the Project Management profession; it will be imperative to conduct surveys to check on the effectiveness of BIM in the sub-disciplines of Project Management as shown in chapter two. Therefore a quantitative approach will be used to evaluate the research questions addressed making the methodology employ a mixed method. There are two main approaches for reasoning, deductive and inductive. The deductive approach is based on already existing hypotheses which are tested in order to through logic reasoning confirm their accuracy (Research Methods Knowledge Base, 2006). For this research a deductive reasoning approach will be used to narrow down from the project management processes, tool application and finally the confirmation of the issues addressing the problem statement. The influences of this methodology originate from figure 3.0 with show selected methods and 3.1 giving back and forth reasoning process.

The aim of the study was achieved through the following objectives:

1) Use of critical literature review on BIM (adoption, challenges and strategies), Project Management discipline and impact of BIM on its sub-disciplines.
2) Concurrent known challenges in the AEC industry in implementing BIM.
3) Develop strategies to be put in place in South African AEC industry for the successful BIM adoption.

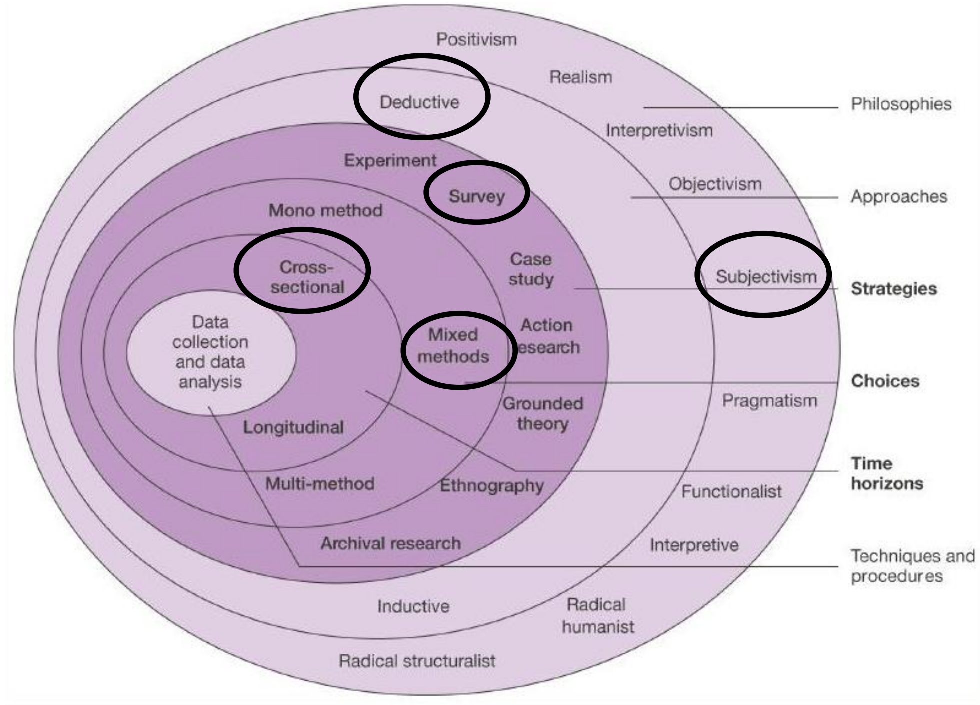


**Fig 3.0: Saunders (2006)**: Research Onion on the description, explanation and justification of methods of research methodology

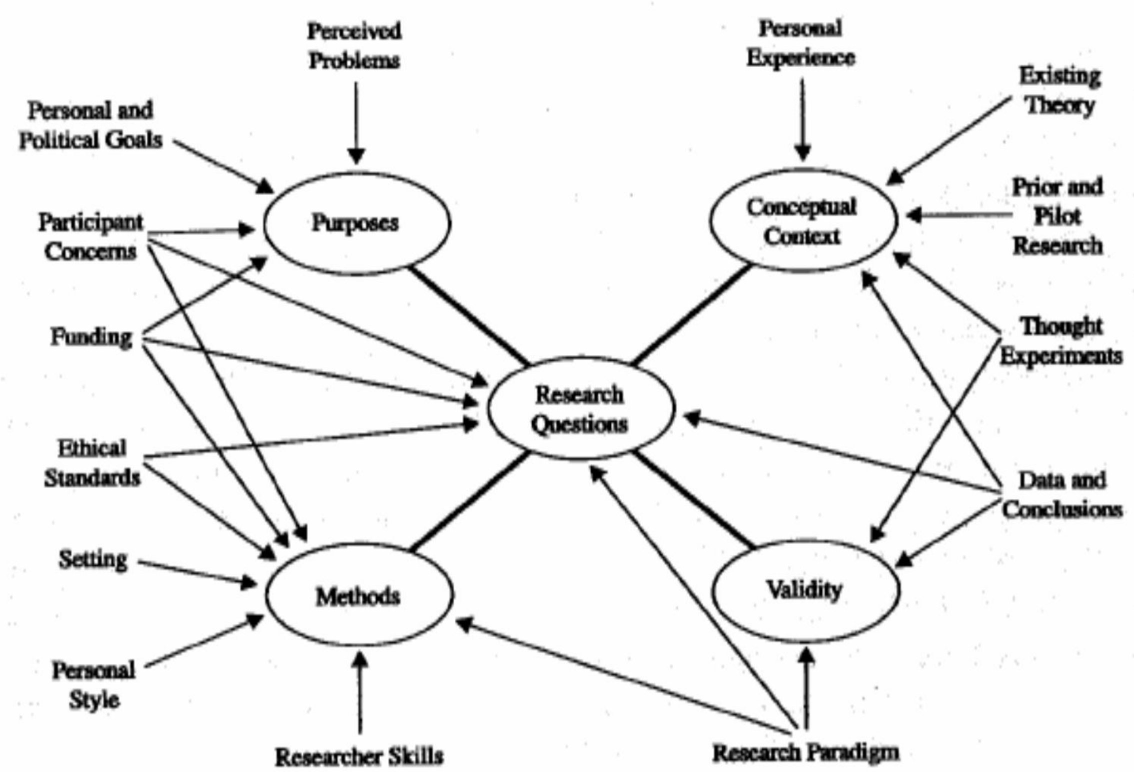


**Fig 3.1: Maxwell (1998)**:
Contextual Factors
Influencing Research

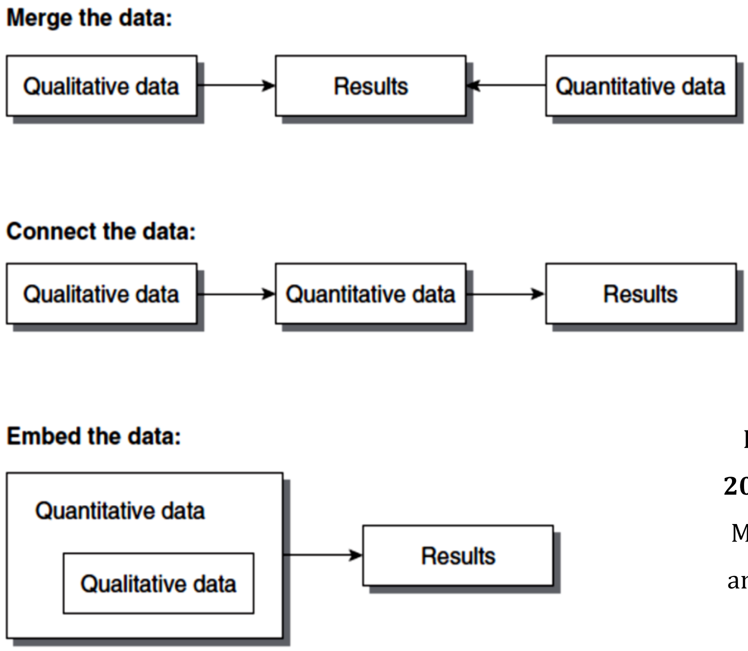


**Fig 3.2: Creswell 2006**: Three Ways of Mixing Quantitative and Qualitative Data

Justification for this type of research are multiple, some analysts such as Baumann, (1999) and Way et al (1994) have attempted to collects data using a quantitative survey instrument and had follow up interviews with a few individuals who participated in the survey to get a detailed picture of their responses. It has been widely argued that both forms of data are necessary today. In addition, qualitative research has evolved to a point where writers consider it a legitimate form of inquiry in the social sciences (Denzin & Lincoln, 2005). But the most important aspect over and above the type of method is choosing the appropriate questions.

Bickman *et al* (1998) reiterates in figure 3.3 the need to have a back and forth process in structuring questions for the data collection. The planning activities in the second stage should happen simultaneously until a final research plan achieved. Revisions of questions are encouraged through pilot studies; it was the aim of this study to follow these guidelines to determine the correct questions in establishing the impact of BIM in project Management.

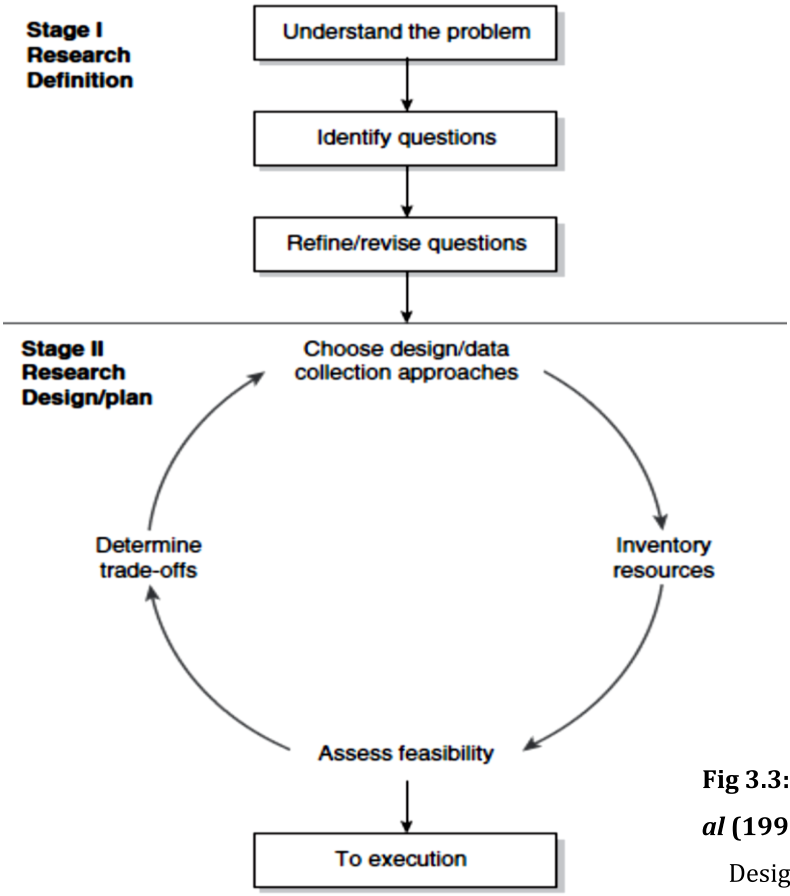


**Fig 3.3: Bickman *et al* (1998)**: Research Design Strategy

The National Research Council (2002) discussed scientific research in education and concluded that three questions need to guide inquiries: *"Description-What is happening? Cause-Is there a systematic effect? And the process or mechanism-Why or how is it happening?"* These questions, in combination, suggest both a quantitative and a qualitative approach to scientific inquiry. Dainty (2008) has expressed the view that encouraging of multiple theoretical models and method approaches also known as "multi-method" have been employed in construction management research. It is certain that each researcher strives to achieve validity and reliability in the methods of research employed both externally and internally and there has not been an agreement as to whether the one method supersedes the other.

Abowitz and Toole (2010) have argued the fact that people play key roles in nearly all aspects of construction suggests that effective construction research requires proper application of social science research methods. It is also evident that in the field of social science research, no one method such as observation, surveys and experiments are ideal. Each method has its merits and demerits. Abowitz and Toole (2010) continue to suggest that combined use of different research techniques can enhance the validity and reliability of a given study and combining quantitative and qualitative approaches in research design and data collection, however, should be considered whenever possible. The main challenge of mixed approach is that it may be costly in the long run in monetary terms.

### 3.3.1 Research design on Quantitative data collection

The following table below shows different statistical tests that can be used for the analysis of data. Several considerations have to be made before choosing an appropriate test which will be discussed subsequently.

| Level of Measurement | Sample Characteristics | | | | | Correlation |
|---|---|---|---|---|---|---|
| | 1 Sample | 2 Sample | | K Sample (i.e., >2) | | |
| | | Independent | Dependent | Independent | Dependent | |
| Categorical or Nominal | $X^2$ or bi-nomial | $X^2$ | Macnarmar's $X^2$ | $X^2$ | Cochran's Q | |
| Rank or Ordinal | | Mann Whitney U | Wilcoxon Matched Pairs Signed Ranks | Kruskal Wallis H | Friendman's ANOVA | Spearman's rho |
| Parametric (Interval & Ratio) | z test or t test | t test between groups | t test within groups | 1 way ANOVA between groups | 1 way ANOVA (within or repeated measure) | Pearson's r |
| | | Factorial (2 way) ANOVA | | | | |

**Fig 3.4: Plonskey: (2001)**: Summary of available statistical tests

In designing the questionnaire for data collection, the use of the literature review was used. The disciplines of the Project Management practise guided the questions that were asked as the research entailed the investigation of the impact of BIM on Project Management. The questionnaire further checked the challenges of BIM and the strategies to be put in place to adopt and increase the use of BIM.

A minimum of 30 respondents who work in the AEC industry in Gauteng was required in this section. A Non-Parametric test was employed in this research. This was guided by two questions: The type of data collected and the goal of the research. The goal of the research is to compare one group to a hypothetical value. The group will be the collective AEC professions who utilise BIM and through analysis hope to accept and reject the questions relating to the impact, challenge or strategy for use of BIM. A Non-parametric approach was used because of the following reasons and as argued by Molusky (1995) in which certain rules should apply including:

a) Observations are independent.
b) Variable under study has underlying continuity.

In this study the samples will be analysed using a non-parametric one sample Kolmogorov-Smirnov test. The KS-test has the advantage of making no assumption about the distribution of data. Other justifications for such a test according to Siegel (1956) are:

*i) Probability statements obtained from most nonparametric statistics are exact probabilities, regardless of the shape of the population distribution from which the random sample was drawn.*
*ii) If sample sizes as small as N=6 are used, there is no alternative to using a nonparametric test.*
*iii) Treat samples made up of observations from several different populations.*
*iv) Can treat data which are inherently in ranks as well as data whose seemingly numerical scores have the strength in ranks.*
*v) They are available to treat data which are classificatory.*
*vi) Easier to learn and apply than parametric tests.*

### 3.3.2 Research design on Qualitative data collection

As this study has employed a mixed method, to validate the surveys in the qualitative method, a follow up interview was used to add onto the data gathered and as a secondary source of data. Respondents were asked if they had additional time for a follow up interview and the results were compared against the quantitative data gathered. A total of two interviews were done as a follow up. A common method in qualitative data collection is interviews; the researcher may realise a great demerit in this method as different nature of data is collected from different interviewees and comparison becomes difficult (Leedy and Ormrod, 2010) Thus this method is only used for validity and reliability purposes for the study. After collection of the data, it was coded appropriately to be used in analysing software. The SPSS application software was used in the analysis.

## 3.4 Pilot Study

According to Diether (2013), in a quantitative study, to validate the effectiveness of the instrument, a pilot study should be employed to trigger the answers that could answer a problem in research questions. A pilot study was conducted prior to the official data collection exercise. Answers gathered prompted the restructuring of the questionnaires. The pilot study took two weeks and a week was used to restructure the questions.

## 3.5 Setting and Participants

The setting of the data collection was the Province of Gauteng due to its proximity and the extensive number of AEC professionals as it's the leading economic province of South Africa. The participants included professions such as Construction Managers, Architects, Quantity Surveyors, Civil/Structural Engineers, Electrical Engineers and Building Contractors.

### 3.6 Procedure

Using peer review journals, questionnaires were formulated using the research questions in Chapter one and the diagram 3.5 shows the genesis of the formulation. A likert scale and continuous scale was used to collect data as shown in the sample questionnaire in the appendix.

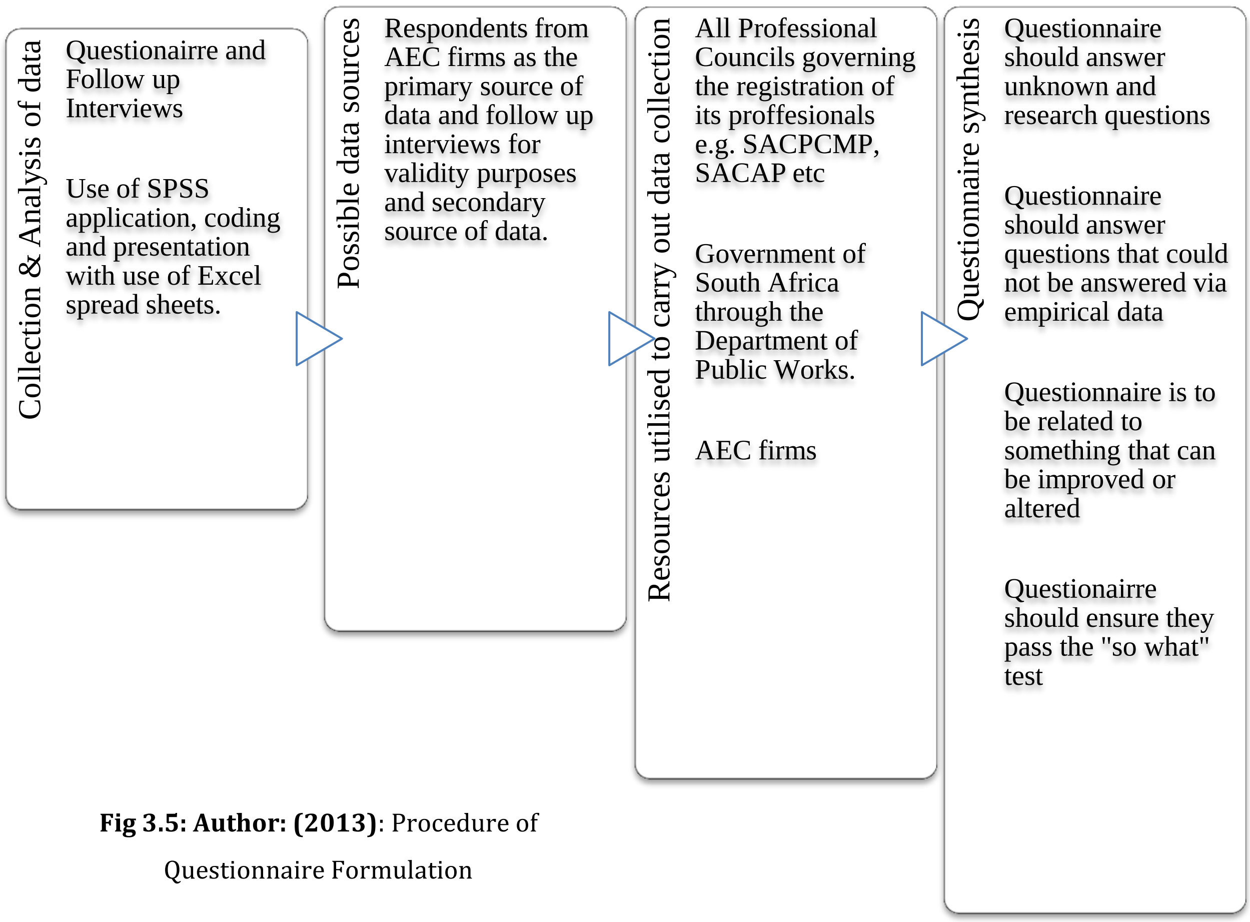


**Fig 3.5: Author: (2013)**: Procedure of Questionnaire Formulation

### 3.7 Internal and External Validity

Diether (2013) stated that internal validity is a confirmation of the correctness of a research design. To ensure the data collecting instrument is clear and unambiguous, pilot studies and testing should be used in both qualitative and quantitative studies and in the study's case the survey instrument had to undergo such an examination. Pilot testing of instruments is a procedure to enable the researcher to make modifications to an instrument based on results. As such the study employed pilot studies to achieve this confirmation and data gathered from the interviews were descriptive in nature and may not require much effort to confirm the validity. (Diether, 2013)

Diether (2013) defines external validity as the *"extent to which the results of the study can reflect similar outcomes elsewhere, and can be generalized to other populations or situations."* Thus the study used triangulation to achieve external validity by using the mixed method. According to Leedy and Ormrod (2010) each method has its own strengths and weaknesses, thus a mixed-method design will enable the effective answering of research questions given the cross cutting of the various methods provides a higher chance of solving a problem.

**3.8 Reliability**

Joppe (2000) cited by Golafshani (2003:598) defines reliability as *"the extent to which results are consistent over time and an accurate representation of the total population under study is referred to as reliability, and if the results of a study can be reproduced under a similar methodology, then the research instrument is considered to be reliable".* As such to enhance reliability, the instruments used have been adopted using the research questions, peer review journals of similar studies from different parts of the world and consistency in the questionnaires. Needless to say all respondents were issued with the same sample questionnaire.

# 4.0 DATA PRESENTATION, ANALYSIS AND DISCUSSION

## 4.1 Introduction

This chapter discusses issues related to data collected and analysis. There was two kinds of questionnaires, one was a general information gathering questionnaire aimed for both the professionals that use BIM and those that do not. The second set of questionnaire was one for the professionals that utilise BIM so as to achieve the research questions asked in the beginning of this study chapter. The main purpose of this chapter is to present the findings so as to identify the critical factors that play an important role of BIM in the AEC industry. It also reports on the impact of BIM on Project Management, challenges faced in South African context and the strategies to be put in place for BIM to be widely used.

## 4.1 Results and Analysis

### 4.1.2 Analysis on evaluation of BIM in Project Management

Selections of the questions asked are tabled below. The tables represent the descriptive statistics of the first questionnaire and each table will be analysed in comparison to the research questions making relevant findings related to the study. A total of 50 Questionnaires were sent out and 34 received, a minimum of five respondents per profession was achieved. In section 4.3, a summary of the follow up interview is outlined and gives the validity for the questions asked. In each tabled result, the follow up interview will be connected to the analysis.

The results were analysed using SPSS software application. The first questionnaire was put through descriptive statistical methods, checking for percentages significant to the questions asked. In the second questionnaire, the data was analysed with a non-parametric method (One-Sample Kolmogorov-Smirnov Test)

| Hypothesis Test Summary (Table 4.0) | | | | |
|---|---|---|---|---|
| | **Null Hypothesis** | **Test** | **Sig.** | **Decision** |
| **1** | The distribution of Project Plan Development is normal with mean 7.12 and standard deviation 1.37. | One-Sample Kolmogorov-Smirnov Test | .406 | Retain the null hypothesis. |
| **2** | The distribution of Project Plan Execution is normal with mean 7.50 and standard deviation 1.54. | One-Sample Kolmogorov-Smirnov Test | .190 | Retain the null hypothesis. |
| **3** | The distribution of Project Change Control is normal with mean 7.06 and standard deviation 1.37. | One-Sample Kolmogorov-Smirnov Test | .031 | Reject the null hypothesis. |
| **4** | The distribution of Project Scope Initiation and Planning is normal with mean 7.88 and standard deviation 1.20. | One-Sample Kolmogorov-Smirnov Test | .024 | Reject the null hypothesis. |
| **5** | The distribution of Project Scope Verification is normal with mean 7.50 and standard deviation 1.21. | One-Sample Kolmogorov-Smirnov Test | .174 | Retain the null hypothesis. |
| **6** | The distribution of Project Scope Change Control is normal with mean 7.35 and standard deviation 1.32. | One-Sample Kolmogorov-Smirnov Test | .183 | Retain the null hypothesis. |
| **7** | The distribution of Project Time Activity Definition, Sequencing & Duration Estimation is normal with mean 7.91 and standard deviation 1.22. | One-Sample Kolmogorov-Smirnov Test | .238 | Retain the null hypothesis. |
| **8** | The distribution of Project Time Schedule Development Control is normal with mean 7.71 and standard deviation 1.14. | One-Sample Kolmogorov-Smirnov Test | .076 | Retain the null hypothesis. |
| **9** | The distribution of Project Time Progress Monitoring is normal with mean 7.79 and standard deviation 1.15. | One-Sample Kolmogorov-Smirnov Test | .079 | Retain the null hypothesis. |
| **10** | The distribution of Quality Planning is normal with mean 7.18 and standard deviation 1.49. | One-Sample Kolmogorov-Smirnov Test | .026 | Reject the null hypothesis. |

| | | | | |
|---|---|---|---|---|
| **11** | The distribution of Quality Assurance is normal with mean 7.09 and standard deviation 1.46. | One-Sample Kolmogorov-Smirnov Test | .037 | Reject the null hypothesis. |
| **12** | The distribution of Quality Control is normal with mean 6.97 and standard deviation 1.57. | One-Sample Kolmogorov-Smirnov Test | .122 | Retain the null hypothesis. |
| **13** | The distribution of Risk Identification is normal with mean 7.12 and standard deviation 1.72. | One-Sample Kolmogorov-Smirnov Test | .092 | Retain the null hypothesis. |
| **14** | The distribution of Risk Analysis is normal with mean 7.18 and standard deviation 1.80. | One-Sample Kolmogorov-Smirnov Test | .736 | Retain the null hypothesis. |
| **15** | The distribution of Risk Monitoring Control is normal with mean 6.97 and standard deviation 1.93. | One-Sample Kolmogorov-Smirnov Test | .450 | Retain the null hypothesis. |
| **16** | The distribution of Project Cost Resource Plan is normal with mean 7.62 and standard deviation 1.21. | One-Sample Kolmogorov-Smirnov Test | .064 | Retain the null hypothesis. |
| **17** | The distribution of Project Cost Estimating is normal with mean 7.50 and standard deviation 1.11. | One-Sample Kolmogorov-Smirnov Test | .120 | Retain the null hypothesis. |
| **18** | The distribution of Project Cost Budgeting Control is normal with mean 7.35 and standard deviation 1.35. | One-Sample Kolmogorov-Smirnov Test | .385 | Retain the null hypothesis. |
| **19** | The distribution of Project Communication Planning is normal with mean 7.56 and standard deviation 0.99. | One-Sample Kolmogorov-Smirnov Test | .036 | Reject the null hypothesis. |
| **20** | The distribution of Project Communication Information Distribution is normal with mean 7.26 and standard deviation 1.11. | One-Sample Kolmogorov-Smirnov Test | .094 | Retain the null hypothesis. |
| **21** | The distribution of Project Communication Performance Reporting is normal with mean 7.21 and standard deviation 1.27. | One-Sample Kolmogorov-Smirnov Test | .211 | Retain the null hypothesis. |

| | | | | |
|---|---|---|---|---|
| **22** | The distribution of Project Human Resource Organisational Planning is normal with mean 6.76 and standard deviation 1.28. | One-Sample Kolmogorov-Smirnov Test | .025 | Reject the null hypothesis. |
| **23** | The distribution of Project Human Resource Staff Acquisition is normal with mean 6.29 and standard deviation 1.03. | One-Sample Kolmogorov-Smirnov Test | .007 | Reject the null hypothesis. |
| **24** | The distribution of Project Human Resource Project Team Closeout is normal with mean 6.09 and standard deviation 1.14. | One-Sample Kolmogorov-Smirnov Test | .005 | Reject the null hypothesis. |
| **25** | The distribution of Project Safety Planning is normal with mean 4.44 and standard deviation 1.85. | One-Sample Kolmogorov-Smirnov Test | .108 | Retain the null hypothesis. |
| **26** | The distribution of Project Safety Plan Execution is normal with mean 4.24 and standard deviation 1.92. | One-Sample Kolmogorov-Smirnov Test | .200 | Retain the null hypothesis. |
| **27** | The distribution of Project Safety Administration and Records is normal with mean 4.12 and standard deviation 1.81. | One-Sample Kolmogorov-Smirnov Test | .183 | Retain the null hypothesis. |
| **28** | The distribution of Project Environmental Planning is normal with mean 2.56 and standard deviation 1.74. | One-Sample Kolmogorov-Smirnov Test | .008 | Reject the null hypothesis. |
| **29** | The distribution of Project Environmental Assurance is normal with mean 2.65 and standard deviation 1.74. | One-Sample Kolmogorov-Smirnov Test | .005 | Reject the null hypothesis. |
| **30** | The distribution of Project Environmental Control is normal with mean 2.76 and standard deviation 2.00. | One-Sample Kolmogorov-Smirnov Test | .009 | Reject the null hypothesis. |
| **31** | The distribution of Project Financial Plan is normal with mean 6.74 and standard deviation 1.75. | One-Sample Kolmogorov-Smirnov Test | .016 | Reject the null hypothesis. |

| | | | | |
|---|---|---|---|---|
| **32** | The distribution of Project Financial Control is normal with mean 6.68 and standard deviation 2.04. | One-Sample Kolmogorov-Smirnov Test | .038 | Reject the null hypothesis. |
| **33** | The distribution of Project Financial Administration is normal with mean 6.53 and standard deviation 2.06. | One-Sample Kolmogorov-Smirnov Test | .005 | Reject the null hypothesis. |
| **34** | The distribution of Project Claim Identification and Quantification is normal with mean 2.91 and standard deviation 1.85. | One-Sample Kolmogorov-Smirnov Test | .031 | Reject the null hypothesis. |
| **35** | The distribution of Project Claim Prevention is normal with mean 2.85 and standard deviation 1.89. | One-Sample Kolmogorov-Smirnov Test | .025 | Reject the null hypothesis. |
| **36** | The distribution of Project Claim Resolution is normal with mean 2.94 and standard deviation 2.04. | One-Sample Kolmogorov-Smirnov Test | .039 | Reject the null hypothesis. |
| **37** | The distribution of Project Procurement Plan is normal with mean 7.71 and standard deviation 1.09. | One-Sample Kolmogorov-Smirnov Test | .151 | Retain the null hypothesis. |
| **38** | The distribution of Project Procurement Solicitation Plan is normal with mean 7.44 and standard deviation 1.50. | One-Sample Kolmogorov-Smirnov Test | .049 | Reject the null hypothesis. |
| **39** | The distribution of Project Procurement Contract Administration is normal with mean 7.32 and standard deviation 1.25. | One-Sample Kolmogorov-Smirnov Test | .046 | Reject the null hypothesis. |
| Asymptotic significances are displayed. The significance level is .05. | | | | |

In the summary, where the null hypothesis is retained, the null hypothesis shows no relationship between the Project Management discipline subset and its impact using BIM. Therefore BIM has no significant effect on the disciplines. Out of the 39 subsets, 19 were able to reject the null hypothesis thus being of statistical significance. Meaning 20 subsets (half of the subsets) retained the null hypothesis and thus a conclusive conclusion that BIM has some significant positive impact in the Project Management practise in the Gauteng AEC industry cannot be made due to equal rejection and retaining of the null hypotheses.

In examining the results, a closer look at the P-Value of less than 0.01; the results are considered highly statistically significant confirming no relationship or impact of BIM on the respective Project Management Knowledge Areas. The following Project Management Knowledge Areas showed after evaluation of BIM application, **no improvement was observed** in the following areas:

a) Project Environmental Planning.
b) Project Environmental Assurance.
c) Project Environmental Control.
d) Project Financial Plan.
e) Project Human Resource Organisational Planning
f) Project Human Resource Staff Acquisition.
g) Project Human Resource Project Team Closeout.
h) Project Communication Planning.
i) Quality Assurance.
j) Quality Planning.
k) Project Change Control.
l) Project Scope Initiation and Planning.

In contrast, in the areas where the p-value is greater than (but not close to) 0.05, the results were considered non-significant confirming the null hypothesis is retained. As such, the evaluation of BIM's utilisation on the following subsets of Project Management showed some **significant improvement**:

a) Project Claim Identification and Quantification
b) Project Claim Prevention
c) Project Claim Resolution
d) Project Procurement Plan
e) Project Financial Control

f) Project Safety Planning
g) Project Safety Plan Execution
h) Project Safety Administration and Records
i) Project Communication Information Distribution
j) Project Communication Performance Reporting
k) Quality Control
l) Risk Identification
m) Risk Analysis
n) Risk Monitoring Control
o) Project Cost Resource Plan
p) Project Cost Estimating
q) Project Cost Budgeting Control
r) Project Scope Verification
s) Project Scope Change Control
t) Project Time Activity Definition, Sequencing & Duration Estimation
u) Project Time Schedule Development Control
v) Project Time Progress Monitoring
w) Project Plan Development
x) Project Plan Execution

### 4.1.3 Analysis of BIM challenges and Strategies

From the series of tabulated results attached in the appendices starting from page 72 to 92 and for the purpose of a summarised presentation of all the results, a figure 4.0A gives a comparison of all the responses according to the highest frequency per question asked. The first column shows the **strategy** needed in place for BIM to work efficiently in that Project Management area and the second column being the **challenge** established that hinders the effective use of BIM in the Project Management knowledge area in South Africa.

| **Table 4.0A: Tabulation of results on Strategies and Challenges** | | |
|---|---|---|
| **STRATEGY ESTABLISHED** | **CHALLENGE ESTABLISHED** | **PM AREA** |
| Govt. and Regulatory Actions/ Mandate | | **Project Plan Development** |
| Govt. and Regulatory Actions/ Mandate | Lack of interest among other project stakeholders | **Project Plan Execution** |
| Training and Development on BIM & Govt. and Regulatory Actions/Mandate | Lack of interest among other project stakeholders | **Integrated Change Control** |
| Govt. and Regulatory Actions/ Mandate | Lack of interest among other project stakeholders | **Initiation and Planning** |
| Govt. and Regulatory Actions/ Mandate | | **Scope Verification** |
| Govt. and Regulatory Actions/ Mandate | | **Change Control in Project Scope** |
| Training and Development on BIM | Scarce Availability of Competent BIM Specialists | **Activity Definition, Sequencing & Duration Estimation** |
| Training and Development on BIM | Scarce Availability of Competent BIM Specialists | **Schedule Development Control** |
| Training and Development on BIM | Scarce Availability of Competent BIM Specialists & No Regulatory Mandate | **Progress Monitoring** |
| Top Management/ Client's Support | | **Quality Planning** |
| Top Management/ Client's Support | | **Quality Assurance** |
| Deployment of BIM Manager | | **Quality Control** |
| Incentives for Utilizing BIM | Lack of interest among other project stakeholders | **Risk Identification** |
| Incentives for Utilizing BIM & Top Management/ Client's Support | Lack of interest among other project stakeholders | **Risk Analysis** |
| Incentives for Utilizing BIM & Top Management/ Client's Support | Lack of interest among other project stakeholders & Lack of Technical support for interoperability | **Risk Monitoring and Control** |
| Training and Development on BIM & Govt. and Regulatory Actions/Mandate & Training and Development on BIM | | **Resource Planning** |
| Training and Development on BIM & Govt. and Regulatory Actions/Mandate & Training and Development on BIM | | **Cost Estimating** |
| Deployment of BIM Specialists on Appropriate Areas & Project BIM Management Plan/ BIM Guidelines | | **Cost Budgeting & Control** |
| Top Management/ Client's Support | | **Communication Planning** |
| Top Management/ Client's Support | | **Information Distribution** |

| STRATEGY ESTABLISHED | CHALLENGE ESTABLISHED | PM AREA |
|---|---|---|
| Better Interoperability through Appropriate Technical Support | | **Organizational Planning** |
| Top Management/ Client's Support | | **Staff Acquisition & Team Development** |
| | | |
| Top Management/ Client's Support | | **Project Team closeout** |
| Top Management/ Client's Support | Lack of Awareness on the application of BIM on the Specific Area of Project Management & Lack of BIM's Capability | **Safety Planning** |
| Deployment of BIM Specialists on Appropriate Areas | Lack of BIM's Capability | **Safety Plan Execution** |
| Deployment of BIM Specialists on Appropriate Areas & Top Management/ Client's Support | Lack of BIM's Capability | **Safety Administration and Records** |
| Deployment of BIM Manager | Lack of BIM's Capability & No Client Insistence | **Environmental Planning** |
| Deployment of BIM Manager | Lack of BIM's Capability | **Environmental Assurance** |
| Deployment of BIM Manager | Lack of BIM's Capability | **Environmental Control** |
| Training and Development on BIM & Top Management/ Client's Support | Legal issues Associated with Ownership of the document | **Financial Planning** |
| Training and Development on BIM & Top Management/ Client's Support | Legal issues Associated with Ownership of the document | **Financial Control** |
| Deployment of BIM Specialists on Appropriate Areas & Project BIM Management Plan/ BIM Guidelines & Training and Development on BIM | | **Financial Administration and Records** |
| Training and Development on BIM | Lack of BIM's Capability | **Claim Identification & Quantification** |
| Training and Development on BIM | Lack of BIM's Capability | **Claim Prevention** |
| Training and Development on BIM | Lack of BIM's Capability | **Claim Resolution** |
| Incentives for Utilizing BIM & Better Interoperability through Appropriate Technical Support & Training and Development on BIM & Deployment of BIM Manager | | **Procurement Planning** |
| Deployment of BIM Specialists on Appropriate Areas & Training and Development on BIM & Better Interoperability through Appropriate Technical Support | | **Solicitation Planning** |
| Training and Development on BIM & Incentives for Utilizing BIM | | **Contract Administration, Contract Closeout** |

## 5.0 CONCLUSIONS AND RECOMMENDATION

### 5.1 Research Overview and discussion of results

As discussed in chapter one, the significance of this study was to investigate the level BIM can achieve positively in complementing the project management practice. The project management processes are significant in any project delivery and with the advantages of BIM proven from various research studies, it strongly remains vulnerable to challenges especially in different locational contexts. The results showed a significant level of agreement that BIM does assist in project management but not fully anticipated with its wide range of merits.

### 5.2 Strategies required for BIM adoptions

As shown from the results, strategies necessary for the adoption of BIM and its effective use in Project management areas are mainly the *involvement of government in establishing regulation and streamlining the contractual inclusion of BIM*. Further, *top level management of AEC organisations are required to play an active role in BIM adoption*, without their interest the top-down approach in organisational structure will hinder BIM developers from penetrating the industry. As such, organisation business restructuring is needed; a form of change management to overcome resistance and smooth transition achieved. Incentives such as tax reliefs is also needed to encourage businesses to utilise BIM; firms are out to make profits and with prospects of saving money by adopting technology, BIM has a fair chance to grow in South Africa. Additionally South Africa's AEC industry lacks skilled BIM specialists to assist in Project Management knowledge areas, more training and awareness is required for this challenge to be overcome.

With strategies put in place BIM has a bright future in South Africa, smaller firms which are the majority of the AEC firms need to be encouraged to adopt

BIM even for small projects. The study has established that BIM is used in larger and more complex projects in South Africa; the professional bodies responsible for the registration and regulation should take charge in implementation of BIM. Lessons can be learned from developing countries such as India where research is highly established in education establishments to investigate Virtual Design and Construction and are now assisting the UK and other European countries to deliver projects using BIM. In addition, BIM developers have a significant role to play to training and educating the AEC industry in South Africa as a whole.

Further research is required to evaluate the significance of BIM in other projects such as civil works; South Africa's economy has heavily relied on Government spending on civil construction for stability as the Western economies suffer due to the last recession of 2008. Numerous civil projects such as bridges, highways and power stations are being undertaken in South Africa and BIM's role in this area has possible positive effects. Although the research was constrained due to time and physical area of data collection, it remains to be seen how the South African government and the AEC players will embrace this global technology as more resources and time to get a clearer picture of BIM's status in the whole of South Africa and not only in Gauteng Province.

### 5.3 Research Results Limitations and Going Forward

BIM has been seen as a great tool in Project Management, especially by its greatest advocates, there are still a number of issues with the technology, methodology and management entities which need to be addressed before BIM can become standard practise across the industry especially Project Management. The following factors have been identified on section 5.2 as playing a role to assist in this attempt: government role in establishing regulation and streamlining the contractual inclusion of BIM and top level management interest. But through extensive literature review in which common issues ran across BIM studies was lacking in this study. Major issues that need further research are as follows:

***Implementation and Set up Costs Issues***

One of the biggest restrictions for small businesses is the initial cost of implementing BIM within their company in a developing country as South Africa. Although it can be quite substantial, for example in South Africa costs range between R 20000 to R 200000. (Autodesk, 2013) But in the end it has been proven that these costs are returned very quickly. The McGraw Hill (2009) Smart Market Report reported that 70% BIM of users who measure return of investment (ROI) see positive returns. Additionally, 93% of BIM users believe there is potential to gain more value from BIM in the future. In addition to savings obtained on individual projects, BIM users are also reporting return of investment through:

a) New business and clients being brought to the company
b) Business with past clients is maintained much more regularly
c) More efficient processes and procedures within the company
d) More rounded project management teams through a better understanding of both the design and construction process.

As such the study did not provide such crucial points in the South African industry, as stated above more research is required to see the financial benefits of BIM in construction companies.

***Project Team Skills Gaps Development***

The study established a lack of skills to utilise BIM but the results show that this is not very strong argument in South Africa. The McGraw Hill (2009) states in its report that with all new technologies it takes time for a strong base of experienced and skilled users to develop. With its requirements of users needing to be skilled in more than their expertise, a complex issue exists in training users to employ interoperability and introduction into small businesses in countries such as South Africa. This is issue is starting to be addressed by some universities providing BIM specific courses but unfortunately many of the participants are students with little to no industry experience and haven't acquired the 'hands on knowledge' methodology behind how a building is built. More South African universities that have built environment programmes should emulate this as a start but the industry as a whole must spear head the process in conjunction with the Government.

As such, since it is difficult to expect that everyone across the industry will be experts in all the various disciplines and it would be a loss to the industry if specific expertise was lost, the introduction of Integrated Project Delivery models is being seen as the main solution to this issue. (McGraw Hill, 2009)

***More Strategic Research Focus on BIM***

Currently BIM is still a large unknown to the Construction Industry as a whole. As a result the industry is still in the initial stages of what exactly BIM is and learning how it can be used. Organisations such as *BuildingSMAR*T have been established to assist to educate players but they are still largely unknown by the general industry and run by volunteers focusing on establishing modelling protocols and management guidelines in the US and UK. A few steps are being taken by Autodesk in South Africa to manage and train players in the industry. (Stoddart, 2014)

The most progressive organisation in regards to research into BIM is VTT, the Technical Research Centre of Finland, a globally networked applied research organization which has been researching BIM since the 1980's. VTT is currently focusing on technical issues related to the downstream applications such as system analysis, simulation and process management. In Australia this issue has been identified by the Australian Government's Department of Innovation Industry, Science and Research (DIISR) which The Built Environment Digital Modelling Working Group (BEDMWG) in 2010 and some research is being completed by some universities, in particular the University of NSW. (Stoddart, 2014)

As the industry become more familiar with BIM and a general consensus is formed that BIM is the way of the future more funding will become available enabling more research. As with any new technology, industry wide acceptance of BIM faces many challenges, both technological and cultural. As more projects use BIM the benefits it provides are increasingly being proven by industry leaders. Government and developers are recognising the significant benefits and are driving the use of BIM through policy and facilitating increased research. It will still be a number of years until BIM becomes standard practice but as with CAD in the late 80's and early 90's it is not until the issues discussed above are resolved and individual members of the industry become comfortable with using the technology that is will become fully accepted. (McGraw Hill, 2009)

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**APPENDICES & INFORMATION SHEETS**

This section is a tabulation of results from questions asked in the survey. Each respondent was asked to give an appropriate answer to their agreement level of a continuous scale of 1-10. Where (1) was completely disagreeing, (5) neutral and (10) completely agree. If any of their answers fell below and including 5, they were asked to give a reason for the disagreement level. If any of their answers was above (5), they were asked to suggest a strategy to be adopted to achieve BIM utilisation in the South African Project Management construction practice. The challenges and strategies were coded as follows:

**Table 4.1: Coding Legend for Tables 4.2 - 4.40**

| | |
|---|---|
| 1 | Lack of BIM Specialists |
| 2 | Lack of interest among other project stakeholders |
| 3 | High Cost of Implementation |
| 4 | Lack of Technical support for interoperability |
| 5 | Lack of Awareness on the application of BIM on the Specific Area of Project Management |
| 6 | No Organizational support to implement BIM |
| 7 | No Client Insistence |
| 8 | No Regulatory Mandate |
| 9 | Scarce Availability of Competent BIM Specialists |
| 10 | Lack of BIM's Capability |
| 11 | Legal issues Associated with Ownership of the document |
| 12 | Deployment of BIM Manager |
| 13 | Deployment of BIM Specialists on Appropriate Areas |
| 14 | Training and Development on BIM |
| 15 | Govt. and Regulatory Actions/ Mandate |
| 16 | Project BIM Management Plan/ BIM Guidelines |
| 17 | Top Management/ Client's Support |
| 18 | Abundant BIM Element Library |
| 19 | Incentives for Utilizing BIM |
| 20 | New Staffing With BIM Knowledge |

| | |
|---|---|
| 21 | Business Process changes according to Collaborative Work |
| 22 | Better Interoperability through Appropriate Technical Support |

**Table 4.2: Project Plan Development**

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| Valid | 12.00 | 3 | 8.8 | 9.4 | 9.4 |
| | 13.00 | 1 | 2.9 | 3.1 | 12.5 |
| | 14.00 | 4 | 11.8 | 12.5 | 25.0 |
| | 15.00 | 10 | 29.4 | 31.3 | 56.3 |
| | 16.00 | 4 | 11.8 | 12.5 | 68.8 |
| | 17.00 | 5 | 14.7 | 15.6 | 84.4 |
| | 18.00 | 4 | 11.8 | 12.5 | 96.9 |
| | 19.00 | 1 | 2.9 | 3.1 | 100.0 |
| | Total | 32 | 94.1 | 100.0 | |
| | Missing | 2 | 5.9 | | |
| Total | | 34 | 100.0 | | |

**Table 4.3: Project Plan Execution**

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| Valid | 2.00 | 2 | 5.9 | 5.9 | 5.9 |
| | 12.00 | 2 | 5.9 | 5.9 | 11.8 |
| | 13.00 | 3 | 8.8 | 8.8 | 20.6 |
| | 14.00 | 6 | 17.6 | 17.6 | 38.2 |
| | 15.00 | 11 | 32.4 | 32.4 | 70.6 |
| | 16.00 | 2 | 5.9 | 5.9 | 76.5 |
| | 17.00 | 4 | 11.8 | 11.8 | 88.2 |
| | 18.00 | 2 | 5.9 | 5.9 | 94.1 |
| | 19.00 | 1 | 2.9 | 2.9 | 97.1 |
| | 20.00 | 1 | 2.9 | 2.9 | 100.0 |

| | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|
| Total | 34 | 100.0 | 100.0 | |

**Table 4.4: Integrated Change Control**

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| Valid | 2.00 | 2 | 5.9 | 5.9 | 5.9 |
| | 7.00 | 1 | 2.9 | 2.9 | 8.8 |
| | 12.00 | 1 | 2.9 | 2.9 | 11.8 |
| | 13.00 | 2 | 5.9 | 5.9 | 17.6 |
| | 14.00 | 8 | 23.5 | 23.5 | 41.2 |
| | 15.00 | 8 | 23.5 | 23.5 | 64.7 |
| | 16.00 | 1 | 2.9 | 2.9 | 67.6 |
| | 17.00 | 6 | 17.6 | 17.6 | 85.3 |
| | 18.00 | 3 | 8.8 | 8.8 | 94.1 |
| | 19.00 | 2 | 5.9 | 5.9 | 100.0 |
| | Total | 34 | 100.0 | 100.0 | |

**Table 4.5: Initiation and Planning**

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| Valid | 6.00 | 1 | 2.9 | 2.9 | 2.9 |
| | 12.00 | 2 | 5.9 | 5.9 | 8.8 |
| | 13.00 | 7 | 20.6 | 20.6 | 29.4 |
| | 14.00 | 8 | 23.5 | 23.5 | 52.9 |
| | 15.00 | 3 | 8.8 | 8.8 | 61.8 |
| | 16.00 | 3 | 8.8 | 8.8 | 70.6 |
| | 17.00 | 5 | 14.7 | 14.7 | 85.3 |
| | 19.00 | 2 | 5.9 | 5.9 | 91.2 |
| | 20.00 | 2 | 5.9 | 5.9 | 97.1 |

| | | | | |
|---|---|---|---|---|
| 21.00 | 1 | 2.9 | 2.9 | 100.0 |
| Total | 34 | 100.0 | 100.0 | |

**Table 4.6: Scope Verification**

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| Valid | 6.00 | 1 | 2.9 | 2.9 | 2.9 |
| | 12.00 | 5 | 14.7 | 14.7 | 17.6 |
| | 13.00 | 4 | 11.8 | 11.8 | 29.4 |
| | 14.00 | 7 | 20.6 | 20.6 | 50.0 |
| | 15.00 | 4 | 11.8 | 11.8 | 61.8 |
| | 16.00 | 3 | 8.8 | 8.8 | 70.6 |
| | 17.00 | 5 | 14.7 | 14.7 | 85.3 |
| | 18.00 | 2 | 5.9 | 5.9 | 91.2 |
| | 19.00 | 3 | 8.8 | 8.8 | 100.0 |
| | Total | 34 | 100.0 | 100.0 | |

**Table 4.7: Change Control in Project Scope**

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| Valid | 6.00 | 1 | 2.9 | 2.9 | 2.9 |
| | 12.00 | 3 | 8.8 | 8.8 | 11.8 |
| | 13.00 | 3 | 8.8 | 8.8 | 20.6 |
| | 14.00 | 9 | 26.5 | 26.5 | 47.1 |
| | 15.00 | 4 | 11.8 | 11.8 | 58.8 |
| | 16.00 | 2 | 5.9 | 5.9 | 64.7 |
| | 17.00 | 4 | 11.8 | 11.8 | 76.5 |
| | 18.00 | 1 | 2.9 | 2.9 | 79.4 |

| | | | | | |
|---|---|---|---|---|---|
| | 19.00 | 4 | 11.8 | 11.8 | 91.2 |
| | 21.00 | 1 | 2.9 | 2.9 | 94.1 |
| | 22.00 | 2 | 5.9 | 5.9 | 100.0 |
| | Total | 34 | 100.0 | 100.0 | |

**Table 4.8: Activity Definition, Sequencing & Duration Estimation**

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| Valid | 9.00 | 2 | 5.9 | 5.9 | 5.9 |
| | 12.00 | 1 | 2.9 | 2.9 | 8.8 |
| | 13.00 | 1 | 2.9 | 2.9 | 11.8 |
| | 14.00 | 5 | 14.7 | 14.7 | 26.5 |
| | 15.00 | 5 | 14.7 | 14.7 | 41.2 |
| | 16.00 | 2 | 5.9 | 5.9 | 47.1 |
| | 17.00 | 3 | 8.8 | 8.8 | 55.9 |
| | 20.00 | 4 | 11.8 | 11.8 | 67.6 |
| | 21.00 | 1 | 2.9 | 2.9 | 70.6 |
| | 22.00 | 10 | 29.4 | 29.4 | 100.0 |
| | Total | 34 | 100.0 | 100.0 | |

**Table 4.9: Schedule Development Control**

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| Valid | 7.00 | 1 | 2.9 | 2.9 | 2.9 |
| | 9.00 | 2 | 5.9 | 5.9 | 8.8 |
| | 13.00 | 2 | 5.9 | 5.9 | 14.7 |
| | 14.00 | 4 | 11.8 | 11.8 | 26.5 |
| | 15.00 | 5 | 14.7 | 14.7 | 41.2 |
| | 16.00 | 2 | 5.9 | 5.9 | 47.1 |
| | 17.00 | 4 | 11.8 | 11.8 | 58.8 |
| | 19.00 | 2 | 5.9 | 5.9 | 64.7 |

| | | | | | |
|---|---|---|---|---|---|
| | 20.00 | 4 | 11.8 | 11.8 | 76.5 |
| | 21.00 | 2 | 5.9 | 5.9 | 82.4 |
| | 22.00 | 6 | 17.6 | 17.6 | 100.0 |
| | Total | 34 | 100.0 | 100.0 | |

**Table 4.10: Progress Monitoring**

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| Valid | 8.00 | 1 | 2.9 | 2.9 | 2.9 |
| | 9.00 | 2 | 5.9 | 5.9 | 8.8 |
| | 12.00 | 1 | 2.9 | 2.9 | 11.8 |
| | 13.00 | 1 | 2.9 | 2.9 | 14.7 |
| | 14.00 | 2 | 5.9 | 5.9 | 20.6 |
| | 15.00 | 9 | 26.5 | 26.5 | 47.1 |
| | 16.00 | 2 | 5.9 | 5.9 | 52.9 |
| | 17.00 | 2 | 5.9 | 5.9 | 58.8 |
| | 18.00 | 1 | 2.9 | 2.9 | 61.8 |
| | 19.00 | 4 | 11.8 | 11.8 | 73.5 |
| | 20.00 | 2 | 5.9 | 5.9 | 79.4 |
| | 21.00 | 1 | 2.9 | 2.9 | 82.4 |
| | 22.00 | 6 | 17.6 | 17.6 | 100.0 |
| | Total | 34 | 100.0 | 100.0 | |

**Table 4.11: Quality Planning**

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| Valid | 1.00 | 1 | 2.9 | 2.9 | 2.9 |
| | 2.00 | 1 | 2.9 | 2.9 | 5.9 |
| | 3.00 | 1 | 2.9 | 2.9 | 8.8 |
| | 9.00 | 1 | 2.9 | 2.9 | 11.8 |
| | 12.00 | 3 | 8.8 | 8.8 | 20.6 |
| | 13.00 | 2 | 5.9 | 5.9 | 26.5 |
| | 14.00 | 1 | 2.9 | 2.9 | 29.4 |
| | 15.00 | 1 | 2.9 | 2.9 | 32.4 |

| | | | | | |
|---|---|---|---|---|---|
| | 16.00 | 3 | 8.8 | 8.8 | 41.2 |
| | 17.00 | 9 | 26.5 | 26.5 | 67.6 |
| | 18.00 | 7 | 20.6 | 20.6 | 88.2 |
| | 20.00 | 1 | 2.9 | 2.9 | 91.2 |
| | 22.00 | 3 | 8.8 | 8.8 | 100.0 |
| | Total | 34 | 100.0 | 100.0 | |

**Table 4.12: Quality Assurance**

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| Valid | 2.00 | 1 | 2.9 | 2.9 | 2.9 |
| | 3.00 | 1 | 2.9 | 2.9 | 5.9 |
| | 8.00 | 1 | 2.9 | 2.9 | 8.8 |
| | 12.00 | 4 | 11.8 | 11.8 | 20.6 |
| | 13.00 | 4 | 11.8 | 11.8 | 32.4 |
| | 14.00 | 1 | 2.9 | 2.9 | 35.3 |
| | 15.00 | 2 | 5.9 | 5.9 | 41.2 |
| | 16.00 | 2 | 5.9 | 5.9 | 47.1 |
| | 17.00 | 8 | 23.5 | 23.5 | 70.6 |
| | 18.00 | 4 | 11.8 | 11.8 | 82.4 |
| | 19.00 | 1 | 2.9 | 2.9 | 85.3 |
| | 20.00 | 1 | 2.9 | 2.9 | 88.2 |
| | 22.00 | 4 | 11.8 | 11.8 | 100.0 |
| | Total | 34 | 100.0 | 100.0 | |

**Table 4.13: Quality Control**

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| Valid | 2.00 | 1 | 2.9 | 2.9 | 2.9 |
| | 3.00 | 1 | 2.9 | 2.9 | 5.9 |
| | 4.00 | 1 | 2.9 | 2.9 | 8.8 |
| | 10.00 | 1 | 2.9 | 2.9 | 11.8 |
| | 12.00 | 7 | 20.6 | 20.6 | 32.4 |
| | 13.00 | 2 | 5.9 | 5.9 | 38.2 |
| | 14.00 | 1 | 2.9 | 2.9 | 41.2 |
| | 15.00 | 1 | 2.9 | 2.9 | 44.1 |

| | | | | |
|---|---|---|---|---|
| 17.00 | 9 | 26.5 | 26.5 | 70.6 |
| 18.00 | 4 | 11.8 | 11.8 | 82.4 |
| 19.00 | 1 | 2.9 | 2.9 | 85.3 |
| 22.00 | 5 | 14.7 | 14.7 | 100.0 |
| Total | 34 | 100.0 | 100.0 | |

**Table 4.14: Risk Identification**

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| Valid | 2.00 | 2 | 5.9 | 5.9 | 5.9 |
| | 8.00 | 1 | 2.9 | 2.9 | 8.8 |
| | 10.00 | 2 | 5.9 | 5.9 | 14.7 |
| | 12.00 | 2 | 5.9 | 5.9 | 20.6 |
| | 13.00 | 3 | 8.8 | 8.8 | 29.4 |
| | 14.00 | 4 | 11.8 | 11.8 | 41.2 |
| | 15.00 | 1 | 2.9 | 2.9 | 44.1 |
| | 16.00 | 3 | 8.8 | 8.8 | 52.9 |
| | 17.00 | 4 | 11.8 | 11.8 | 64.7 |
| | 18.00 | 2 | 5.9 | 5.9 | 70.6 |
| | 19.00 | 5 | 14.7 | 14.7 | 85.3 |
| | 20.00 | 2 | 5.9 | 5.9 | 91.2 |
| | 22.00 | 3 | 8.8 | 8.8 | 100.0 |
| | Total | 34 | 100.0 | 100.0 | |

**Table 4.15: Risk Analysis**

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| Valid | 2.00 | 2 | 5.9 | 5.9 | 5.9 |
| | 6.00 | 1 | 2.9 | 2.9 | 8.8 |
| | 7.00 | 1 | 2.9 | 2.9 | 11.8 |
| | 10.00 | 2 | 5.9 | 5.9 | 17.6 |
| | 12.00 | 2 | 5.9 | 5.9 | 23.5 |
| | 13.00 | 4 | 11.8 | 11.8 | 35.3 |
| | 14.00 | 3 | 8.8 | 8.8 | 44.1 |

| | | | | |
|---|---|---|---|---|
| 16.00 | 3 | 8.8 | 8.8 | 52.9 |
| 17.00 | 5 | 14.7 | 14.7 | 67.6 |
| 18.00 | 3 | 8.8 | 8.8 | 76.5 |
| 19.00 | 5 | 14.7 | 14.7 | 91.2 |
| 20.00 | 1 | 2.9 | 2.9 | 94.1 |
| 22.00 | 2 | 5.9 | 5.9 | 100.0 |
| Total | 34 | 100.0 | 100.0 | |

**Table 4.16: Risk Monitoring and Control**

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| Valid | 2.00 | 2 | 5.9 | 5.9 | 5.9 |
| | 4.00 | 2 | 5.9 | 5.9 | 11.8 |
| | 9.00 | 1 | 2.9 | 2.9 | 14.7 |
| | 10.00 | 2 | 5.9 | 5.9 | 20.6 |
| | 12.00 | 2 | 5.9 | 5.9 | 26.5 |
| | 13.00 | 4 | 11.8 | 11.8 | 38.2 |
| | 14.00 | 2 | 5.9 | 5.9 | 44.1 |
| | 15.00 | 1 | 2.9 | 2.9 | 47.1 |
| | 16.00 | 3 | 8.8 | 8.8 | 55.9 |
| | 17.00 | 5 | 14.7 | 14.7 | 70.6 |
| | 18.00 | 2 | 5.9 | 5.9 | 76.5 |
| | 19.00 | 5 | 14.7 | 14.7 | 91.2 |
| | 20.00 | 1 | 2.9 | 2.9 | 94.1 |
| | 22.00 | 2 | 5.9 | 5.9 | 100.0 |
| | Total | 34 | 100.0 | 100.0 | |

**Table 4.17: Resource Planning**

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| Valid | 6.00 | 1 | 2.9 | 2.9 | 2.9 |
| | 12.00 | 2 | 5.9 | 5.9 | 8.8 |
| | 13.00 | 2 | 5.9 | 5.9 | 14.7 |
| | 14.00 | 6 | 17.6 | 17.6 | 32.4 |
| | 15.00 | 6 | 17.6 | 17.6 | 50.0 |
| | 16.00 | 4 | 11.8 | 11.8 | 61.8 |

| | | | | | |
|---|---|---|---|---|---|
| | 17.00 | 6 | 17.6 | 17.6 | 79.4 |
| | 18.00 | 2 | 5.9 | 5.9 | 85.3 |
| | 19.00 | 3 | 8.8 | 8.8 | 94.1 |
| | 22.00 | 2 | 5.9 | 5.9 | 100.0 |
| | Total | 34 | 100.0 | 100.0 | |

**Table 4.18: Cost Estimating**

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| Valid | 6.00 | 1 | 2.9 | 2.9 | 2.9 |
| | 12.00 | 1 | 2.9 | 2.9 | 5.9 |
| | 13.00 | 6 | 17.6 | 17.6 | 23.5 |
| | 14.00 | 5 | 14.7 | 14.7 | 38.2 |
| | 15.00 | 4 | 11.8 | 11.8 | 50.0 |
| | 16.00 | 5 | 14.7 | 14.7 | 64.7 |
| | 17.00 | 5 | 14.7 | 14.7 | 79.4 |
| | 18.00 | 2 | 5.9 | 5.9 | 85.3 |
| | 19.00 | 3 | 8.8 | 8.8 | 94.1 |
| | 22.00 | 2 | 5.9 | 5.9 | 100.0 |
| | Total | 34 | 100.0 | 100.0 | |

**Table 4.19: Cost Budgeting & Control**

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| Valid | 6.00 | 1 | 2.9 | 2.9 | 2.9 |
| | 12.00 | 4 | 11.8 | 11.8 | 14.7 |
| | 13.00 | 6 | 17.6 | 17.6 | 32.4 |
| | 14.00 | 2 | 5.9 | 5.9 | 38.2 |
| | 15.00 | 4 | 11.8 | 11.8 | 50.0 |
| | 16.00 | 6 | 17.6 | 17.6 | 67.6 |
| | 17.00 | 4 | 11.8 | 11.8 | 79.4 |
| | 18.00 | 1 | 2.9 | 2.9 | 82.4 |
| | 19.00 | 3 | 8.8 | 8.8 | 91.2 |

| | | | | | |
|---|---|---|---|---|---|
| | 20.00 | 1 | 2.9 | 2.9 | 94.1 |
| | 22.00 | 2 | 5.9 | 5.9 | 100.0 |
| | Total | 34 | 100.0 | 100.0 | |

**Table 4.20: Communication Planning**

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| Valid | 12.00 | 3 | 8.8 | 8.8 | 8.8 |
| | 13.00 | 2 | 5.9 | 5.9 | 14.7 |
| | 14.00 | 5 | 14.7 | 14.7 | 29.4 |
| | 15.00 | 3 | 8.8 | 8.8 | 38.2 |
| | 16.00 | 2 | 5.9 | 5.9 | 44.1 |
| | 17.00 | 9 | 26.5 | 26.5 | 70.6 |
| | 18.00 | 7 | 20.6 | 20.6 | 91.2 |
| | 19.00 | 1 | 2.9 | 2.9 | 94.1 |
| | 22.00 | 2 | 5.9 | 5.9 | 100.0 |
| | Total | 34 | 100.0 | 100.0 | |

**Table 4.21: Information Distribution**

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| Valid | 12.00 | 3 | 8.8 | 8.8 | 8.8 |
| | 13.00 | 3 | 8.8 | 8.8 | 17.6 |
| | 14.00 | 7 | 20.6 | 20.6 | 38.2 |
| | 15.00 | 1 | 2.9 | 2.9 | 41.2 |
| | 16.00 | 4 | 11.8 | 11.8 | 52.9 |
| | 17.00 | 8 | 23.5 | 23.5 | 76.5 |
| | 18.00 | 5 | 14.7 | 14.7 | 91.2 |
| | 19.00 | 2 | 5.9 | 5.9 | 97.1 |
| | 22.00 | 1 | 2.9 | 2.9 | 100.0 |
| | Total | 34 | 100.0 | 100.0 | |

**Table 4.22: Performance Reporting & Administrative Closure**

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| Valid | 12.00 | 5 | 14.7 | 14.7 | 14.7 |
| | 13.00 | 3 | 8.8 | 8.8 | 23.5 |
| | 14.00 | 5 | 14.7 | 14.7 | 38.2 |
| | 15.00 | 2 | 5.9 | 5.9 | 44.1 |
| | 16.00 | 2 | 5.9 | 5.9 | 50.0 |
| | 17.00 | 5 | 14.7 | 14.7 | 64.7 |
| | 18.00 | 4 | 11.8 | 11.8 | 76.5 |
| | 19.00 | 2 | 5.9 | 5.9 | 82.4 |
| | 20.00 | 1 | 2.9 | 2.9 | 85.3 |
| | 21.00 | 1 | 2.9 | 2.9 | 88.2 |
| | 22.00 | 4 | 11.8 | 11.8 | 100.0 |
| | Total | 34 | 100.0 | 100.0 | |

**Table 4.23: Organizational Planning**

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| Valid | 5.00 | 1 | 2.9 | 2.9 | 2.9 |
| | 12.00 | 2 | 5.9 | 5.9 | 8.8 |
| | 13.00 | 1 | 2.9 | 2.9 | 11.8 |
| | 14.00 | 3 | 8.8 | 8.8 | 20.6 |
| | 15.00 | 4 | 11.8 | 11.8 | 32.4 |
| | 16.00 | 3 | 8.8 | 8.8 | 41.2 |
| | 17.00 | 6 | 17.6 | 17.6 | 58.8 |
| | 18.00 | 1 | 2.9 | 2.9 | 61.8 |
| | 19.00 | 3 | 8.8 | 8.8 | 70.6 |
| | 20.00 | 1 | 2.9 | 2.9 | 73.5 |

| | | | | | |
|---|---|---|---|---|---|
| | 21.00 | 1 | 2.9 | 2.9 | 76.5 |
| | 22.00 | 8 | 23.5 | 23.5 | 100.0 |
| | Total | 34 | 100.0 | 100.0 | |

**Table 4.24: Staff Acquisition & Team Development**

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| Valid | 5.00 | 1 | 2.9 | 2.9 | 2.9 |
| | 12.00 | 3 | 8.8 | 8.8 | 11.8 |
| | 13.00 | 1 | 2.9 | 2.9 | 14.7 |
| | 14.00 | 3 | 8.8 | 8.8 | 23.5 |
| | 15.00 | 4 | 11.8 | 11.8 | 35.3 |
| | 16.00 | 2 | 5.9 | 5.9 | 41.2 |
| | 17.00 | 8 | 23.5 | 23.5 | 64.7 |
| | 18.00 | 3 | 8.8 | 8.8 | 73.5 |
| | 19.00 | 1 | 2.9 | 2.9 | 76.5 |
| | 20.00 | 2 | 5.9 | 5.9 | 82.4 |
| | 21.00 | 3 | 8.8 | 8.8 | 91.2 |
| | 22.00 | 3 | 8.8 | 8.8 | 100.0 |
| | Total | 34 | 100.0 | 100.0 | |

**Table 4.25: Project Team closeout**

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| Valid | 5.00 | 1 | 2.9 | 2.9 | 2.9 |
| | 9.00 | 1 | 2.9 | 2.9 | 5.9 |
| | 14.00 | 5 | 14.7 | 14.7 | 20.6 |
| | 15.00 | 7 | 20.6 | 20.6 | 41.2 |
| | 16.00 | 2 | 5.9 | 5.9 | 47.1 |
| | 17.00 | 10 | 29.4 | 29.4 | 76.5 |
| | 18.00 | 3 | 8.8 | 8.8 | 85.3 |
| | 19.00 | 2 | 5.9 | 5.9 | 91.2 |
| | 22.00 | 3 | 8.8 | 8.8 | 100.0 |

| | | | | |
|---|---|---|---|---|
| Total | 34 | 100.0 | 100.0 | |

**Table 4.26: Safety Planning**

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| Valid | 2.00 | 3 | 8.8 | 8.8 | 8.8 |
| | 5.00 | 3 | 8.8 | 8.8 | 17.6 |
| | 6.00 | 1 | 2.9 | 2.9 | 20.6 |
| | 8.00 | 1 | 2.9 | 2.9 | 23.5 |
| | 10.00 | 6 | 17.6 | 17.6 | 41.2 |
| | 12.00 | 3 | 8.8 | 8.8 | 50.0 |
| | 13.00 | 3 | 8.8 | 8.8 | 58.8 |
| | 14.00 | 2 | 5.9 | 5.9 | 64.7 |
| | 15.00 | 2 | 5.9 | 5.9 | 70.6 |
| | 17.00 | 6 | 17.6 | 17.6 | 88.2 |
| | 18.00 | 1 | 2.9 | 2.9 | 91.2 |
| | 20.00 | 2 | 5.9 | 5.9 | 97.1 |
| | 22.00 | 1 | 2.9 | 2.9 | 100.0 |
| | Total | 34 | 100.0 | 100.0 | |

**Table 4.27: Safety Plan Execution**

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| Valid | 1.00 | 1 | 2.9 | 2.9 | 2.9 |
| | 2.00 | 2 | 5.9 | 5.9 | 8.8 |
| | 4.00 | 1 | 2.9 | 2.9 | 11.8 |
| | 5.00 | 3 | 8.8 | 8.8 | 20.6 |
| | 6.00 | 1 | 2.9 | 2.9 | 23.5 |
| | 8.00 | 1 | 2.9 | 2.9 | 26.5 |
| | 9.00 | 1 | 2.9 | 2.9 | 29.4 |
| | 10.00 | 6 | 17.6 | 17.6 | 47.1 |
| | 13.00 | 6 | 17.6 | 17.6 | 64.7 |
| | 14.00 | 1 | 2.9 | 2.9 | 67.6 |
| | 15.00 | 5 | 14.7 | 14.7 | 82.4 |

| | | | | |
|---|---|---|---|---|
| 16.00 | 3 | 8.8 | 8.8 | 91.2 |
| 18.00 | 1 | 2.9 | 2.9 | 94.1 |
| 21.00 | 2 | 5.9 | 5.9 | 100.0 |
| Total | 34 | 100.0 | 100.0 | |

**Table 4.28: Safety Administration and Records**

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| Valid | 2.00 | 1 | 2.9 | 2.9 | 2.9 |
| | 5.00 | 3 | 8.8 | 8.8 | 11.8 |
| | 6.00 | 1 | 2.9 | 2.9 | 14.7 |
| | 7.00 | 1 | 2.9 | 2.9 | 17.6 |
| | 8.00 | 1 | 2.9 | 2.9 | 20.6 |
| | 10.00 | 9 | 26.5 | 26.5 | 47.1 |
| | 13.00 | 6 | 17.6 | 17.6 | 64.7 |
| | 14.00 | 1 | 2.9 | 2.9 | 67.6 |
| | 15.00 | 2 | 5.9 | 5.9 | 73.5 |
| | 17.00 | 6 | 17.6 | 17.6 | 91.2 |
| | 18.00 | 1 | 2.9 | 2.9 | 94.1 |
| | 22.00 | 2 | 5.9 | 5.9 | 100.0 |
| | Total | 34 | 100.0 | 100.0 | |

**Table 4.29: Environmental Planning**

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| Valid | 1.00 | 1 | 2.9 | 2.9 | 2.9 |
| | 3.00 | 1 | 2.9 | 2.9 | 5.9 |
| | 4.00 | 3 | 8.8 | 8.8 | 14.7 |
| | 5.00 | 1 | 2.9 | 2.9 | 17.6 |
| | 7.00 | 4 | 11.8 | 11.8 | 29.4 |
| | 10.00 | 16 | 47.1 | 47.1 | 76.5 |
| | 12.00 | 6 | 17.6 | 17.6 | 94.1 |
| | 14.00 | 1 | 2.9 | 2.9 | 97.1 |
| | 15.00 | 1 | 2.9 | 2.9 | 100.0 |

| | | | | |
|---|---|---|---|---|
| Total | 34 | 100.0 | 100.0 | |

**Table 4.30: Environmental Assurance**

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| Valid | 1.00 | 1 | 2.9 | 2.9 | 2.9 |
| | 2.00 | 1 | 2.9 | 2.9 | 5.9 |
| | 3.00 | 1 | 2.9 | 2.9 | 8.8 |
| | 4.00 | 3 | 8.8 | 8.8 | 17.6 |
| | 5.00 | 1 | 2.9 | 2.9 | 20.6 |
| | 6.00 | 1 | 2.9 | 2.9 | 23.5 |
| | 7.00 | 3 | 8.8 | 8.8 | 32.4 |
| | 8.00 | 1 | 2.9 | 2.9 | 35.3 |
| | 10.00 | 14 | 41.2 | 41.2 | 76.5 |
| | 12.00 | 6 | 17.6 | 17.6 | 94.1 |
| | 14.00 | 1 | 2.9 | 2.9 | 97.1 |
| | 15.00 | 1 | 2.9 | 2.9 | 100.0 |
| | Total | 34 | 100.0 | 100.0 | |

**Table 4.31: Environmental Control**

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| Valid | 1.00 | 2 | 5.9 | 5.9 | 5.9 |
| | 2.00 | 1 | 2.9 | 2.9 | 8.8 |
| | 3.00 | 1 | 2.9 | 2.9 | 11.8 |
| | 4.00 | 2 | 5.9 | 5.9 | 17.6 |
| | 5.00 | 1 | 2.9 | 2.9 | 20.6 |
| | 7.00 | 3 | 8.8 | 8.8 | 29.4 |
| | 8.00 | 2 | 5.9 | 5.9 | 35.3 |
| | 10.00 | 14 | 41.2 | 41.2 | 76.5 |
| | 12.00 | 6 | 17.6 | 17.6 | 94.1 |
| | 14.00 | 1 | 2.9 | 2.9 | 97.1 |
| | 15.00 | 1 | 2.9 | 2.9 | 100.0 |
| | Total | 34 | 100.0 | 100.0 | |

**Table 4.32: Financial Planning**

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| Valid | 1.00 | 1 | 2.9 | 2.9 | 2.9 |
| | 10.00 | 1 | 2.9 | 2.9 | 5.9 |
| | 11.00 | 5 | 14.7 | 14.7 | 20.6 |
| | 12.00 | 2 | 5.9 | 5.9 | 26.5 |
| | 13.00 | 2 | 5.9 | 5.9 | 32.4 |
| | 14.00 | 7 | 20.6 | 20.6 | 52.9 |
| | 15.00 | 1 | 2.9 | 2.9 | 55.9 |
| | 16.00 | 2 | 5.9 | 5.9 | 61.8 |
| | 17.00 | 8 | 23.5 | 23.5 | 85.3 |
| | 18.00 | 2 | 5.9 | 5.9 | 91.2 |
| | 19.00 | 2 | 5.9 | 5.9 | 97.1 |
| | 20.00 | 1 | 2.9 | 2.9 | 100.0 |
| | Total | 34 | 100.0 | 100.0 | |

**Table 4.33: Financial Control**

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| Valid | 9.00 | 1 | 2.9 | 2.9 | 2.9 |
| | 10.00 | 2 | 5.9 | 5.9 | 8.8 |
| | 11.00 | 4 | 11.8 | 11.8 | 20.6 |
| | 12.00 | 1 | 2.9 | 2.9 | 23.5 |
| | 13.00 | 2 | 5.9 | 5.9 | 29.4 |
| | 14.00 | 6 | 17.6 | 17.6 | 47.1 |
| | 15.00 | 2 | 5.9 | 5.9 | 52.9 |
| | 16.00 | 3 | 8.8 | 8.8 | 61.8 |
| | 17.00 | 5 | 14.7 | 14.7 | 76.5 |
| | 18.00 | 3 | 8.8 | 8.8 | 85.3 |
| | 19.00 | 3 | 8.8 | 8.8 | 94.1 |
| | 20.00 | 1 | 2.9 | 2.9 | 97.1 |
| | 22.00 | 1 | 2.9 | 2.9 | 100.0 |
| | Total | 34 | 100.0 | 100.0 | |

**Table 4.34: Financial Administration and Records**

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| Valid | 1.00 | 1 | 2.9 | 2.9 | 2.9 |
| | 10.00 | 2 | 5.9 | 5.9 | 8.8 |
| | 11.00 | 4 | 11.8 | 11.8 | 20.6 |
| | 12.00 | 2 | 5.9 | 5.9 | 26.5 |
| | 13.00 | 5 | 14.7 | 14.7 | 41.2 |
| | 14.00 | 6 | 17.6 | 17.6 | 58.8 |
| | 15.00 | 2 | 5.9 | 5.9 | 64.7 |
| | 16.00 | 5 | 14.7 | 14.7 | 79.4 |
| | 17.00 | 3 | 8.8 | 8.8 | 88.2 |
| | 19.00 | 2 | 5.9 | 5.9 | 94.1 |
| | 20.00 | 1 | 2.9 | 2.9 | 97.1 |
| | 21.00 | 1 | 2.9 | 2.9 | 100.0 |
| | Total | 34 | 100.0 | 100.0 | |

**Table 4.35: Claim Identification & Quantification**

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| Valid | 1.00 | 3 | 8.8 | 8.8 | 8.8 |
| | 2.00 | 1 | 2.9 | 2.9 | 11.8 |
| | 4.00 | 1 | 2.9 | 2.9 | 14.7 |
| | 5.00 | 1 | 2.9 | 2.9 | 17.6 |
| | 8.00 | 3 | 8.8 | 8.8 | 26.5 |
| | 10.00 | 16 | 47.1 | 47.1 | 73.5 |
| | 12.00 | 1 | 2.9 | 2.9 | 76.5 |
| | 14.00 | 4 | 11.8 | 11.8 | 88.2 |
| | 16.00 | 1 | 2.9 | 2.9 | 91.2 |
| | 18.00 | 2 | 5.9 | 5.9 | 97.1 |
| | 20.00 | 1 | 2.9 | 2.9 | 100.0 |
| | Total | 34 | 100.0 | 100.0 | |

**Table 4.36: Claim Prevention**

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| Valid | 2.00 | 2 | 5.9 | 5.9 | 5.9 |
| | 8.00 | 3 | 8.8 | 8.8 | 14.7 |
| | 10.00 | 19 | 55.9 | 55.9 | 70.6 |
| | 12.00 | 2 | 5.9 | 5.9 | 76.5 |
| | 14.00 | 4 | 11.8 | 11.8 | 88.2 |
| | 16.00 | 1 | 2.9 | 2.9 | 91.2 |
| | 18.00 | 2 | 5.9 | 5.9 | 97.1 |
| | 20.00 | 1 | 2.9 | 2.9 | 100.0 |
| | Total | 34 | 100.0 | 100.0 | |

**Table 4.37: Claim Resolution**

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| Valid | 2.00 | 1 | 2.9 | 2.9 | 2.9 |
| | 7.00 | 1 | 2.9 | 2.9 | 5.9 |
| | 8.00 | 3 | 8.8 | 8.8 | 14.7 |
| | 10.00 | 20 | 58.8 | 58.8 | 73.5 |
| | 12.00 | 1 | 2.9 | 2.9 | 76.5 |
| | 14.00 | 4 | 11.8 | 11.8 | 88.2 |
| | 16.00 | 1 | 2.9 | 2.9 | 91.2 |
| | 18.00 | 2 | 5.9 | 5.9 | 97.1 |
| | 21.00 | 1 | 2.9 | 2.9 | 100.0 |
| | Total | 34 | 100.0 | 100.0 | |

**Table 4.38: Procurement Planning**

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| Valid | 9.00 | 1 | 2.9 | 2.9 | 2.9 |
| | 12.00 | 4 | 11.8 | 11.8 | 14.7 |
| | 13.00 | 7 | 20.6 | 20.6 | 35.3 |
| | 14.00 | 5 | 14.7 | 14.7 | 50.0 |
| | 17.00 | 3 | 8.8 | 8.8 | 58.8 |
| | 18.00 | 1 | 2.9 | 2.9 | 61.8 |
| | 19.00 | 6 | 17.6 | 17.6 | 79.4 |
| | 20.00 | 1 | 2.9 | 2.9 | 82.4 |
| | 22.00 | 6 | 17.6 | 17.6 | 100.0 |
| | Total | 34 | 100.0 | 100.0 | |

**Table 4.39: Solicitation Planning**

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| Valid | 9.00 | 2 | 5.9 | 5.9 | 5.9 |
| | 10.00 | 1 | 2.9 | 2.9 | 8.8 |
| | 12.00 | 3 | 8.8 | 8.8 | 17.6 |
| | 13.00 | 6 | 17.6 | 17.6 | 35.3 |
| | 14.00 | 6 | 17.6 | 17.6 | 52.9 |
| | 15.00 | 1 | 2.9 | 2.9 | 55.9 |
| | 16.00 | 2 | 5.9 | 5.9 | 61.8 |
| | 18.00 | 1 | 2.9 | 2.9 | 64.7 |
| | 19.00 | 6 | 17.6 | 17.6 | 82.4 |
| | 20.00 | 1 | 2.9 | 2.9 | 85.3 |
| | 22.00 | 5 | 14.7 | 14.7 | 100.0 |
| | Total | 34 | 100.0 | 100.0 | |

**Table 4.40: Contract Administration, Contract Closeout**

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| Valid | 9.00 | 2 | 5.9 | 5.9 | 5.9 |
| | 12.00 | 3 | 8.8 | 8.8 | 14.7 |
| | 13.00 | 7 | 20.6 | 20.6 | 35.3 |
| | 14.00 | 7 | 20.6 | 20.6 | 55.9 |
| | 16.00 | 1 | 2.9 | 2.9 | 58.8 |
| | 18.00 | 1 | 2.9 | 2.9 | 61.8 |
| | 19.00 | 7 | 20.6 | 20.6 | 82.4 |
| | 20.00 | 1 | 2.9 | 2.9 | 85.3 |
| | 22.00 | 5 | 14.7 | 14.7 | 100.0 |
| | Total | 34 | 100.0 | 100.0 | |

Below is a transcription summary of the follow up interviews of two respondents A and B both Architects and have used BIM for the past 4 years. They highlighted the following issues:

a) Reasons for use of BIM are better return on Investment, better time management and quality assurance.

b) Confirmed BIM's significant positive change in Project predesign, design and construction phase.

c) Strongly agreed that BIM has a positive impact on Scope, Quality, and Communications management but not in Procurement management as such.

d) Attributed reluctance of AEC professionals to use BIM as a major challenge in projects.

e) Attributed that there is no enough demand from clients on BIM, Project Managers should encourage clients.

f) A database resource from which all consultants can derive information would be indispensible at the onset. Value added design and engineering could be far easier facilitated.

g) Strongly agreed that BIM developers and Client request would assist in the implementation in the SA AEC industry.

*This research will adhere to the framework and policies of the School of Construction Economics and Management, University of the Witwatersrand Research Ethics Committee. Any data for research publication purposes will be treated with anonymity unless permission is granted for it to be used otherwise. In addition, the data obtained will not be used for either commercial purposes or made available to third parties without express consent to use the data for research stated. You also confirm that you are not below the age of 16 and also acknowledge your right to discontinue participation in this research at any time without reason. The findings emerge from the study will be made available to all project participants on request.*

# Project Management Applications of BIM in South African AEC industry - A Current Status

The research entails an investigation of the current status, challenges and improvement strategies of BIM implementation in the Project Management practices of South African AEC industry.

| (Optional) | |
|---|---|
| **Name of Company** | |
| **Name & Position** | |
| **Address** | |
| **Email Address & Tel** | |

**IN YOUR OPINION, EVALUATE THE APPLICATION OF BIM ON THE FOLLOWING KNOWLEDGE AREAS OF PROJECT MANAGEMENT BASED ON YOUR PAST BIM IMPLEMENTATION EXPERIENCE**

| Project Management Knowledge Areas | Project Management Processes | Agreement Level: Ranging from 1: Strongly Disagree to 5: Neutral to 10: Strongly Agree | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Project Integration Management | Project Plan Development | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| | Project Plan Execution | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| | Integrated Change Control | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| Project Scope Management | Initiation and Planning | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| | Scope Verification | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| | Change Control in Project Scope | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| Project Time Management | Activity Definition, Sequencing & Duration Estimation | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| | Schedule Development Control | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| | Progress Monitoring | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| Project Quality Management | Quality Planning | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| | Quality Assurance | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| | Quality Control | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| Project Risk Management | Risk Identification | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| | Risk Analysis | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| | Risk Monitoring and Control | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |

| Project Management Processes | If your answer is 1 – 5 then choose the appropriate reasons: Lack of BIM Specialists | Lack of interest among other project stakeholders | High Cost of Implementation | Lack of Technical support for interoperability | Lack of Awareness on the application of BIM on the Specific Area of Project Management | No Organizational support to implement BIM | No Client Insistence | No Regulatory Mandate | Scarce Availability of Competent BIM Specialists | Lack of BIM's Capability | Legal issues Associated with Ownership of the document |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Project Plan Development | | | | | | | | | | | |
| Project Plan Execution | | | | | | | | | | | |
| Integrated Change Control | | | | | | | | | | | |
| Initiation and Planning | | | | | | | | | | | |
| Scope Verification | | | | | | | | | | | |
| Change Control in Project Scope | | | | | | | | | | | |
| Activity Definition, Sequencing & Duration Estimation | | | | | | | | | | | |
| Schedule Development Control | | | | | | | | | | | |
| Progress Monitoring | | | | | | | | | | | |
| Quality Planning | | | | | | | | | | | |
| Quality Assurance | | | | | | | | | | | |
| Quality Control | | | | | | | | | | | |
| Risk Identification | | | | | | | | | | | |
| Risk Analysis | | | | | | | | | | | |
| Risk Monitoring and Control | | | | | | | | | | | |

| Project Management Processes | If answer is 6 –10 then choose the appropriate strategy adopted/ forced you to achieve the same: Deployment of BIM Manager | Deployment of BIM Specialists on Appropriate Areas | Training and Development on BIM | Govt. and Regulatory Actions/ Mandate | Project BIM Management Plan/ BIM Guidelines | Top Management/ Client's Support | Abundant BIM Element Library | Incentives for Utilizing BIM | New Staffing With BIM Knowledge | Business Process changes according to Collaborative Work | Better Interoperability through Appropriate Technical Support |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Project Plan Development | | | | | | | | | | | |
| Project Plan Execution | | | | | | | | | | | |
| Integrated Change Control | | | | | | | | | | | |
| Initiation and Planning | | | | | | | | | | | |
| Scope Verification | | | | | | | | | | | |
| Change Control in Project Scope | | | | | | | | | | | |
| Activity Definition, Sequencing & Duration Estimation | | | | | | | | | | | |
| Schedule Development Control | | | | | | | | | | | |
| Progress Monitoring | | | | | | | | | | | |
| Quality Planning | | | | | | | | | | | |
| Quality Assurance | | | | | | | | | | | |
| Quality Control | | | | | | | | | | | |
| Risk Identification | | | | | | | | | | | |
| Risk Analysis | | | | | | | | | | | |
| Risk Monitoring and Control | | | | | | | | | | | |

| PM Knowledge Areas | Aspects of PM | Agreement Level: Ranging from<br>1: Strongly Disagree to 5: Neutral to 10: Strongly Agree | | | | | | | | | | If your answer is 1 – 5 then choose the appropriate reasons | | | | | | | | | | | If answer is 6 –10 then choose the appropriate strategy adopted/ forced you to achieve the same. | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | Lack of BIM Specialists | Lack of interest among other project stakeholders | High Cost of Implementation | Lack of Technical support for interoperability | Lack of Awareness on the application of BIM on the Specific Area of Project Management | No Organizational support to implement BIM | No Client Insistence | No Regulatory Mandate | Scarce Availability of Competent BIM Specialists | Lack of BIM's Capability | Legal issues Associated with Ownership of the document | Deployment of BIM Manager | Deployment of BIM Specialists on Appropriate Areas | Training and Development on BIM | Govt. and Regulatory Actions/ Mandate | Project BIM Management Plan/ BIM Guidelines | Top Management/ Client's Support | Abundant BIM Element Library | Incentives for Utilizing BIM | New Staffing With BIM Knowledge | Business Process changes according to Collaborative Work | Better Interoperability through Appropriate Technical Support |
| **Project Cost Management** | Resource Planning | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | | | | | | | | | | | | | | | | | | | | | | |
| | Cost Estimating | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | | | | | | | | | | | | | | | | | | | | | | |
| | Cost Budgeting & Control | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | | | | | | | | | | | | | | | | | | | | | | |
| **Project Communications Management** | Communication Planning | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | | | | | | | | | | | | | | | | | | | | | | |
| | Information Distribution | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | | | | | | | | | | | | | | | | | | | | | | |
| | Performance Reporting & Administrative Closure | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | | | | | | | | | | | | | | | | | | | | | | |
| **Project Human Resource Management** | Organizational Planning | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | | | | | | | | | | | | | | | | | | | | | | |
| | Staff Acquisition & Team Development | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | | | | | | | | | | | | | | | | | | | | | | |
| | Project Team closeout | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | | | | | | | | | | | | | | | | | | | | | | |
| **Project Safety Management** | Safety Planning | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | | | | | | | | | | | | | | | | | | | | | | |
| | Safety Plan Execution | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | | | | | | | | | | | | | | | | | | | | | | |
| | Safety Administration and Records | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | | | | | | | | | | | | | | | | | | | | | | |
| **Project Environmental Management** | Environmental Planning | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | | | | | | | | | | | | | | | | | | | | | | |
| | Environmental Assurance | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | | | | | | | | | | | | | | | | | | | | | | |
| | Environmental Control | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | | | | | | | | | | | | | | | | | | | | | | |
| **Project Financial Management** | Financial Planning | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | | | | | | | | | | | | | | | | | | | | | | |
| | Financial Control | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | | | | | | | | | | | | | | | | | | | | | | |
| | Financial Administration and Records | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | | | | | | | | | | | | | | | | | | | | | | |
| **Project Claim Management** | Claim Identification & Quantification | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | | | | | | | | | | | | | | | | | | | | | | |
| | Claim Prevention | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | | | | | | | | | | | | | | | | | | | | | | |
| | Claim Resolution | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | | | | | | | | | | | | | | | | | | | | | | |
| **Project Procurement Management** | Procurement Planning | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | | | | | | | | | | | | | | | | | | | | | | |
| | Solicitation Planning | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | | | | | | | | | | | | | | | | | | | | | | |
| | Contract Administration, Contract Closeout | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | | | | | | | | | | | | | | | | | | | | | | |