Building Information Modelling as a Catalyst for an Integrated Construction Project Delivery Culture in South Africa

A thesis submitted in fulfilment of the requirements for the award of the degree of Doctor of Philosophy in Construction Management

Faculty of Engineering, the Built Environment and Information Technology

Nelson Mandela Metropolitan University

Port Elizabeth, South Africa

by

Timothy Froise (193307810)

Promoter – Professor Winston Shakantu

March 2014

Abstract

The importance of technology in construction partnering agreements has been recognised as a vital part of integrated project delivery (IPD) philosophy. Building information modelling (BIM) is increasingly being used by consultants in South Africa during the design phase of construction projects. However, its use is generally not aimed at an integrated project delivery approach, but rather as a tool to generate documentation, as BIM is generally more efficient than traditional computer aided design (CAD) software.

For the full benefits of BIM to be realised, a greater degree of acculturation is required between construction project organisations (CPOs). The current cultures of CPOs are separationist in nature and tend to inhibit acculturation within the industry. BIM provides a central source of information that can improve communications between CPOs and foster a collaborative culture.

The research examines IPD and BIM in the South African context and investigates how BIM can contribute to IPD. A survey was conducted among registered contractors from the three top grades and architecture practices from two regions in South Africa. The survey was placed in context by a case study that analysed the use of BIM and the resulting communication network seen in a public works project using typical procurement methods. The associated problems with the current accepted paradigm are illuminated by the research.

Declaration

A thesis submitted in fulfilment of the requirements for the award of the degree of Doctor of Philosophy in Construction Management. I, Timothy Froise, declare that this thesis is my original work and has not previously been submitted in part or in full to any other learning institution for examination.

Signed………………..

Date…………………..

Acknowledgements

The presentation of this work is not the result of a solo effort and would not have been possible without the contributions that have been made by many people.

I would firstly like to acknowledge and thank my supervisor, Professor Winston Shakantu, for making this research possible by setting up the programme in the Built Environment Centre of Excellence. I would also like to express my appreciation for the direction and guidance that contributed to the completion of this work.

I would also like to acknowledge the contributions of others in the department, including Dr Fidelis Emuze, Dr Kahilu Kajimo-Shakantu, Professor Bruce Robertson and Dr Marle Van Eyk, who all contributed to the research. I would like to thank in particular Dr Amanda Werne and Professor Gaye Le Roux for their interest in the research and their encouragement and comments.

The research would not have been possible without the CIDB, which funded the Centre of Excellence and provided funding for the research.

I would like to convey my gratitude to the architects and staff from the participating organisation for allowing access to their confidential information on which the case study was based. The project architect was always willing to help with finding information and confirming matters that were unclear.

Thank you also to those from the industry who responded to the surveys.

The contents of the research also resulted from numerous discussions with those involved in the industry who gave their time to discuss concepts of the research. There are too many to name individually,

Thank you to Samantha Venter for proofreading the document at a late stage.

Finally, I thank my wife, Mary, and children, Borin, Jo, Anna and Eva for supporting me during the research and allowing me time and space to complete the work.

Table of contents

List of figures

List of acronyms

3D	3 dimensional
4D	3D plus time
5D	4D plus cost
ABM	Agent-based modelling
AEC	Architecture, engineering and construction
AIA	American institute of architects
APES	Actor process event scheme
BBBEE	Broad based black economic empowerment
BIM	Building information modelling
BIM	Building information model
BIS	Business Innovation and Skills
BSI	British Standards Institution
CAD	Computer aided design/draughting
CBR	Case based reasoning
CIDB	Construction industry development board
CNC	Computer numerical control
CPO	Construction project organisations
DWG	AutoCAD file extension
IFC	Industry Foundation Classes
IOP	Interactive on-line platforms
IPD	Integrated project delivery
IT	Information technology
JRM	Joint risk management
KM	Knowledge management
KPI	Key performance indicators
LoD	Level of detail
MPS	Model progression specification
nD	5D plus any amount of other dimensions
OB	Organisational behaviour
OCPM	Online collaboration and project management
PA	Principal agent
PDF	Portable document format

PIMS	Production information management system
RAM	Random access memory
RFI	Request for information
RFID	Radio frequency identity tag
RIBA	Royal Institute of British Architects
ROI	Return on investment
SAIA	South African Institute of Architects
SNA	Social network analysis
VDC	Virtual design and construction

List of tables

Definitions of key words and terms used within the study

Acculturation	The modification of cultures when they are exposed to each other.
BIM	The development and use of a computer software model to simulate the construction and operation of a facility. The resulting model, a Building Information Model, is a data-rich, object-oriented, intelligent and parametric digital representation of the facility, from which views and data appropriate to various users' needs can be extracted and analysed to generate information that can be used to make decisions and improve the process of delivering the facility. (The Contractors' Guide to BIM (AGC, 2006)).
CAD	Computer aided design/draughting – two dimensional diagrammatic representations of a building (Smith & Tardif, 2009: 14).
Construction project organisations	Temporary coalition of organisations to bring together various specialisations required for a construction project (Ankrah, 2007: 19), including the client, consultants, contractor, sub-contractors and suppliers (Ankrah, 2007: 20).
Culture	The qualities of any specific human group that are passed from one generation to the next (Naoum, 2011: 131).

Explicit knowledge	Knowledge, which can be documented and shared via traditional communication networks (Ngah & Jusoff 2009: 217).
Integrated project delivery	A project delivery approach that integrates people, systems, business structures and practices into a process that collaboratively harnesses the talents and insights of all participants to reduce waste and optimize efficiency through all phases of design, fabrication and construction (Hardin, 2009: 20).
Interactive online platforms	Electronic platform within an organisation where employees can access processes, procedures and checklists, but also allows employee interaction through forums, searches and peer interaction (Javernick-Will & Hartmann, 2011: 31).
Knowledge management	Knowledge management is the discipline of creating a thriving work and learning environment that fosters the continuous creation, aggregation, use and re-use of both organisational and personal knowledge in the pursuit of new business value (Cross, 1998: 11, cited in Quintas, 2005: 12).
Organisational culture	The culture of an organisation dominated by its values and behaviour (Naoum, 2011: 131).
Partnering	A voluntary, organised process by which two or more organisations having shared interests

	perform as a team to achieve mutually beneficial goals (Razlim, Mustaffa and Yaakob, 2010: 2).
Social network analysis	A network of actors and relationships, where nodes consist of actors and the edges represent interactions between the actors (Aggarwal, 2011: 2).
Tacit knowledge	Knowledge, which is embedded in the mind (Ngah & Jusoff, 2009: 217). And is difficult to transfer (Egbu *et al.,* 2004: 209).

Note on the use of language

This thesis is presented using British English. Direct quotations from North American texts have been reproduced with the American usage, whereas paraphrases have used the British English.

Note on citations

The APA (American Psychological Association) style of referencing is used for the citations and bibliography in this research.

Note on software references

Software from various producers has been cited in the research. Autodesk software has been used for illustrative purposes due to the researcher's familiarity with the software. Software cited in the research does not offer an endorsement of the product and it is acknowledged that competing software may have similar capabilities.

Software	**Producer**	**Type**
Revit	Autodesk	Full BIM software
AutoCAD	Autodesk	CAD software
Navisworks	Autodesk	Time and scheduling software to work in conjunction with BIM software
Archicad		Full BIM software
Microstation	Bentley Systems	Full BIM software
Viso		Costing software based on level of detail in BIM
Sketchup		3D modelling software – no inherent data included
Portable document format	Adobe	A file format that allows users to exchange and view electronic documents independently of the environment in which they are created (Adobe Systems Incorporated, 2006)
Excel	Microsoft	Spreadsheet software used for analysis.
Access	Microsoft	Database software used for analysis

Chapter 1 - Overview

1.1 Background to research

The performance of the construction industry internationally has been criticised due to a number of issues related to the realisation of project objectives. These include poor quality, resistance to change, lack of innovation and waste. Although the problems in the industry have been known for many years, awareness has gained impetus with the publication of the Latham Report (1994) and the Egan Report (1998), in the United Kingdom (UK). Cain (2003: 6) notes that the UK is not unique in recognising these problems and that similar reports have been produced in 'most of the developed world'. These include *The 1995 Construction and Building Sub-committee Report* in the United States, *Construction 21* in Singapore (1999) and *The Royal Report into the Building and Construction Industry* in Australia (2003).

Problems associated with the construction industry are increasingly referred to as organisational cultural problems. Walker (2011: 196) notes that although the use of the idea of 'the construction industry culture' is not yet universally accepted, the concept is gaining more recognition. The Latham Report (1994) refers to the word 'culture' three times, while the Egan Report (1998) mentions 'culture' fourteen times, suggesting that there is an increasing awareness of an inherent culture within the industry that needs to be addressed. Egan (1998) notes the slow take-up of technology that is required for increased efficiency within the industry. However, the report states that the use of technology alone is not sufficient for better performance and that the culture of the industry needs to be addressed first.

> "The advice offered to construction by leading manufacturing industries is to approach change by first sorting out the culture, then defining and improving processes and finally applying technology as a tool to support these cultural and process improvements (Egan, 1998: 28)."

Cain (2003: 6) notes that shortcomings within the construction industry are seen across different countries with different cultures. This suggests that there is an industry culture that overshadows different anthropological cultures. These shortcomings include:

- Relationships in construction (Client, consultants, contractor and subcontractors) are antagonistic and contracts are designed to shift blame away (Ankrah 2007: 34; Cain 2003: 81);
- Lack of innovation, such as the slow use of building information modelling (BIM) and other technologies (Lee, Wu and Aouad 2007: 3); and
- Cost is the main motivator for choosing the team (Cain 2003: 83).

The above-mentioned problems have also been noted in the South African construction industry. Van der Merwe and Basson (2008: 269) note how the culture of the construction industry in South Africa is influenced by adversarial attitudes. They observe that a lack of group cohesion prevents synergistic working relationships. They found that traditional procurement systems had a detrimental effect on project team cohesion and performance. Fouche (2004: 2) notes that the engineering and construction providers within the South African petrochemical industry are often characterised by disputes, claims, litigations, cost and schedule overruns and poor design standards.

1.1.1 BIM in the construction industry

A building information model (BIM) is a computer simulation of a building. Hardin (2009: 3) gives the following definition:

> "BIM is a digital representation of the building process to facilitate exchange and interoperability of information in digital format."

Lee, Wu, and Aouad (2007: 4) use the term nD to suggest the multi-dimensional aspect of BIM, as it can be used for design, analysis, construction, management, maintenance and operations. The BIM can be used to generate traditional documents, but they have the advantage of being accurate and co-ordinated, as they are all derived from the same database (Lee, Wu, & Aouad 2007: 5).

Krygiel (in Hardin, 2009: xiii) observes that workflows aligned to better visualisation, better building metrics and improved analysis are changing the way the industry communicates and designs buildings. Previously, information was exchanged using two dimensional ideas on paper. BIM produces three dimensional virtualised buildings that contain vast amounts of information. This allows for an unprecedented amount of knowledge and control over the building before work starts on site.

Hardin (2009: 2) notes that BIM can no longer be seen as an emerging technology and has produced results for the construction industry all over the world. However, this is not universally acknowledged. Hardin (2009: 26) states that many still remain sceptical. Others have noted that while there is increasing use of BIM, it is not used to its full extent. Sexton (2007: 304) observes that with regard to information sharing, consultants are reluctant to change. He suggests that there is still a degree of scepticism and architects cited the following limitations to the use of BIM:

- Ownership of drawings;
- Assignment of risk;
- Impact on professional indemnity;
- Structure and legal system of the industry needs to be changed, and
- Current systems work because:
  - We have a document management system in place.
  - We are happy with the current system.
  - Document management systems are aligned to the way the industry works.
  - The BIM tool is not aligned to the current methods of construction.

Commentators have noted how the construction industry is slow to adopt change. Suermann (2009: 24) argues that the construction industry is not optimising the pace of implementation of the technology. Typically, architects that have adopted BIM solutions use it for developing visualisations, drawings and schedules, while it is not generally used as a cross-disciplinary information sharing data-base. Suermann (2009: 37) notes an international survey that indicates that the primary use of BIM is to create construction documents. A McGraw-Hill survey (2010: 6) also shows that architects believe BIM offers them the most value during the design stage and do not generally see its collaborative potential.

An exploratory study conducted in South Africa (Smallwood, Emuze, & Allen, 2012: 144-145) found that there is limited use of BIM in South Africa. The study also suggests that architects view BIM as having its main potential during the design stage (Smallwood, Emuze, & Allen, 2012: 150).

Lee, Wu, and Aouad (2007: xix) state that the success of construction undertakings depends on the ability of the stakeholders to consider and communicate multi-disciplinary concerns, constraints, goals and perspectives. They remark that this needs to occur in a 'timely, economical, accurate, effective and transparent way'. They suggest that multi-dimensional modelling (BIM) is possibly the most promising tool and method available to address this challenge.

The accelerating advance of both hardware and software is changing the way the industry works, allowing for a collaborative approach more so than was previously possible. Industry stakeholders need to be aware of these trends in order to remain competitive in a changing environment.

The BIM database and collaboration software allow for a single point where construction project organisations (CPOs) input and extract information. This allows for a simpler knowledge management mechanism and facilitates CPO collaboration. The BIM becomes the CPO cultural 'melting pot', an analogy being the community hall, where different cultures are exposed to each other.

1.1.2 Acculturation in the construction industry

The literature that deals with culture from an anthropogenic stance refers to acculturation as the process that results when different cultures are exposed to each other. Lee and Nissen (2010: 318) discuss organisational acculturation and how the term is used in the mergers and acquisitions literature. They note how effective acculturation requires effective knowledge transfers.

Lee and Nissen (2010: 313) discuss different forms of knowledge, where explicit knowledge, such as specialised information systems or a method to achieve a task can give an organisation a competitive advantage. Explicit knowledge is temporary as competing organisations can discover this. They suggest that organisations operating in intercultural environments need to rely increasingly on tacit knowledge that is not necessarily tangible to be effective or to gain a competitive advantage. Tacit knowledge is that which is known by individuals in an organisation, but is not easily communicated. Javernick-Will and Hartmann (2011: 24) also discuss explicit and tacit knowledge. They refer to the observability of knowledge and that knowledge transfer is difficult. Knowledge needs to be observed to be possessed (2011: 25). They comment on how companies need to make the observability of knowledge easy for their employees, but difficult for their competitors if there is a strategic advantage to that knowledge.

Lee and Nissen (2010: 321) note that organisational acculturation is not required for its own sake, but to improve performance. They note that acculturation should be accelerated for organizational achievement and innovation. Chinowsky (2011: 191) notes how all members in an organisation should be engaged. He stresses that all members need to believe in the long-term success of the organisation and that each member is a contributor to the process.

The literature indicates that organisational integration depends on knowledge flows within the team and that tacit knowledge, which needs to be observed, is required for innovation. BIM and collaboration technology could potentially be the knowledge hub for the improved exchange of information and knowledge between CPOs that are involved with integrated project delivery (IPD) partnerships.

1.2 Problem formulation and hypotheses

The current cultures of construction industry stakeholders result in incongruent relationships, which affect the cost and quality of construction projects.

Chinowsky (2011: 41) notes that project success relies on multiple participants working together to achieve a goal. He suggests that project success is linked to social aspects within a team, including trust, reliance and communication levels. Chinowski (2011: 15), discussing IPD, suggests that the successful transformation to collaborative delivery requires 'fundamental shifts in organisational operations and attendant culture'. Walker (2011: 50) also links culture with trust in collaborative partnerships. Toole *et al*. (2011: 70) observe that promising technology based information innovations only deliver their full benefit when adopted on a project by all project participants. This would suggest that a degree of integration between the interacting organisations is required.

Egbu *et al.* (2004: 2009) discuss how tacit knowledge is required for innovation in organisations. Javernick-Will and Hartmann (2011: 24) note that observability of knowledge is required for tacit knowledge transfer. They discuss (2011: 32) interactive online platforms (IOPs) and how they contain static information and explicit knowledge. They comment on how technology can be used for tacit knowledge exchange.

The problem statement is derived from these observations. A lack of a common source of knowledge hinders acculturation, which is required for integrated project delivery. The thesis argues that a better understanding and utilisation of a central source of information (BIM and collaboration software) could facilitate knowledge transfers and then give significant impetus to collaborative working efforts.

1.2.1 Problem statement

There is a sub-optimal utilisation of integrated project delivery technologies and a limited culture of collaboration in construction project organisations in South Africa.

Sub Problem 1

There is a lack of collaboration in construction project organisations

Sub Problem 2

There is a reluctance to share information among construction project organisations

Sub Problem 3

Unnecessary errors and omissions are evident in project documents

Sub Problem 4

Learning and innovation within the industry are sub-optimal

Sub Problem 5

Levels of BIM use in South Africa are lower than in developed countries

1.2.2 Hypotheses

The hypotheses are numerically related to the sub-problems listed above.

Hypothesis 1

The current South African environment hinders collaboration between CPOs

Hypothesis 2

Traditional ownership of project information inhibits knowledge flows between construction project organisations

Hypothesis 3

Multiple sources of information lead to errors and omissions in the documentation

Hypothesis 4

The use of BIM in IPD projects enhances organisational learning and in turn enhances innovation

Hypothesis 5

Increased use of BIM in South Africa improves the accuracy of construction project documentation

1.3 Research aim and objectives

The aim of the research is to gain a broad understanding of the use of BIM in South Africa by examining its use as a collaboration tool between CPOs and to establish if it can become a mutual point for organisational acculturation. The research posits that the greater use of BIM will have a positive effect on the industry and that when all partners in CPOs are involved in the production and use of the construction project information, which is embedded in the BIM software, CPO acculturation will be facilitated.

The fields of CPO collaboration and BIM are both relatively new. Current literature refers to both of these subjects. The subject of partnering has not received much attention in the South African construction industry. The research addresses these lines of enquiry by gaining new primary data about perceptions and actual involvement with collaboration in the South African construction industry. The findings are used to determine how BIM can be a catalyst to IPD in South Africa.

Much of the current literature promotes collaboration during construction projects and acknowledges the value of sharing information. The research examines the effect of the current method of exchanging information and how it affects the project. This reveals the extent to which knowledge is shared during the lifetime of a project.

The research also assesses the effect that technology has on culture and examines the benefits of IPD and how the use of BIM can facilitate this. The perceptions of industry practitioners are sought in order to establish current barriers to the use of both BIM and IPD in the South African construction industry.

1.3.1 Research objective

The objective of the research is to assess how BIM is being used in South Africa and to provide a comparison with its use in developed countries. This will enable the industry to compare its current position in the international context. The extent and level of current usage is also assessed and compared with international trends. The research also examines how BIM software has developed and reveals how the trend may continue, offering increased BIM functionality. Methods of information exchange are reviewed to determine the extent that the industry is using technology. The importance of a single source of data, using BIM in the context of IPD arrangements is addressed.

The research also addresses why partnering is gaining momentum internationally, but there is little interest in South Africa. The literature indicates that there are clear advantages to collaboration during projects that are being embraced elsewhere. Barriers that are specific to the South African construction environment are identified.

The research investigates the communication networks that are currently being used in a project and how these relate to the social network that can allow (or limit) knowledge transfer. The cultural networks in project organisations and how these could be enhanced using technology are assessed.

1.3.2 Justification for the research

The literature indicates that the collaborative use of BIM benefits the partners involved in construction projects. However, in South Africa there is limited use of partnering as a mechanism for project delivery (Van der Merwe & Basson, 2008: 267). Although BIM technology is increasingly being used by consultants, its use is usually limited to the production of documentation. Consultants involved in construction projects still operate in the traditional manner. Typically, architects use the software for the benefits that it offers, including more accurate production of documentation and its ability to produce 3D images and visualisations. The rest of the design team (engineers, quantity surveyors and consultants) produce their own information independently, resulting in incomplete information, ambiguities and errors. Reasons for this include resistance to change, the traditional procurement practices and the legal responsibilities of the parties with regard to liability (Shelbourn *et al.,* 2012: 10). Smallwood, Emuze, and Allen (2012: 150) note that BIM is still in its infancy in South Africa and has the potential to offer major benefits to both the industry and the built environment. A greater acceptance of BIM and collaboration software could result in improved knowledge transfers for partners in IPD relationships and assist in the organisational acculturation required for collaborative construction partnerships.

Internationally, both BIM and IPD are increasingly being adopted by the industry. Adoption at national levels is currently occurring in the UK, USA (Race, 2012: 16), China (Wang, 2012: 27), Hong Kong, Singapore, South Korea, Finland (Takim, Harris and Nawawi, 2013: 25) and Norway (Statsbygg, 2011). Although the industry in South Africa uses BIM during the design stage, there is little evidence of it being used as a collaborative tool, which could potentially increase innovation in the industry.

The research endeavours to reveal and understand barriers that are preventing IPD arrangements and the collaborative use of BIM in South Africa.

1.4 The Research design and methodology

A combination of approaches was used to collect information for the research. These approaches included the generation of new primary data and a review of the secondary data. The methodology is discussed in Chapter Three.

1.4.1 Review of the secondary data

Initially, the secondary data is examined in a detailed literature review, contained in Chapter Two. This is used to gain an understanding of how BIM is used in collaboration in construction projects from an international perspective and to determine its contribution to an integrated approach. The review also reveals the extent of the use of BIM generally in South Africa and determines the extent to which partnering agreements are used in South African construction projects. Barriers which limit collaboration are examined from a South African context.

The information examined includes books and book sections, published and unpublished theses, journal articles and conference papers that relate to the topic.

1.4.2 Review of the primary data

The second phase obtains quantitative empirical data by conducting a survey among South African architects and contractors. The surveys are designed to determine the extent of BIM use and the perceptions on collaboration in the South African context. These data are compared to the observations from the literature review to determine if any correlation exists. The findings and discussion of the surveys are discussed in Chapter Four.

The third phase generates new primary data that is examined in the form of a case study and investigates the information production and exchange from a completed construction project. The case study is descriptive in nature and involved the identification of a suitable project in which the project information could be analysed. The information includes the BIM, drawings and their subsequent revisions, specifications, requests for information (RFIs), correspondence, including letters and emails and other project information that is available. Analysis of the information after the completion of the project identifies errors and omissions, completeness of the information and shortcomings in the transfer of information. This analysis reveals the effects on the project with regard to cost and quality resulting from insufficient information and communication. Interviews with those that authored and managed the BIM are used to augment the findings. The case study findings are presented in Chapter Five.

1.4.3 Validity and reliability of the findings

The study analyses recorded information, and as such, the data are primarily objective data that can be recorded and analysed. Regula Kyburz-Graber (2004: 54) notes that explorative case studies go beyond description and provide an understanding of the case against the background of its context. She suggests that they can be used for later extended analysis. Currently available analysis tools can be used to analyse the effect of information transfer methods on the outcome of projects. These findings can be used for further research to establish if the results are applicable to the industry as a whole.

1.4.4 Assumptions of the study

Assumptions are conditions that are taken for granted. Neuman (2006: 52) states that they are a necessary starting point and should be identified. The following assumptions are made for the study:

- Lower project costs are sought by all parties involved in the project; and
- High quality projects are sought after by all parties involved in the project.

The UK governments report (Cabinet Office, 2012: 3) shows how substantial savings have been achieved by driving collaborative arrangements. The document highlights how this has resulted positively on the economy. A further case study (Cabinet Office, 2012: 16) shows how the new strategies are improving workflows, documentation and building projects from concept through to occupation.

1.5 Structure of the thesis

Chapter one provides an overview of the subject matter and factors that led to the formulation of the problem statements and hypotheses. The aims and objectives of the research are addressed, and the scope of the study is outlined. The chapter closes with an overview of the structure of the thesis.

Chapter Two presents the findings of a detailed literature review. The chapter is divided into sections that focus on different aspects of the problem. The first section examines organisational acculturation, with a specific view on knowledge sharing and exchange. The second section looks at collaboration in the construction industry and IPD precedents. The third part looks at BIM generally and discusses its current use in the industry from an international and local perspective.

Chapter Three presents the methodology and justifies the methods used for the research. The ontological approach and epistemological assumptions are addressed. Data analysis and interpretation methods are discussed.

Chapter Four presents and examines the results obtained from the survey.

Chapter Five discusses the findings of the case study and considers the implications.

Chapter Six concludes the study and makes recommendations based on the findings.

Chapter 2 – Review of the literature

2.1 Introduction

The study examines the relationship between technologies emerging in the construction industry aimed at sharing and integrating information and their role in assisting with acculturation among construction project organisations (CPOs). The first section of the literature review examines collaboration and acculturation between CPOs. The literature that deals with knowledge management and flows between CPOs is subsequently reviewed to evaluate how knowledge sharing could affect the organisational culture of CPOs that are involved in collaborative partnerships. The effects of knowledge transfer on an organisation's learning culture are explored and how these assist with a 'systems thinking' approach to construction projects. The study then reports on emerging technologies that can be used for collaboration on projects and how these can foster learning organisations.

2.2 Organisational culture

Culture is defined as the traits of a community or group. Fellow and Liu (2006: 139) state that culture is learned and not inherited genetically. It manifests in behaviour and is learned and practiced by responding to and replicating the behaviour of others in the group. They state that it is collective and the group may be defined by ethnic origin, political nation or as an organisation (2006: 139).

The word 'culture' is difficult to define when used as a description in organisations and industries. According to Walker (2011: 177), the concept of organisational culture came into prominence in the early 1980s with four books that promoted the idea of a strong organisational culture and that management could change or control the organisational culture of a company. These were:

- Ouchi's Theory X (1981)[1] ;
- Pascale and Athos – The Art of Japanese Management (1982);

[1] This appears to be an error – Ouchi, William G. (1981). Theory Z. New York: Avon Books, which is based on theory X and theory Y

- Peters and Waterman – In Search of Excellence (1982) and
- Deal and Kennedy – Corporate Cultures (1982).

Walker, drawing on the work of Huyzynski and Buchannan (2007: 178) noted that the roots of organisational culture as a concept originated in the early part of the twentieth century where the classical management school was challenged to approach management in a more humane way (Walker, 2011: 178). He notes that there have been attempts to apply the idea of culture onto whole industries and that culture has been taken up by the construction industry as the root of all its problems. He quotes Palmer and Hardy (2000) to show the difficulty in understanding the meaning of 'organisational culture' (Walker, 2011: 179):

> "A range of management definitions of culture can be found; some of these definitions mention beliefs and values; others emphasize 'knowledge'; some highlight shared meanings; others point to an organisation's 'ethos'; some mention myths, symbols and rituals. Some writers maintain that agreement exists around the fact that culture is holistic, historically determined, anthropological, socially constructed, soft and difficult to change. Others, however, question even this degree of consensus arguing that culture has become a buzzword meaning 'many different and sometimes contradictory things'…. Sathe (1983) argues that it is pointless to argue about which definition of culture is correct because it does not have a 'true and sacred meaning that is to be discovered'. He also suggests that there is a lack of a sufficient definition and suggests that there is no accepted understanding of what organisational culture is and that this inhibits meaningful research."

However, the concept is used widely in current literature. Ackoff (2006: 241), Senge (2006: 267) and Naoum (2011: 132) all refer to organisational culture. Naoum compiled a list of some cultural matters that are related to organisations. These include:

- The characteristics of the people employed by the organisation;
- The level of qualifications required for professional employees;

- The level of past experience required;
- Rewards and promotion of employees;
- Social activities available;
- Decision making level and how much risk the company takes;
- Subordinates' awareness of company objectives;
- The system of communication and coordination used; and
- Information documentation system used.

Capra (2003: 96) notes that there are two different cultures that exist in an organisation. The first is the formal structure of the organisation that relates to tangible characteristics, such as rules and hierarchy, and the second is the networks that exist within that structure. Capra argues that the network structures are complex and are based on non-linear dynamic systems. This could potentially explain the difficulty in understanding organisational culture that is shown in the literature, as the structure and networks are not looked at independently.

He uses a metaphor to illustrate this difference – the organisation is a machine, and the organisation is an organism (Capra, 2003: 90), where the machine represents the formal structure of the organisation and the organism represents the networks, which are less tangible. Capra notes (2003: 75) that culture is a complex, highly non-linear dynamic system that continually evolves based on feedback loops, drawing on theories of non-linear dynamics (chaos theory). Senge (2006: 285) also comments on the continually changing aspect of culture in organisations:

> "It is common to talk of an organisation's culture as if it is simply 'the way things are.' But no culture is static. It is continually reinforced by how we live with one another day to day."

From this, the culture of an organisation can then be seen as two parts. The first is the formal organisational culture, or the tangible organisational behaviour of Walker (2011) and the machine aspect of Capra (2003). The second is the less tangible aspect of the organisation, the intertwining networks, or the organism as defined by Capra (2003: 90).

Pryke (2006: 239-240) discusses the machine metaphor in the context of construction projects. The readily accepted management approaches conceptualize construction organisations as 'goal seeking machines'. He suggests that the metaphor reflects the strong engineering orientation among practitioners and researchers in construction. Pryke (2006: 213) also reiterates the complex, non-linear and interactive environment and emphasises how this is particularly relevant to a construction project.

Construction projects typically rely on the formal organisational culture to transfer information via well established and formalised distribution networks. This is referred to as explicit knowledge. The organism as defined by Capra can be seen as the distribution network for tacit knowledge, which is less tangible. Capra, drawing on the work of Nonaka and Takeuchi (1995), suggests that although tacit knowledge is created by individuals it can be transformed into explicit knowledge through the social interactions that occur in the organisation.

Collaboration in construction projects requires that teams with different cultures integrate. In order for this to occur, positive acculturation is required between project participants.

2.2.1 Acculturation in the construction industry

Acculturation is the process of adopting traits of another culture when different cultures are exposed to each other. Acculturation can either be a positive or negative process. When it is positive, integration takes place among interacting parties and when it is negative, it results in marginalisation (Berry, 2011: 2.6).

Acculturation occurs when different cultures are exposed to each other and the original cultures are modified. Berry (2011: 2.6) noted that different modes of acculturation occur in society, shown in Figure 2-1. The first mode is assimilation, where the non-dominant culture seeks to adopt the culture of the dominant cultural group. Separation is when a cultural group does not wish to integrate and they keep their original culture. Integration occurs when each culture preserves its own culture, while interacting harmoniously; and marginalisation occurs when the dominant culture prevents the non-dominant culture from assimilating. He notes that the last mode may occur due to reasons of exclusion or domination. Berry (2011: 2.9) also refers to integration as multiculturalism, which he views as being the preferable mode for acculturation in society.

Songer and Chinowski (2011: 17) discuss the integration of CPOs and have developed what they call an 'Integration Matrix', which bears some resemblance to Berry's modes and is shown in Figure 2-2. The four quadrants of the matrix refer to varying levels of trust and communication. The first of the four quadrants is isolation, with low levels of trust and communication. The second is fragmentation, when communication is increased but there are low levels of trust. Connection occurs when there is trust, but with low levels of communication. The final state is that of integration, where both trust and communication levels are high. They note that this is the preferred state for collaboration to occur.

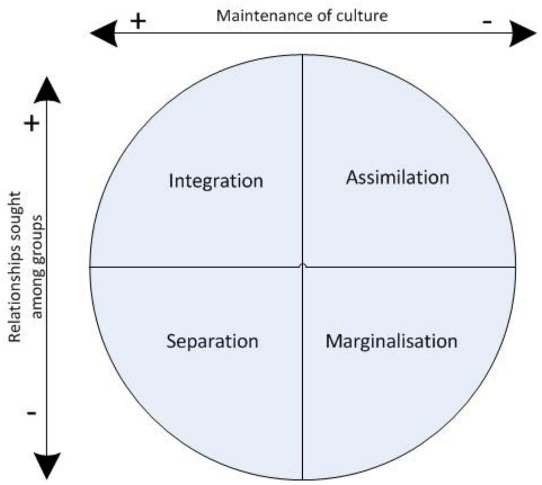


Figure 2-1 Acculturation modes (Berry, 2011)

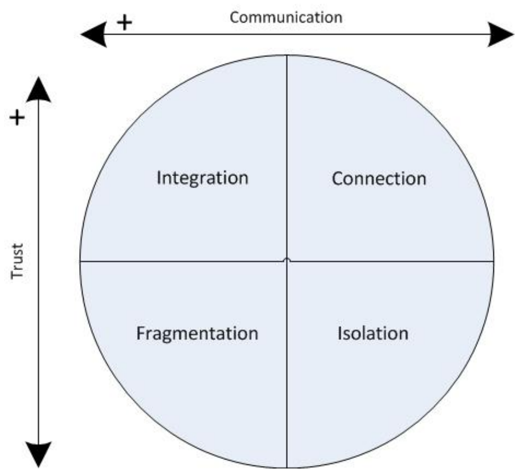


Figure 2-2 Chinowskys integration matrix (Chinowsky & Songer 2011: 17)

Chinowsky (2011: 51) observes relationships across organisations where information links exist along with coordination, learning and cultural differences. He suggests that in order to achieve high performance in inter-organisational relationships, the focus needs to be on facilitating communications and relationships.

Chinowsky (2011. 42-43) discusses the concept of high performance organisations and how they exceed the expectations of the project and demonstrate innovative approaches. These organisations combine individual strengths and knowledge to generate knowledge that exceeds the capability of any team member. He observes that there is a high degree of connectivity between the team members. The team is characterised by positive collaboration, which encourages action and creativity. Chinowsky (2011: 43) notes that the concept of high performance is routinely implemented in diverse industries but has received little attention in the construction industry, where success is typically measured using traditional indicators, such as time, cost and quality. He ascribes this to contractual and industry barriers rather than to lack of intent. Chinowsky (2011: 43) suggests that the problem can be addressed by viewing the construction team as an integrated group of participants within a network, rather than as a group of participants. The team needs to consist of a cohesive network where members focus on building long term relationships that are transferred from activity to activity.

2.2.2 Knowledge transfer

Ngah and Jusoff (2009: 217) refer to Polanyi's (1966) classification of knowledge into two types. The first is explicit knowledge, which can be documented and shared via traditional communication networks. The second type is tacit knowledge, which is embedded in the mind. Explicit knowledge is easy to find and transfer, while tacit knowledge is difficult to transfer. Javernick-Will and Hartmann (2011: 24) also discuss explicit and tacit knowledge. They note that complex knowledge, both tacit and explicit, is difficult to transfer and requires years of training and background before employees can understand it (2011: 25). They also refer to the observability of knowledge and that knowledge transfer is difficult. Knowledge needs to be observed to be learned (2011: 25). They comment on how companies need to make the observability of knowledge easy for their employees, but difficult for their competitors if there is a strategic advantage to that knowledge. Lee and Nissen (2010: 313) discuss explicit and tacit knowledge and note that tacit knowledge flows narrowly and slowly when it is required to flow between cultures but that knowledge transfer is imperative to operate effectively.

Chinowsky (2011: 47-52) discusses information based networks in organisations. He notes that knowledge networks are required for high performance results, and organisations need to have social networks with trust and value sharing before this form of knowledge transfer can occur. He also discusses culture networks and that weak interpersonal relationships in culturally diverse teams will impede adequate knowledge exchange. Egbu *et al.* (2004: 209) also observed how tacit rather than explicit knowledge is required for innovation within organisations. They also comment on the difficulty of transferring tacit knowledge. They note that structures that transfer only explicit knowledge will severely limit contributions to innovation and project success (Egbu *et al*., 2004: 209).

Capra (2003: 100), drawing from the work of Tuomi (1999) discusses how tacit knowledge can be transferred into explicit knowledge. He quotes Michael Polanyi, who originally used the terms tacit and explicit knowledge, and stated that tacit knowledge is a pre-requisite for explicit knowledge.

Tizani (2007: 15) discusses how communication and information flow between the design organisations is required to complete the design and that this can waste time. He suggests (2007: 17) that integration is required and that this will require technological and cultural changes to the implementation of construction projects.

Hardin (2009: 20) states that for successful IPD, complete collaboration of the team is required. The collaborative group can then leverage the latest technology to foster flexibility and successful project outcomes. Songer and Chinowsky (2011: 15) add that improved trust and communication is required from project partners. This requires a fundamental shift in an organisation’s operations and culture.

2.2.3 Explicit and tacit knowledge transfers

Organisations primarily use explicit knowledge in running their day to day operations. Explicit knowledge is visible and codified (Sanchez, 2004: 12). However, many members of the organisation have tacit knowledge assets that are not easily or readily communicated.

Javernick-Will and Hartmann (2011: 25) note that if knowledge is difficult to observe it will be more difficult to transfer. They comment that it is important for firms to make their work processes easily observable. But they also need to make it hard for their competitors to observe, which makes it challenging for organisations in highly competitive fields. This may illustrate why the culture of the construction industry is adversarial. CPOs need to limit the amount of information that they share in order to remain competitive, which can be detrimental to the project. Sanchez (2004: 10) also observes that the first step in harnessing tacit knowledge is to observe who has the knowledge. Observability of knowledge can assist in making tacit knowledge explicit.

Senge (2006: 270) comments on the social dimension of knowledge and notes the connection to collaboration. He states that to manage knowledge, collaboration needs to be addressed with tools that help people collaborate.

Tacit knowledge can be converted into explicit knowledge once it is in a tangible form, such as a drawing (Sanchez, 2004: 12). Collaboration will allow members from partnering teams to observe the knowledge, after which it becomes their own tacit knowledge.

BIM deals primarily with explicit knowledge. However, the literature refers to tacit knowledge being the key to innovation and acculturation. Tacit knowledge transfer requires that it is observed. The observability of explicit knowledge allows it to become tacit. For meaningful collaboration to occur, organisations need to make the best use of knowledge management and tacit knowledge exchange.

Nonaka (2007: 165) illustrates how the articulation of tacit knowledge allows it to become explicit. He notes that as explicit knowledge is shared throughout organisations, it becomes internalised. They broaden and extend it to reframe their own tacit knowledge (Nonaka 2007: 166). Nonaka notes how the concepts of articulation and internalisation form a spiral where new knowledge is created within an organisation, illustrated in Figure 2-3.

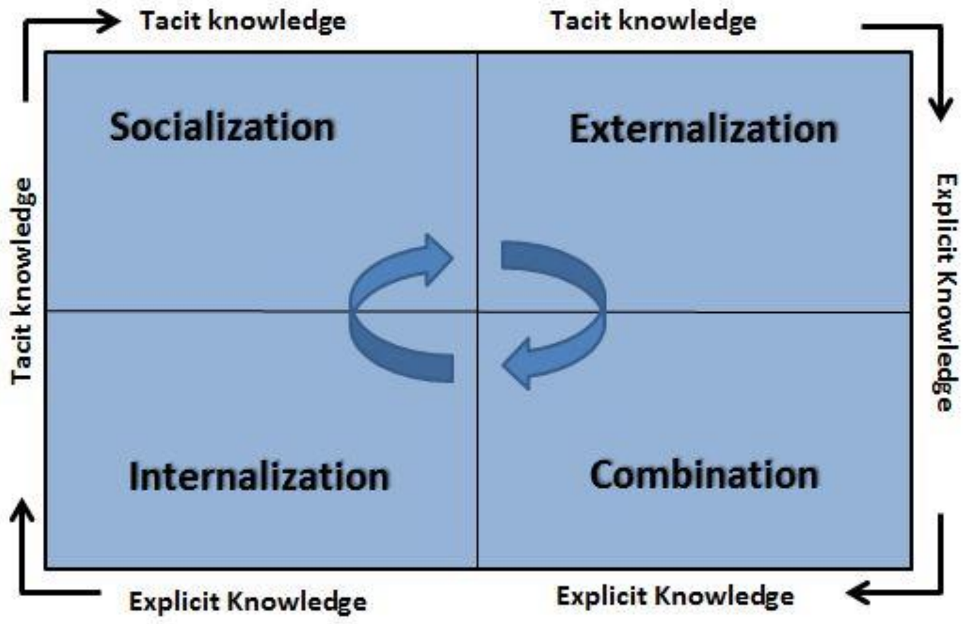


Figure 2-3 Spiral of knowledge creation (Nonaka and Takeuchi)

.

Egbu and Robinson, (2005: 41) discuss the 'knowledge paradox', where organisations that operate on the same project need knowledge to be transferred for project success, but this exposes their knowledge to other organisations. This would suggest that organisations that operate in long-term collaborative partnerships would have an advantage, as knowledge is transferred over time, while it is still held within the collaborating CPOs.

Collaboration software, such as online collaboration and project management software (OCPM) allows all the relevant data for a project to be accessible. Each document contains explicit information. But the organised collection of this explicit information provides a source for tacit information transfers between the collaborative parties. If the collaboration effort is pursued over a number of projects, tacit knowledge transfer is accelerated.

Sheehan *et al.* (2005: 55) suggest that teams need to have an appropriate culture in order to transfer tacit knowledge. They note how intranet based technology can be used to share information and use Arup as an example of how this can be achieved. Each individual has their own webpage where they can share their interests and expertise, allowing the transfer of tacit information within organisations.

Morris (2006: 70) considers explicit and tacit knowledge transfers within construction organisations and emphasises that socialisation is the most important quadrant in Nonaka's and Takeuchi's diagram (Figure 2-3). Leon and Laing (2012: 110) suggest that new insights and ideas, effective communication and collaboration can be achieved by linking different professional viewpoints and creating a shared understanding among all stakeholders.

Smith and Tardiff (2009: 36) show how the transfer of information from one party to another poses risks for the author of the information as they will be held accountable for the information that they transmit. This generates an environment where information sharing is discouraged due to the associated risks. Smith and Tardiff (2009: 36) compare this to an environmental ecosystem where organisms receive the products of other organisms for their survival. The receiving organism is entirely responsible for how the resource is used. Traditional construction environments do not encourage knowledge sharing as there is a risk in doing so. This prevents tacit knowledge transfer within the industry and inhibits organisational learning and innovation. In order to address this, participants need to be equally responsible for the information that is generated and shared.

2.3 Collaboration

Lo and Parlamis (2012: 6) discuss how Berry's acculturation modes (Figure 2-1) do not imply that acculturation is positive. Assimilation and integration are seen as positive modes of acculturation. But marginalisation and separation do not allow much room for collaboration as there is no exposure to alternative cultural norms. They suggest that there is a significant amount of negotiation and conflict before collaboration can occur (Lo & Parlamis, 2012: 6).

The importance of collaboration in construction projects is increasingly being acknowledged in the construction literature (Songer & Chinowsky, 2011: 15; Race, 2007: 27; Smith & Tardif, 2009: 35; Naom, 2011: 121).

Morris (2006: 60) discusses how criticism of the construction industry focused on institutional and contractual practices rather than addressing the management of projects. Only recently has knowledge about managing projects been seen as an important factor. He refers to the Egan report (Rethinking Construction: the report of the construction task force, 1998) which identifies five key drivers to improve the industry. These include the commitment of the leadership, customer focus, quality, a focus on people and integrated teams.

Pryke and Smyth, (2006: 51) refer to Handy (1992), who stated that projects are best suited to a task culture. They challenge this view and suggest that the task culture is based on objectives and tasks to complete the project, and therefore has a secondary regard for people and relationships. Failure to achieve objectives results in blame being apportioned, which develops a blame culture within organisations. The internal blame leads to the adversarial tradition of project environments. Pryke and Smyth, (2006: 51) suggest that the blame culture results in defensive and risk-averse behaviour and results in people working as individuals, which inhibits teamwork. They identify trust as a parmount trait of collaborative working (2006: 51).

2.3.1 Trust

Smyth (2006: 97) emphasises how the importance of trust has gained recognition over the last decade, particularly in relation to alliances such as partnering. He asserts that trust is not sufficiently understood and that there is no agreed definition (Smyth, 2006: 99). He suggests that there is general agreement in the literature that trust involves a willingness to be vulnerable, which is linked to an expectation of positive outcomes. He notes that trust is an investment and is built with care through relationships, and that each party must be aware of the willingness of other parties to be equally trustworthy. It is developed over time and its focus is on a return in the long run, rather than a short term return (Smyth, 2006: 103). It is based on confidence in the other parties in the relationship.

Mosey (2009: 33) discusses how organisations fear opportunistic behaviour and how this can have an adverse effect on the efficiency of the construction process. Opportunistic behaviour can be the result of not having a comprehensive contractual plan. He stresses the importance of having a clear and binding preconstruction phase agreement so that trusting relationships are easier to achieve.

Smyth (2006:97) examines the importance of trust in partnering arrangements. He sees trust as a competency that can be developed. He gives a definition for trust as follows:

> “Trust is a disposition and attitude, giving rise to a belief, concerning the willingness to be vulnerable in relation to another party or circumstance (Smyth, 2006: 99).”

Smyth (2006: 101) suggests that the primary obstacle to developing trust is a lack of willingness of an organisation to be vulnerable, as other parties may not have the organisation’s best interests as an objective. He refers to the Nash equilibrium, which presents four possible outcomes for two parties. These are:

1. Win-win
2. Win-lose
3. Lose-win
4. Lose-lose

Trust is present when one party looks after their own interests and the interests of the other party and there is a win-win result. Smyth (2006: 102) states that a win-win outcome derived from mutual self-interest is more likely where there is a series of exchanges or ‘repeat games’. Trust is more likely to develop with long term relationships.

Chinowsky (2008: 808) shows how trust is a prerequisite for acculturation, which is required for information and knowledge transfer. New members of the organisation’s network will not feel comfortable exchanging anything other than required information until they become assimilated within the organisation. Chinowsky (2008: 807) states that achieving trust and shared values within the project network will increase the exchange of knowledge and information and result in higher performance output.

2.3.2 Partnering

Walker (2011: 197) discusses the adversarial nature of the construction industry. He suggests that the 'claims culture' is a familiar aspect of the construction industry culture and that cultural inertia needs to be overcome before change can occur. Walker suggests that partnering is a major initiative that could address this problem. The benefits of collaboration on construction projects have been noted by many writers, including Latham (1994), Egan (1998), Thomsen, Darrington and Dunne (2010: 11), Walker (2011: 50) and Naom (2011: 121).

Cain (2003: 21) lists two factors that differentiate best practice from traditional procurement. These are:

- Abandonment of lowest capital cost as the value comparator; and
- Involvement of specialist contractors and suppliers in design from the outset.

Pryke (2012: 38) refers to the Banwell report of 1964 where the 'open tendering' and 'selective tendering' processes were challenged. Open tendering refers to the process where anyone can submit a tender, while selective tendering invites tenderers from a list of preferred contractors. The inherent waste and cost to the industry in both these options should be noted. Where six selected tenderers are invited to tender, each prepares a bid at considerable cost and time and, with all being equal, a one in six chance of a successful bid. In this scenario, the tenderer is likely to be awarded a contract once every six times that he bids. This means that he has to cover the cost of five unsuccessful tender attempts with the profit made on the successful contract. The inherent hidden cost borne by the industry for every awarded tender is the cost to prepare six tenders in this hypothetical example.

Radosavljevic and Bennett (2012: 177) reveal that the concept of partnering in construction originates from the Japanese manufacturing industries, particularly in the motor industry. Their superior performance was based on cooperative long-term relationships, in contrast to the West's reliance on competition and formal contracts. Similar studies in construction revealed that the Japanese construction industry had adopted a similar approach. They achieved reliably high levels of efficiency in terms of quality, time and cost. Radosavljevic and Bennett (2012: 177) state that the first use of partnering outside Japan was in the United States and was quickly adopted by leading construction companies in the United Kingdom. Thomsen, Darrington and Dunne (2010: 14) say that the first partnering contract in the UK was with British Petroleum (BP) to construct an offshore oil drilling platform during the 1990s. Traditional construction approaches would not have provided an economical solution. BP tried an innovative risk/reward structure within a collaborative project delivery model. The project cost two thirds of the original estimate and was completed six months ahead of schedule. The concept became known as 'project alliancing'. Thomsen notes that the concept has been used extensively in Australia and that there have been a number of successful public and private projects that have been completed using alliancing.

Collaboration on construction projects has various labels, including alliancing, relational contracting and integrated project delivery (IPD) (Songer & Chinowsky 2011: 15). Other authors refer to collaboration as partnering (Walker 2011: 193, Razlim, Mustaffa and Yaakob 2010: 2).

Razlim, Mustaffa and Yaakob (2010: 2) offer the following definition of partnering from The Dispute Avoidance and Resolution Task Force (DART) of the American Arbitration Association:

> "Partnering is a voluntary, organized process by which two or more organizations having shared interests perform as a team to achieve a mutually beneficial goal. Typically, the partners are organizations that in the past worked at arm's length or may have had competitive or adversarial relationship with one another. Generally, the more partners involved, the better the overall results. Partnering is also a collaborative process that focuses on co-operative reconciliation (win-win) as opposed to either compromise (lose-lose) or concession (win-lose). It is not a social process that simply promotes courtesy and politeness among participants, but rather good faith and joint resolution of problems. Partnering is a non-binding process. It neither alters the contract

> documents nor the relationships between the parties to use the agreed-upon partnering process and to deal with one another as true partners.”

Hardin (2009: 20) gives the following definition of IPD, from the AIA California Council, 2007:

> “Integrated project delivery (IPD) is a project delivery approach that integrates people, systems, business structures and practices into a process that collaboratively harnesses the talents and insights of all participants to reduce waste and optimize efficiency through all phases of design, fabrication and construction.”

The American Institute of Architects (AIA, 2007: 3) lists the advantages of IPD for the three major stakeholder groups (owners, designers and constructors). A major advantage for the owner of the proposed facility is the early and open sharing of project knowledge that allows owners to balance project options to meet their goals. The project team’s understanding of the owner’s desired outcomes is strengthened, improving their ability to manage costs and increase the likelihood that the project goals are achieved. For the constructors, their participation during the design phase provides the opportunity for strong pre-construction planning, timely and informed understanding of the design, and gives them the ability to anticipate and resolve design related issues and visualise construction sequencing prior to the start of construction. Designers benefit from the early contribution of the constructor’s expertise during the design phase, such as budget estimates which inform design decisions and early resolution of buildability issues.

Bertelsen (2004: 4) notes that partnering is gaining more of a foothold in Danish organisations due to a reduction in claims and suggests that partnering is a more efficient way of generating project value. Van der Merwe and Basson (2008: 266) discuss the concept of partnering in South Africa between constructors and the design team and note how integrated and coordinated information is required for successful partnering arrangements. They state that ‘creative harmony’ is required between the personalities.

Songer and Chinowsky (2011: 15) suggest that globally there is call for a cultural change in the industry but that the fragmented nature of the industry is a challenge for a collaborative process. The sharing of information requires a significant level of trust. They suggest that fundamental changes to the organisational structure and the effective use of technology are required for sustainable collaboration. They note that a common theme among IPD projects is organisational boundary collapse. They suggest that the next generation of construction leader will need the skills to transform corporate cultures of isolation into those of integration. Naoum (2011: 134) mentions the construction industry culture and 'cultural diversity' among the project participants leading to the fragmented nature of the construction industry.

Pryke (2006: 159) observes that during the design stage the biggest failure is that consultants fail to coordinate their work with other professionals. He emphasises that with the current process, design and construction are seen as different activities and that often this is conducted by different teams involved with the project. He gives an example where the client representative during the design development stage is often replaced by a project manager during the construction stage and that this has an impact on the continuity of the project. Often, problems in the project only become apparent during the construction phase, and it may be difficult or costly to rectify these. Pryke (2006: 160) notes how problems reported during the construction phase are generally relationship based.

Pryke (2006: 169) proposes that relational contracting provides a framework for exploring ways of reducing conflict. He stresses common team objectives, collaborative approaches and joint risk management (JRM). JRM involves managing risks by all parties as opposed to allocating risk, which is typical of traditional contracting. He contrasts the modern approach to construction management, which is goal orientated to the post-modern approach, where the process is emphasised.

The American Institute of Architects (AIA) (2007: 11) discuss how success within an organisation involved in a project does not necessarily relate to the success of the project. Project participants strive to achieve individual financial success for their organisations. This is potentially detrimental to the success of the project or other participants. Individual success that is linked to project success is a powerful driver for project success.

2.3.3 Barriers to partnering

Radosavljevic and Bennett (2012: 182) suggest that, although partnering can be effective for individual projects, there is considerable cost in selecting construction companies that are willing to cooperate and running workshops to streamline the collaboration effort. Ensuring that the whole project team works together takes time, and ingrained competitive instincts can be difficult to overcome. There is a steep learning curve for individuals involved in a partnering arrangement for the first time. However, the benefits of partnering are easier to achieve on a second or third project. They refer to this as strategic partnering.

Smith and Tardif (2009: 35) point out that while the intensive collaboration required for IPD does increase trust, it would be naïve to think that trust alone can be used to build complex business relationships. Teams are made up of team members. Members do not necessarily act in the best interests of the project.

Shelbourn *et al.* (2012: 10) note the following challenges to collaboration:

- Time and data loss during information exchange;
- Incompatible communication infrastructures used by different participants;
- Misunderstandings caused by ill-defined information;
- Complex iterative negotiations when solutions conflict;
- Lack of effective tools for organising and exchanging project information; and
- Co-ordination of complex work processes.

Pryke and Smyth (2006: 49) discuss the way in which people learn. Affective learning accounts for about 80% of what is learned, and is based on experience during the formative years and career experience. Other learning is achieved by cognitive learning, that which is taught. During the formative years, beliefs, values and attitudes are developed. They refer to these as mind-sets, which are reinforced by career experience. The difficulty with mind-sets is that they are set and are therefore difficult to change. Behaviour is based on the mind-set. When competencies are required for a new method, such as partnering, behaviour and mind-set need to change. Pryke and Smyth (2006: 50) notes that the norms of organisational behaviour need to be addressed before performance will change. Pryke and Smyth (2006: 51) list the barriers to organisational change. These include threats to existing power relationships, threats to expertise, group inertia, structural inertia and threats to existing resource allocation.

2.3.4 Partnering in other countries

The importance of partnering in construction projects has been explored internationally. Race (2012: 16) discusses the 'National 3D-4D-BIM Program, additional BIM Guide Series', which was issued by the Office of the Chief Architect, Public Building Services of the US General Services Administration. In the UK, partnering is increasingly seen as the preferable route for construction relationships and is actively encouraged by the government. In the UK's 'Government Construction Strategy' (Cabinet_Office, 2012), the authors state that the main barrier to reduced costs and increased growth is the lack of integration in the construction industry and that the current procurement process reinforces this barrier. They acknowledge that the strategy represents a 'challenging change programme' that can only be implemented with significant involvement and leadership from both the government and the industry. In South Africa the current environment does not promote partnering for construction. There is a reliance on separate single-stage tendering agreements for the different parties involved with public works projects.

2.3.5 Early contractor involvement

Mosey (2009: 6) recalls how the separation of the design and construction phases of projects was identified as a problem by government industry reports in the UK as early as 1962 by Emerson, who identified how removed the responsibility for design is from the responsibility of production. This was reiterated in the Banwell report (1964) and the Latham report (1994). Mosey states that it has long been recognised that design contributions should be made by contractors and specialist suppliers, as well as by the consultants (Mosey, 2009: 7). He suggests that procurement models that omit the contractor can increase risk, reduce communications between team members, cause delays and create incorrect information which can lead to disputes and claims.

Hardin (2009: 111) notes how knowledge resides in experienced minds and that the contractor's knowledge should be seen as a resource. Constructability issues and the methods of building grow in importance as the design develops. Contractors can contribute to this process. This results in a knowledge sharing environment, where a systems thinking approach becomes possible.

Mosey (2009: 47) discusses the reasons for increased cost on projects that were identified in a study in the UK (Construction Procurement by Government' 1995). These include:

- Objectives that were unrealistic, or changed during the course of the project;
- Estimates were too optimistic;
- Project briefs were incomplete, unclear or inconsistent; and
- The design was incomplete at the time of tender, or lacked coordination or buildability

2.3.6 Barriers to early contractor involvement

Mosey (2009: 176) lists three categories of obstacles to the early appointment of the contractor. These are project-specific obstacles, procedural obstacles and personal obstacles. Personal obstacles include the inherent resistance to change in the industry. Personal attitudes may not be changeable, but training, education and persuasion might address this.

A major procedural obstacle can be constitutional or regulatory constraints that require that the main contractor is selected according to the lowest fixed price bid. He suggests that this barrier may be overcome by demonstrating that a two stage procurement process can achieve best value. He suggests that there is no inconsistency between the requirements for 'most economically advantageous tender' and the two stage tendering process (Mosey, 2009: 181).

Mosey suggests that the time and cost required to create and finalise agreements is a disincentive. Unfamiliarity with different types of contracts may lead teams to seek legal advice or require them to renegotiate with their professional indemnity insurers.

Project specific obstacles include project size and simplicity, where for smaller projects the advantage of earlier contractor appointment is negligible. Project funding, such as PFI initiatives, may be an obstacle where this is linked to abdication of risk rather than collaborative risk management (Mosey, 2009: 180). However, he sees the biggest barrier as the method of procurement, and suggests that single-stage tendering is the main project-specific obstacle to early contractor appointment. This is the model that is used in South Africa for public works.

Figure 2-4 shows the construction process using a single-stage traditional tendering arrangement. This is compared with Figure 2-5, which shows a two-stage tendering process. The illustration shows how this allows for a more complete project design before construction starts on site. It allows for more accurate cost projections, as sub-contractors can complete their design and provide costs while the other construction documentation is being completed. Any potential clashes are noted and corrected early, which simplifies both the design process and the construction process.

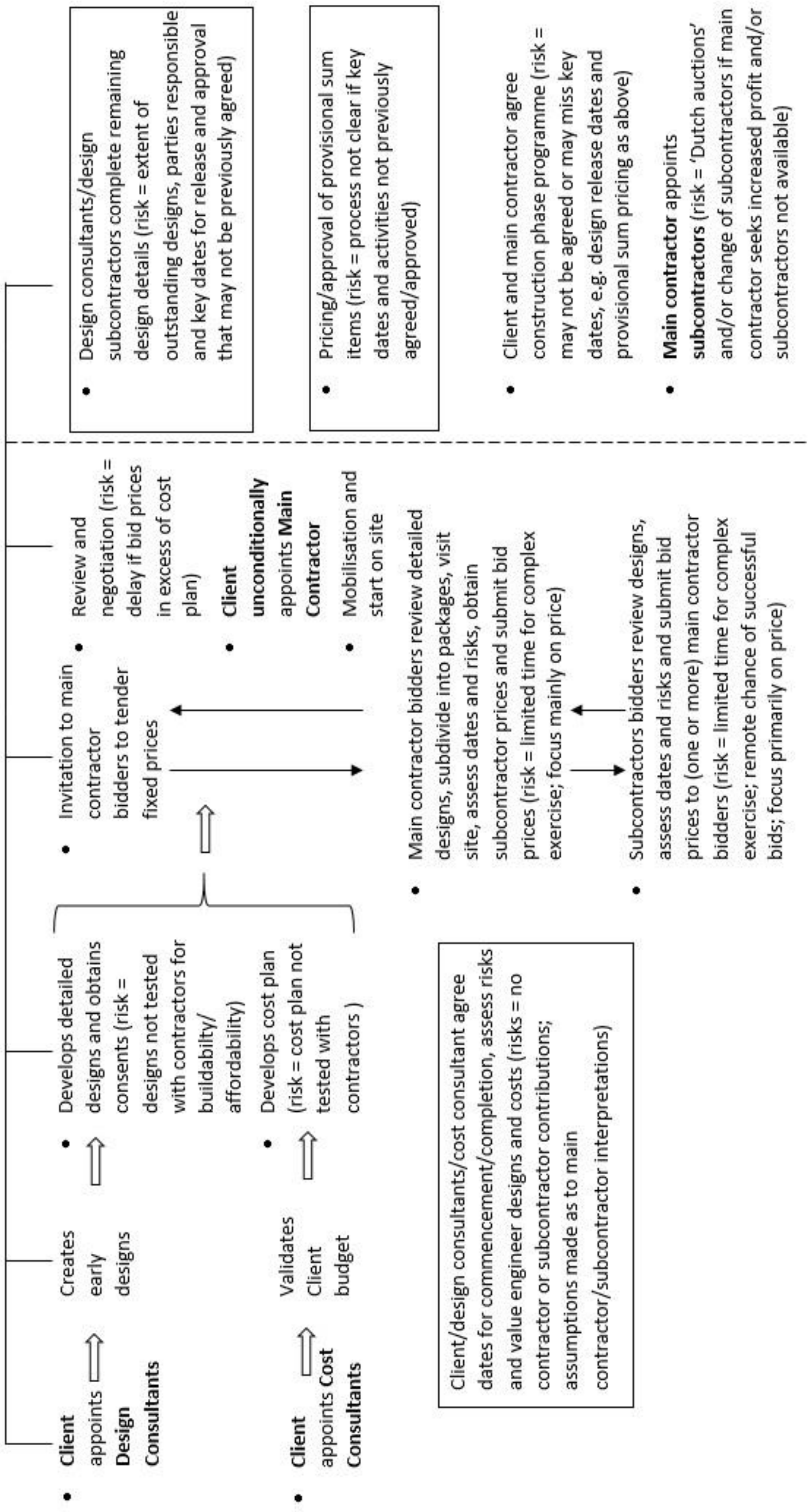


Figure 2-4 Project flowchart - single stage tendering (from Mosey, 2009)

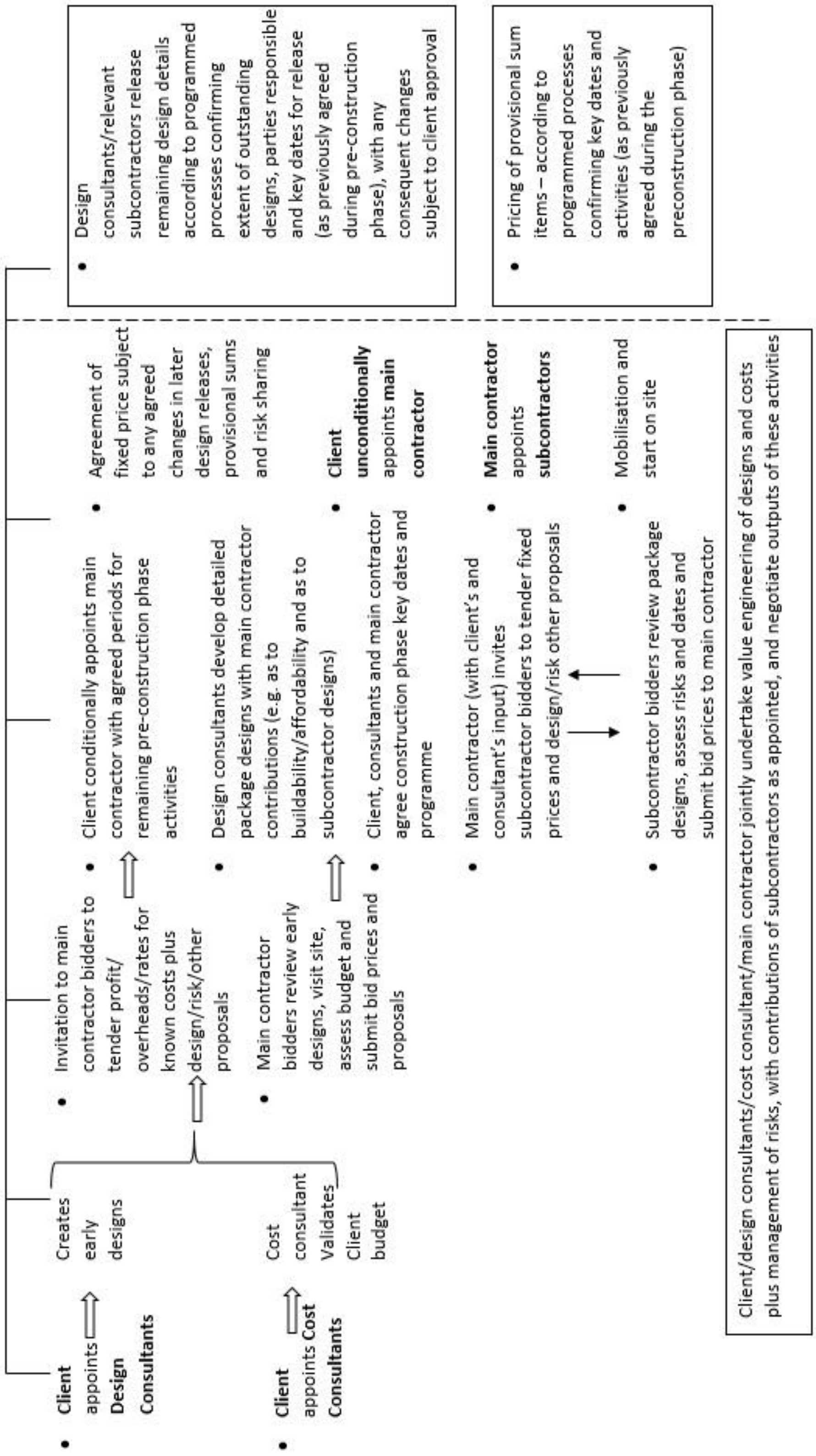


Figure 2-5 Project flowchart - two stage tendering (from Mosey, 2009)

2.4 Collaborative construction software

The literature indicated that collaboration requires trust, and therefore increased communication to increase positive acculturation. Communications during construction projects flow through various modes. Information, drawings, specifications and schedules all form part of the construction documentation. Current technologies, such as BIM, and technologies that augment BIM, such as interactive online platforms (IOPs) and project management information systems (PMISs) can be used as a basis for collaboration. This section investigates these technologies.

2.4.1 Origins of computer draughting

Bezier (1998: 38) reflects on how computer draughting originated in the automotive and aerospace industries. He describes the process involved in modelling a car body before the advent of widespread computer usage. He recalls the process as a long, difficult and painstaking task. During the 1970s a computer system was prohibitively expensive for most companies and required a substantial investment. Software to run the applications needed to be developed independently. It was during this period that the car company, Renault began using software to model car components and by 1975, designers and draughtsmen became convinced that the system was easier to use (Bezier, 1998: 40).

The development of software that could be used more generally for draughting is attributed to Ivan Sutherland. In his 1963 PhD thesis he presented Sketchpad, which is acknowledged as the forerunner of computer aided design (CAD) software. In a representation of his thesis in 2003, Blackwell and Rodden wrote an additional preface to the release and note that Sketchpad was the most influential software that had been developed by an individual. 2D CAD developed from the concept. During the 1980s, CAD systems became available to draughtsmen to expedite the draughting process when compared to the drawing board.

Thomsen, Darrington and Dunne (2010: 49) discuss how initially CAD was similar to traditional drawing methods, but that the lines were drawn using a computer instead. They note that from this ‘smart objects’ were added that had properties that controlled their behaviour.

2.4.2 Development of the BIM concept

From this concept, Thomsen, Darrington and Dunne (2010: 50) show how the next logical step was to give the whole building similar properties. The process would govern the associated information. Smith and Tardif (2009: xv) recall how in December 2002 Jerry Laiserin, an industry analyst, published an article on the emerging design technology that would replace CAD. He noted that the lack of a clear term or acronym was hindering meaningful discussion on the next generation of design software. He suggested the term ‘building information modelling’ or BIM, although he acknowledges that he did not author the term. This has since become the recognised acronym for the concept of a data-rich, single source digital representation of a building.

Aranda-Mena, Crawford and Chevas (2009: 421) give the following definition of BIM, from the American General Contractors:

> “Building Information Modelling is the development and use of a computer software model to simulate the construction and operation of a facility. The resulting model, a Building Information Model, is a data-rich, object-oriented, intelligent and parametric digital representation of the facility, from which views and data appropriate to various users’ needs can be extracted and analysed to generate information that can be used to make decisions and improve the process of delivering the facility. The process of using BIM models to improve the planning, design and construction process is increasingly being referred to as Virtual Design and Construction (VDC)” (The Contractors’ Guide to BIM (AGC, 2006)).

Rischmoller (2007: 89) notes that the term 4D has been used to consider the representation of project activities, or the programming of the project. Because the digital representation of the building is based on information, the building can be analysed from many different perspectives, such as cost, materials take-off and spatial relationships (Rischmoller 2007: 89). Lee, Wu and Aouad (2007:

5) note how the concept of 4D becomes nD when any number of concepts can be analysed, such as acoustics, energy consumption and security. Thomsen (2010: 51) also notes that 4D is the inclusion of time into a model and that 5D is the analysis of cost. Smith & Tardif (2009: xx) state that the nD phenomenon is an integral part of the original meaning of BIM, not something beyond BIM.

Smith and Tardif (2009: 29) consider the impact that information technology has had on the construction industry and how little is known about it. They suggest that the industry has not benefitted from the productivity gains that have been achieved in other industries.

2.4.3 Advantages of BIM for the construction industry

Hardin (2009: 2) states that BIM is a revolutionary technology that changes the way buildings are designed, analysed, constructed and managed. Weygant (2011: vii) states that BIM is a technology that has improved the way that structures are designed and built and that it involves many more project participants than just the architect. Smith and Tardif (2009: xvi) differentiate BIM from previous methods (CAD) by its ability to 'understand' that the objects that have been created represent real world components of actual buildings. One of BIM's major advantages is that it is contained in a single source. A change to any aspect of the design automatically reflects in any other related documentation, resulting in up-to-date and accurate project documentation. The process is illustrated in Figure 2-6.

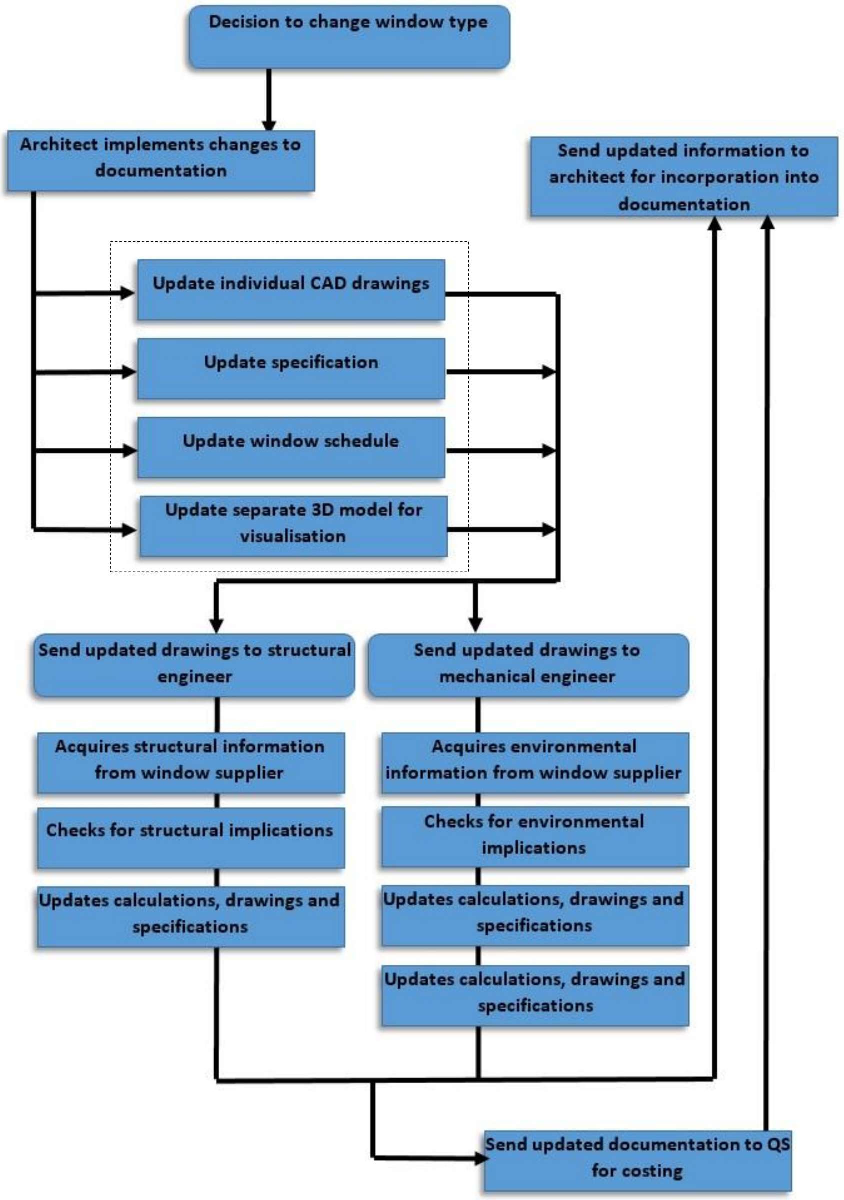


Figure 2-6 Sequence of events to implement a design change decision

The illustration shows how the level of detail (LoD) affects the information flow during the project and its contribution to collaboration. Figure 2-6 depicts the processes involved when the decision is made to change the window supplier during the design phase. Shaded areas show the manual processes that are involved with the design decision and the tasks that are required by the CPOs.

Figure 2-6 shows the current process, where CAD or elementary BIM is used for documentation. The process illustrates how CPOs independently update their information and return it the different organisations. Almost all tasks are manually achieved, each task is prone to errors, and each information transfer process may result in a miscommunication.

Figure 2-6 shows the effect of a change to the design and the sequence of events to update the documentation where traditional CAD based processes are used. The dotted rectangle shows the processes that are combined into a single step using BIM for design documentation only. Although this results in substantially less time to update the architect's documentation, the downstream processes remain unaltered.

The illustration shows that when using elementary levels of BIM, the process is similar to previous working methods, with the advantage of all drawings and documentation being updated automatically.

Figure 2-7 shows the process involved where the supply chain supplies updated information from their knowledge base. An efficient BIM model and components eliminates most of the tasks involved with the decision and eliminates communication errors. When using the full power of BIM all participants have access to the information. The process is significantly more streamlined and the amount of non-value adding tasks is significantly reduced.

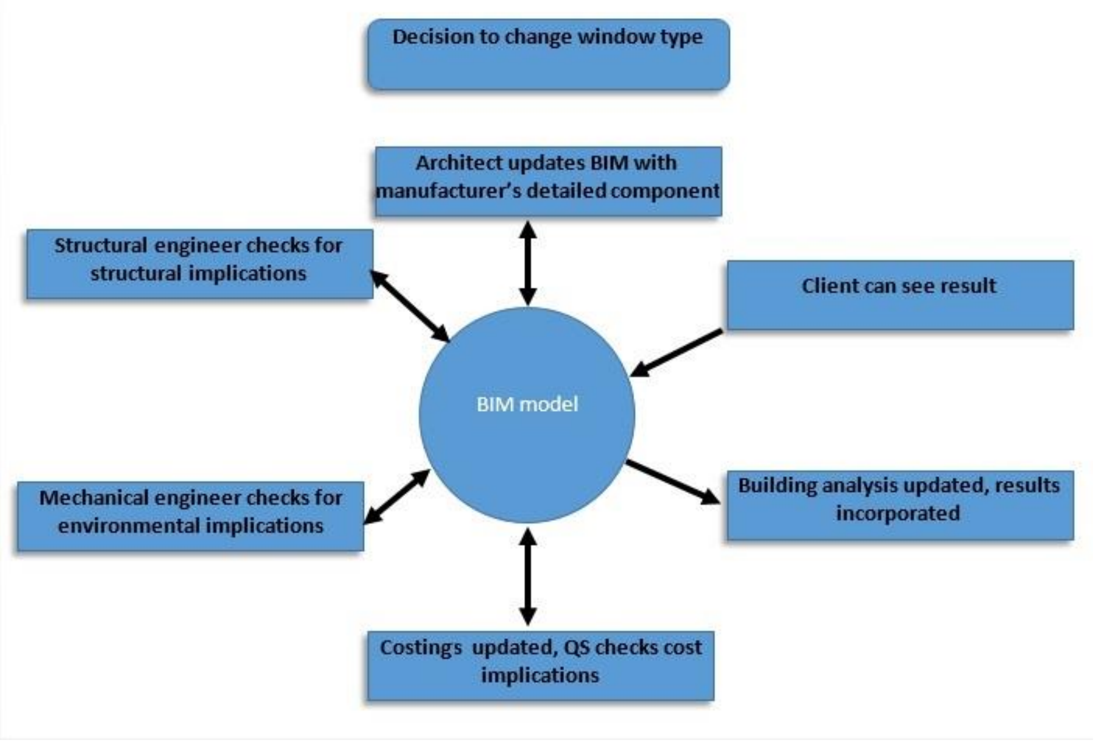


Figure 2-7 Sequence of events using BIM collaboratively

Smith and Tardif (2009: 103) show how BIM can address the cost of changes to the design. BIM does not eliminate mistakes, but the team can discover mistakes earlier. The identification of errors can occur earlier, more quickly and at a much lower cost. Resolving obvious clashes between building components is only one of the most apparent benefits. They show the relationship between time and design development, where the cost to change the design increases as the design develops, while the ability to impact cost decreases with design development and during the construction phase. This is illustrated in Figure 2-8 and suggests that design decisions should be made as early as possible.

Vanossi, Veliz, Balbo, and Ciribini (2012: 254) also show that besides changes to the design, the cost of human errors and misunderstandings increases as the project progresses through the design stage into construction. They suggest that collaboration using BIM can address these issues.

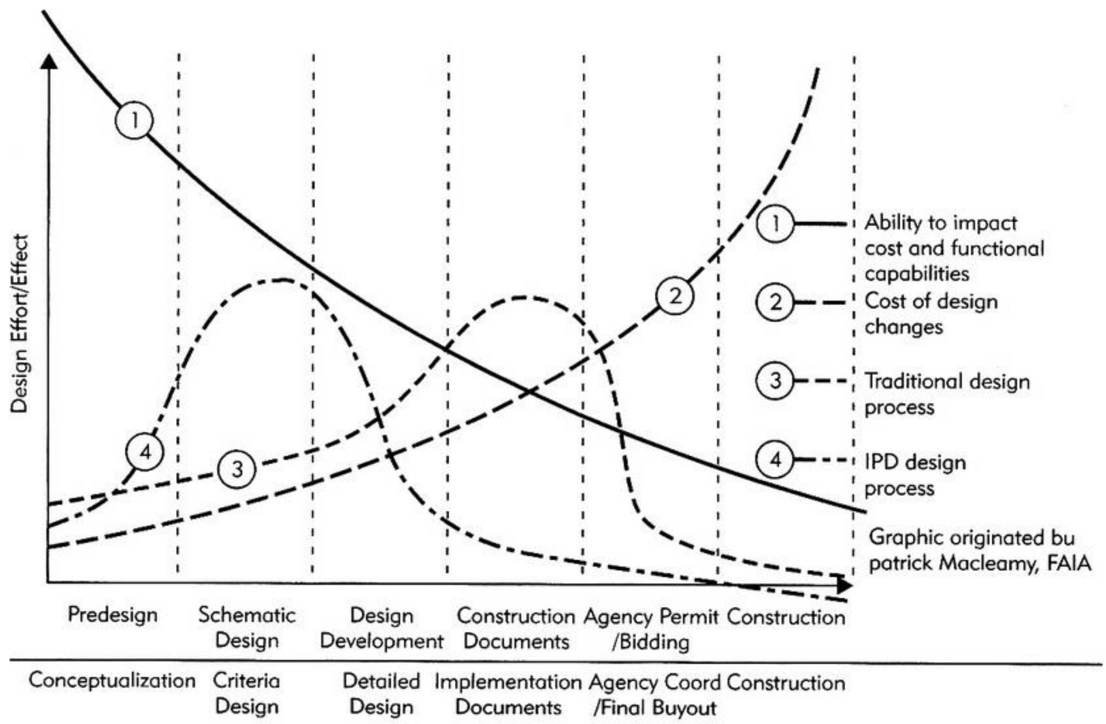


Figure 2-8 BIM and CAD workflows (from Smith and Tardif, 2009: 104)

Commentators have noted that it is difficult to quantify the advantages of using BIM. However, a study conducted by an MEP contractor in the USA compared 408 projects completed between 2003 and 2009 with a total contract value of $558 858 574. Projects were divided into those that used 2D processes (No BIM use), those that used in BIM in an isolated environment and those that used BIM in a collaborative environment. In projects where no BIM was used, there was an increased cost of 18.4% due to change orders. Those that used BIM in isolation had increased costs due to change orders of 11.7% while those that had used BIM collaboratively had change orders worth 2.7% of total project value. This demonstrates a clear cost advantage to using BIM, particularly in a collaborative environment.

2.4.4 Current BIM usage

Smith (2007: 12) states that a basic premise of BIM is that of collaboration by different stakeholders at different stages of the project. He also notes that the concept is to model the building virtually before building it physically in order to work out problems, and to simulate and analyse their impacts. However, its current use in the industry is mainly during the design phase of a construction project. The software offers many advantages to the designer, even when used in isolation. These include:

- Visualisation – 3D visualisation assists clients to gain a better idea of the design and concepts. It also assists the designers and consultants.
- Collaboration of drawings and documents – 2D drawings are generated from the model, but because they all originate from the same source, all drawings co-ordinate. A change to any part of the model will automatically update all drawings and associated documents.
- ‘What if’ scenarios – different scenarios can be examined in one model.
- Phasing control.
- Easier and quicker draughting due to the use of smart components.
- Collaboration with team members.

BIM software is increasingly being used during the design phase of the project. The advantages to the principal designer can be seen in Figure 2-9 and Figure 2-10 (p 44).

Hardin (2009: 5) refers to a study conducted by McGraw-Hill Construction Research and Analytics, which refers to the following reasons for using BIM during the design phase:

- Less time draughting, more time designing;
- Owners demand it on their projects;
- Improved communication between client and consultants;
- Parametric modifications of designs;
- Opportunity to reduce construction costs;
- Improved interoperability;
- Reduced number of requests for information (RFIs);
- Improved document version control;
- Improved cost estimating;
- Opportunity to reduce construction time;
- Clash detection;

- Reduced insurance claims;
- Improved scheduling capabilities; and
- Safer worksites.

Many sources note that its usage still imitates the manual process. Davis (2007: 16) suggests that culturally, architecture, engineering and construction (AEC) organisations do not view information technology (IT) on projects as a core or strategic business activity. She notes that AEC organisations are still mimicking a manual process and are not using BIM to restructure internal working methods to be more IT focused or collaborative. A McGraw-Hill survey (2010: 6) reports that architects in Western Europe view BIM as a tool to improve the design process rather than as a collaborative tool. Suermann (2009: 37) reports on a survey that shows that the top ranking criterion for the use of BIM was the production of drawings. Race (2007: 109) notes that current BIM use encourages compartmentalisation. It is not difficult to understand why designers are embracing BIM as a production tool and if it is used to its full potential (for the production of documentation) it offers many benefits to designers. Figure 2-9 illustrates the typical method for the production of construction documentation using traditional IT solutions. The diagram shows the difficulty with producing accurate, correlating information and why it is difficult to make even a small change to the design, increasingly so as the design develops. Figure 2-10 illustrates the production of documentation using a BIM solution. This offers substantial time savings to the designers and allows flexibility to change the design, even at a late stage.

Horn (2007: 309) also comments on how current processes do not acknowledge the advantages of BIM. Although the advantages of working in a 3D environment are increasingly being recognised, BIM is being used primarily for presentation and marketing purposes.

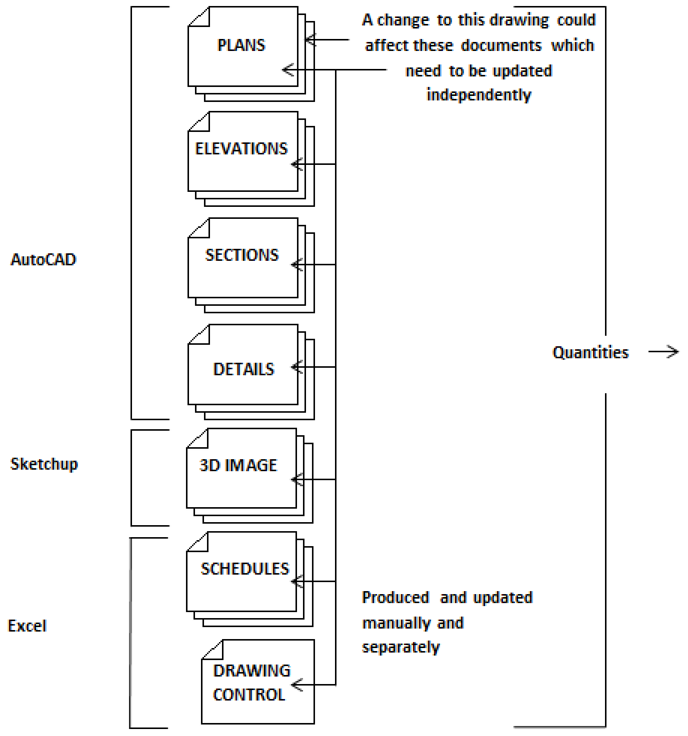


Figure 2-9 Traditional production of information

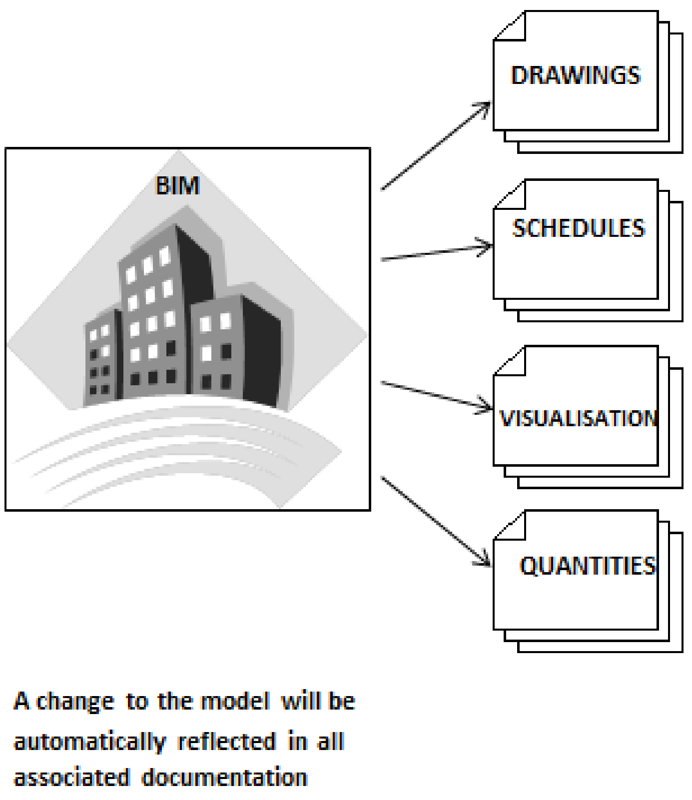


Figure 2-10 Using BIM for documentation

Rogers (2009: 35) argues that for a BIM implementation strategy to succeed, a cultural transformation strategy is required. He suggests that building industry partners need to view each other as collaborators with a mutual interest in a successful outcome. The main challenge of BIM is cultural transformation rather than technical transformation.

Bouchlaghem (2012: 192) discusses the importance of information exchange using CAD and 3D models in collaborative project environments. Bouchlaghem does not distinguish between CAD and BIM and the importance of the type of information that is exchanged. Commentators have recognised the advantages of collaboration without noting the importance of accurate information and all participants having access to the information.

Zahiroddiny (2012: 208) discusses reasons that are hindering BIM implementation. He divides these into four categories.

2.4.4.1 Technological reasons

The technology is not sufficiently advanced for BIM to be used as a single model due to bandwidth limitations, and interoperability between different software platforms. He suggests that those that have adopted BIM are using it as a tool rather than as a centralised source of information.

2.4.4.2 People

Zahiroddiny (2012: 208) suggests that BIM implementation is limited because stakeholders resist change and lack knowledge about BIM. He suggests that the method of using email as the main means of communicating design intent is inherent in the industry culture. People are comfortable with current systems and methods. There is a lack of knowledge and training with regard to BIM and IT, due to the cost of training. Current processes do not provide for document management, which is required for an efficient BIM system to work.

2.4.4.3 Processes

The traditional environment views drawings as formal documents required for the construction process and communications occur both formally and informally.

2.4.4.4 Policy

Zahiroddiny (2012: 209) suggests that a central BIM model is not being used due to professional worrying about liability issues with regard to the ownership of the model. Traditional procurement methods are still being used and there are no strategies for communication. A lack of guidance from government (in the UK) is seen as a limitation to take-up.

2.4.5 nD BIM

Lee, Wu and Aouad, (2007: 5) discuss how concepts of time (4D), costing (5D) and further analysis (nD) using BIM allow the true functionality of BIM to be exploited, where any parameter that can be incorporated into a component can be analysed. Current BIM software can link with other specialist software for analysis.

Hardin (2009: 96) discusses the 4D concept of BIM, which he states is a powerful tool for construction managers using BIM. He uses the Autodesk analysis software, Navisworks, to demonstrate schedule animation, sequencing animation and clash detection. BIM is used to provide an information database of the building components and their relationships, whereas analysis software, such as Navisworks, is used to model the activities. This becomes a powerful planning tool.

Weygant (2011: 79) demonstrates how BIM is used for cost estimating on a project, known as 5D. The American Institute of Architects (AIA) has released BIM protocols which assigns a level of development (LoD) for each phase of a project. There are five levels, each with increasing detail. The first is LoD 100, from which basic cost estimates based on floor areas can be made. This level of detail consists of massing studies of the project, with very little detail. As successive levels of development are added to the model, the cost estimates become increasingly accurate. LoD 400 contains sufficient detail for the creation of construction documents and model analysis with accurate cost information. LoD 500 is the most detailed level and represents a fully accurate digital model of manufacturers' components and is not always necessary, but contains information for highly detailed renderings.

Lee, Wu and Aouad (2007: 6) show how BIM can be extended to analyse a variety of metrics. They suggest that this ability will aid the decision making process and allow 'what if' scenarios. Besides costing and scheduling (4D and 5D), the BIM can be used to maximise the sustainability of the building, investigate energy requirements, examine the building's acoustics, incorporate crime deterrent features, determine maintenance needs and analyse accessibility. nD functions will allow intelligent and dynamic evaluation of prototype designs, with the ability to analyse any number of dimensions. Lee, Wu and Aouad, (2007: 9) state that this provides a knowledge base for the construction of the building.

Hardin (2009: 95) shows how component fabricators, such as duct manufacturers, are increasingly manufacturing from 3D models using computer numerical control (CNC) machines to laser cut the sheet metal and fold them into correctly sized components. He notes that this is increasingly true for structural steel, casework, precast concrete, fire protection, piping and other specialist manufacturing. These manufacturers often supply 2D sheet drawings to the consultants, who are often unaware that the information exists in a 3D environment that can be incorporated into a BIM model.

2.4.6 Information sharing technology

One of the current barriers to BIM implementation appears to be the ownership of information. Sexton (2007: 304) interviewed architect and contractor companies and suggests that there is a generic scepticism among some architects, with one of the main reasons being the ownership of drawings. Race (2012: 13) recognises how architects operate in an increasingly litigious atmosphere, and need to be vigilant in obtaining and filtering information.

BIM cannot operate as a technology in isolation and requires supporting networks so that users can access the model. Even with BIM, many documents will be produced independently, such as correspondence, approvals and construction photographic records. Technologies that facilitate sharing of information can enhance the collaborative effort. These technologies are provided by various suppliers. Authors use different terminology for such a system, such as online collaboration and project management (OCPM)

(Becerik & Pollalis 2006: 11), IOP (interactive on-line platform) (Javernick-Will & Hartmann 2011: 31) and PIMS (production information management system) (Thomsen 2010: 63).

Becerik and Pollalis (2006: 11) note that OCPM technologies are required for transparent and continuous communication between the entire project team. They also note that these are used to facilitate construction workflows, such as RFIs and sharing construction documentation.

Hardin (2009: 94) describes how BIM is used in conjunction with other software for further BIM capability (nD). 4D refers to the incorporation of time into the BIM (Lee, Wu, & Aouad, 2007: 5). An example of such software is Autodesk Navisworks, which is used for analysis of the BIM. The BIM model can be compiled and linked to a schedule for construction timing analysis and clash detection (Hardin, 2009: 94). 5D software, such as MPS from Vico Software allows for integration between a BIM model and scheduling functions, based on the level of detail within the model component, which is assigned a numerical value to determine the extent of detail within the component, and therefore its cost accuracy.

BIM and Model Progression Specification (MPS) can work together to produce accurate scheduling and pricing during the pre-construction phase. This eliminates the typical 'value engineering' phase from the construction process.

Thomsen (2010: 63) describes PIMS as a web based centralised data base, created and used by the whole team. He notes that it is a pre-requisite for collaboration and lists the following advantages of using the technology (2010: 64):

- It's the cheapest way to gather information because it's only done once;
- It's the most reliable way to host information because many eyes scrutinize centralized data and mistakes are more likely to be found and corrected;
- It's the first line of defence against political or legal attack;
- It's a clear window into the project that leaders can use instead of relying on delayed or biased reports filtered through layers of management;

- It improves performance because it measures it; it's a report card for both team members and management; and
- It educates the team and makes better managers because it tells true stories.

Javernick-Will and Hartmann (2011: 31) discuss interactive online platforms (IOPs) and suggest that recent knowledge management strategies use IOPs to combine socialisation and processes. They note that the systems contain static information and explicit knowledge that can be accessed by users but that they also encourage tacit knowledge exchange through people to people connections using forums, searches and promoting peer interaction through the organisation of communities.

2.4.7 Collaboration software and its role in integration

Hardin (2009: 6) discusses how the traditional delivery mechanism is a linear process, with the client approaching the architect, who develops the design. Other consultants are then brought on board, such as structural, electrical and mechanical engineers, who prepare a full set of documents and invite contractors to bid for the work. Often at this point, the contractor is asked to 'value engineer' the project to cut costs. The process is similar for each project that the consultants and contractor work on and the process is repeated. Walker (2011: 290) discusses learning organisations in construction. He notes that to achieve a learning organisation, the traditional ways of thinking need to be discarded. Organisations need to work together to achieve a vision that everyone can agree on and to be open with each other. He states that construction organisations should be learning organisations by instinct. Walker (2011: 291) illustrates how learning networks in construction are those that provide practitioners with a physical and virtual platform where collective learning takes place.

Senge (2006: 12) states that for a systems thinking approach to work, building shared vision, a focus on openness, team learning and personal mastery are required. Collaboration along with an accessible central source of information can facilitate this. Rogers (2009: 37) maintains that improving the quality of building information (by using BIM) will help to shift the current adversarial business climate to that of collaboration.

Smith and Tardif (2009: 35) claim that cultural transformation within the construction industry is a greater challenge than the technological transformation that will result from BIM. They stress that a culture of collaboration is required before any successful BIM implementation strategy can succeed and that a greater climate of trust is required for IPD to use BIM.

They suggest that in the current environment, responsibility for the integrity of the information lies with the author, but in an environment of trust and information exchange, the responsibility will lie with both the author and recipient (2009: 37). Project team members will work in an environment where they work collaboratively to identify mistakes early and correct them. They propose that frequent information exchange will result in greater transparency, where responsibilities are apparent and bottlenecks are identified early.

Smith and Tardiff (2009: 37) discuss an additional advantage of using BIM where information stewardship is considered. When the BIM is created it often has value for future projects if the information is easily stored, accessible and retrievable. Information can be preserved in a useful form for the future if it can effectively be exchanged.

2.4.8 Levels of BIM take-up

Surveys that were conducted in the USA and Europe suggest that BIM is becoming established in some countries and that the trend indicates that the majority of the industry will soon use BIM. A McGraw-Hill survey (McGraw-Hill, 2010) showed that BIM adoption in the European construction industry (UK, France and Germany) had reached 36% in 2010. A separate survey (McGraw-Hill, 2012) showed that BIM adoption levels in the USA were 49% in 2009 and 71% in 2012, which illustrates how BIM is becoming firmly entrenched in some countries.

2.4.9 Use of BIM in other countries

Race (2012: 16) discusses the drive in other countries to adopt BIM, and how it is actively being encouraged by major clients and government bodies. He refers to the National 3D 4D BIM program, additional BIM Guide Series, issued by the Office of the Chief Architect in the USA. He notes that many states are introducing initiatives based on the policy statement and that the state of Wisconsin had declared that state funded facilities above a value of $5m will use BIM technology. Race (2012: 18) recalls that in 2010 the UKs chief advisor on construction indicated that BIM would play a key part in government's procurement strategy. He suggests that the government's lead in incorporating BIM could have a significant shift in the way that the UK construction industry operates. Gibbs, Emmitt, Ruikar and Lord (2012: 41) also comment on how BIM has gained more interest due to the UK government's drive to use it on public sector projects by 2016.

The Chief Executive Officer for the Construction Industry Council in the UK, Graham Watts, claims that BIM will integrate the construction process and, therefore, the industry (HM_Government, 2012). He notes the following advantages to using BIM for the UK:

- It will enable intelligent decisions about construction methodology;
- Provide safer working arrangements;
- Improve energy efficiency, leading to carbon reductions;
- Give a critical focus on the whole life performance of facilities; and
- Provide benefits for the economy that will accrue from better buildings and infrastructure delivered by the construction industry.

It has been noted that the UK construction industry is becoming a leader in implementing BIM (Race, 2007: 18). The BIM Task Group has been set up to provide and disseminate information about BIM to government and clients in the UK. Mark Bew[2], Chair of the Task Group suggests that this is because the BIM Task Group, government and the supply chain have substantially contributed towards increasing awareness, but attributes the success to government ministers and chief construction advisors.

[2] www.bimtaskgroup.org Newsletter, 19th edition | Week ending 26th May 2013

The government's current Chief construction advisor in the UK, Peter Hansford[3], predicts that beyond 2016 no government intervention will be required for government funded projects to use BIM. The current drive will provide a kick start. The current drive and awareness programmes in the UK are as a result of a concerted effort. The BIM Steering Group has set up the Business Innovation and Skills (BIS) programme and is developing the UK strategy for the development of BIM. The Chair of the BIS, Dr Barry Blackwell[4] notes that their programmes are being commented on around the world and that the approach is improving the image of the construction industry, both nationally and internationally. He suggests that there is anecdotal evidence that the efforts are 'winning work' for the industry. He believes that BIM is the portal into the 'new world' and its potential is only beginning to be understood. He notes that the UK is not the only country that is making the change to BIM. He says that the 'genie is out the bottle' and that innovation will be relatively swift with the new technology. Standing still in the new environment will mean going backwards, as other countries will 'leap-frog, the implementation of BIM in an increasingly global environment. Countries will not remain globally competitive without embracing the new technology and that these opportunities will erode the domestic insulation from global companies. He believes that the UK government's current drive will give them a competitive advantage.

The UK government's BIM strategy paper (HM_Government, 2012) also comments on the rapid uptake of BIM in other countries and that developing markets may be able to 'leap frog' using innovative technologies and methods of working. They note that in China the government is fully supportive of using BIM and that BIM will be the future IT solution in China. Wang (2012: 27) notes that in 2012 the Chinese government, the Ministry of Housing and Rural Urban Development released several BIM related national standards programmes. In Australia, the Built Environment Industry Innovation Council identified two key

[3] www.bimtask group.org Newsletter, 18th edition | Week ending 19th May 2013

[4] www.bimtaskgroup.org Newsletter, 21st edition | Week ending 9th June 2013

recommendations on BIM. The first is to encourage industry wide adoption and support and the second is to consider BIM as a key part of the government's procurement process.

Takim, Harris and Nawawi (2013: 25) note that BIM is being adopted at the national level in many countries around the world, including Hong Kong, Singapore and South Korea. They state that Finland is the world leader with regard to BIM implementation. Norway has also created a national standard for using BIM (Statsbygg, 2011).

2.4.10 Adoption of innovative technologies

Rogers (1983) discusses what he has called the 'diffusion of innovations' and shows how an innovation takes some time to spread, even if it is objectively better. Rogers (1983: 234) refers to the 'diffusion effect' where the rate of adoption of an innovation creates self-generated pressure towards adoption. As there is more take-up of an innovation, more awareness is generated through peer networks, which increases the rate of take-up. Once adoption of the innovation has reached 50% the rate of adoption starts to slow, as the awareness levels with regard to the innovation become widespread through the adopting group.

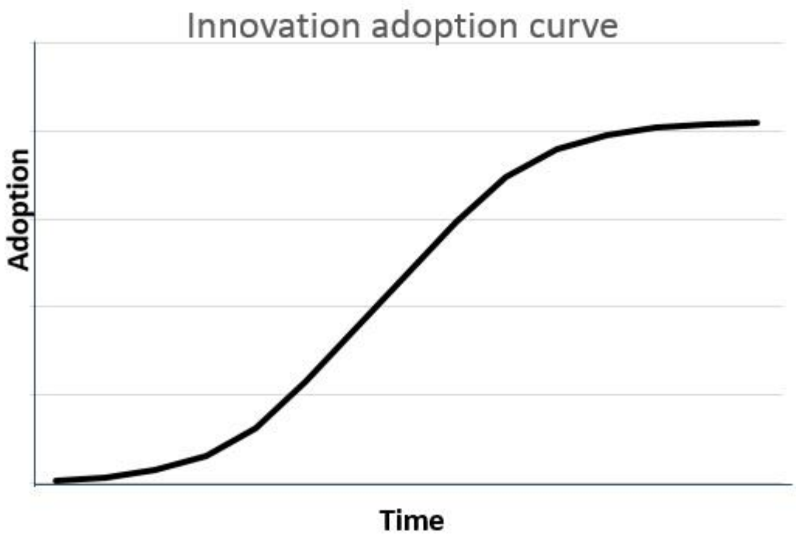


Figure 2-11 Cumulative adoption of an innovation (Rogers, 1983: 243)

Adoption levels are related to the amount of information that an individual has with respect to the innovation. Where there is not much knowledge about the innovation, any single individual is unlikely to become an adopter. However, as the knowledge of the innovation increases, it passes a threshold level where adoption starts to take place. There is a relationship between the amount of knowledge and the adoption rate of an innovation, but it is not direct or linear. When the awareness rate advances to between twenty and thirty percent, adoption rates are low. Once the threshold has been passed, there is increasing adoption, where every percentage point of increase in awareness relates to an increase in adoption of several percentage points (Rogers, 1983: 235). Rogers notes that the threshold is different for every innovation, but appears to happen when opinion leaders start to favour the innovation.

Rogers discusses categories of adopters and how they are distributed. Adoption of an innovation is based on a normal (bell) curve and one method of dividing adopters into categories is by using the mean of the sample and the standard deviation. Using this method, categories of adopters are derived and shown in Figure 2-12. Innovators then fall into the first category, which is two standard deviations below the mean. Early adopters fall into the second category, which is between one and two standard deviations below the mean. The early majority fall between the mean and one standard deviation below the mean, while the late majority fall between the mean and two standard deviations. Rogers (1983: 246-247) suggests that there is no point in categorising the laggards as there is no clear distinction between what may be classified as early and late laggards.

Rogers (1983: 245) states that adoption rates of between 10% and 20-25% represent the heart of the adoption process. After this point it becomes difficult or impossible to stop the further diffusion of the idea.

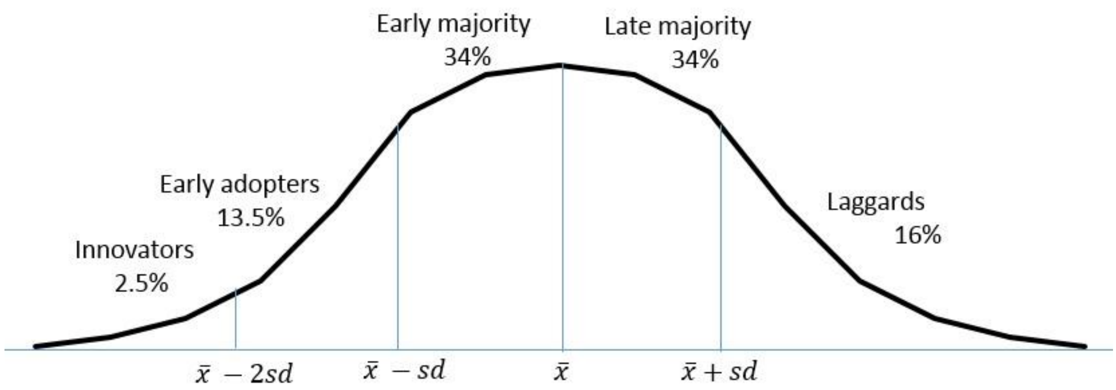


Figure 2-12 Innovation diffusion categories (Rogers, 1983: 247)

When comparing the take-up of BIM in Europe (36% in 2010) it can be seen that adoption had reached the early majority category, while the USA (71% in 2012) had reached the late majority stage. From the trends suggested by Rogers (1983) it can be seen that the BIM phenomenon is firmly established in these countries and that the BIM innovation has reached maturity.

2.4.11 Future of BIM

Underwood and Isikdag (2011: 253) describe how BIM has existed in some form for over thirty years and is only recently receiving widespread interest from the industry. However, computing power was insufficient to run advanced BIM software thirty years ago.

Kurzweil (2005: 56) illustrates the exponential trends in computing power. He recalls Moore's law, which states that twice as many transistors are incorporated into integrated circuits every twenty four months. Gordon Moore, one of the inventors of integrated circuits, made the prediction in the mid-seventies. Processor performance doubles even faster than this, every eighteen months, as transistor speeds increase as they become smaller (Kurzweil, 2005: 64). If this trend continues, it can be seen that computers will be about 100 times faster than they are now in ten years time and about ten thousand times faster in twenty years.

Kurzweil (2005: 67) observes that the exponential growth of computing power also preceded Moore and that the trend has continued through different technologies. He refers to these as different technological paradigms, with the first being the electromechanical systems in the early 1900s. Relays were introduced during the 1940s (second paradigm), vacuum tubes during the 1950s (third paradigm) and transistors during the 1960s. The fifth (current) paradigm started during the late 1960s, using integrated circuits. Kurzweil (2005: 112) predicts that the exponential growth will continue, as there is compelling progress with three dimensional molecular computing and other supporting technologies, such as nanotubes, computing with molecules and computing with DNA. These will introduce the sixth paradigm.

As computers have become faster, software delivers more functionality. An examination of the Autodesk release notes for different versions of Revit (a major BIM software), shows that system requirements to run the software required 256 MB of random access memory (RAM) in 2003. The current version of the software (Revit 2014) requires 16 GB of RAM for a larger project. The following graph (Figure 2-13) shows how the RAM requirements of the software have increased exponentially.

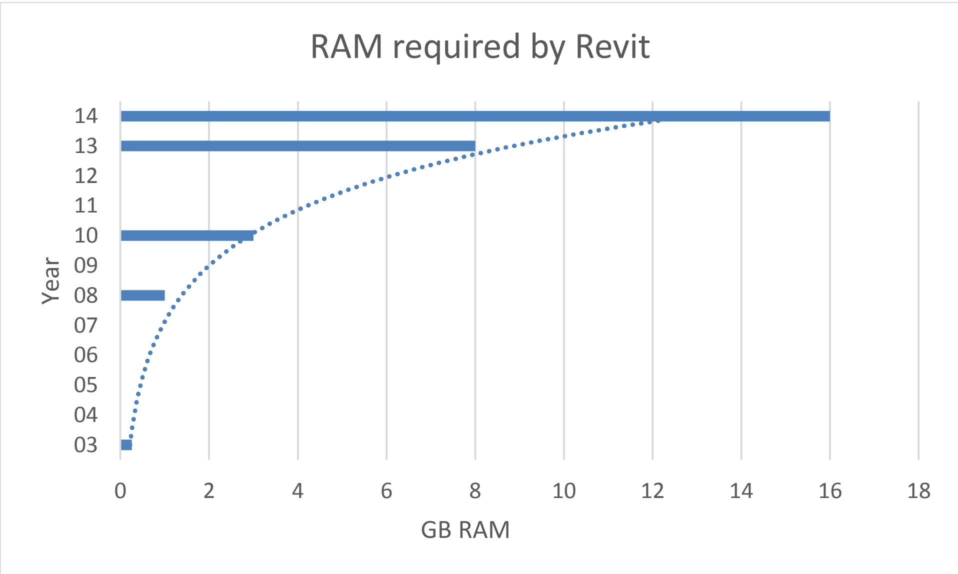


Figure 2-13 Increasing RAM requirements by Revit

If computing power trends continue, as Kurzweil suggests, then it is likely that BIM software will continue to offer more functionality. Figure 2-14 speculatively shows the RAM that Revit might be using by the end of the decade, based on a doubling every eighteen months.

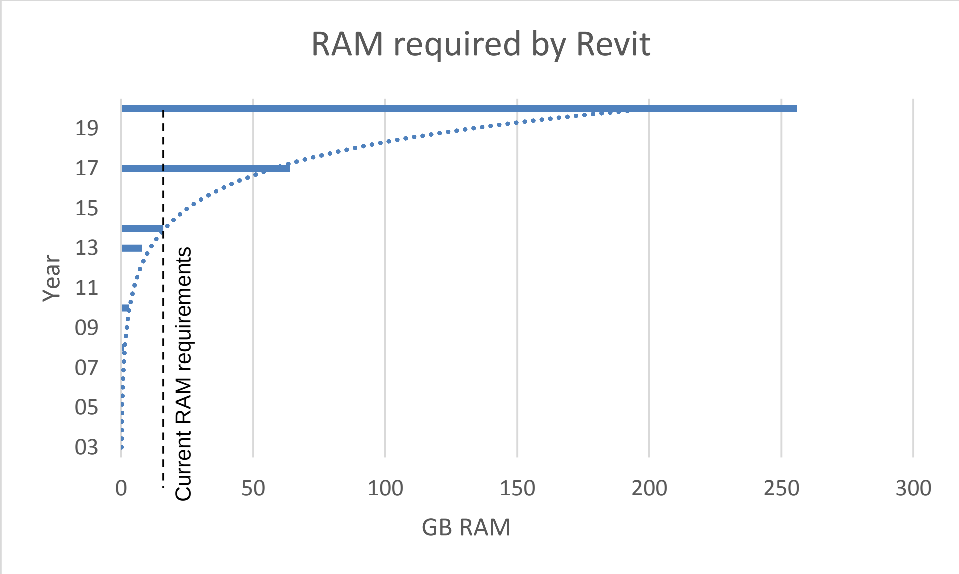


Figure 2-14 RAM requirements of Revit if trends continue

The ‘new features’ documentation for the different releases of Revit reveals that the functionality has only recently allowed for effective collaboration. An early innovation (2003) was to allow a single model to be accessed by different users simultaneously, allowing multiple users to edit the same model, which enabled collaboration within an office. The first version aimed specifically at structural engineers (Revit Structures) was subsequently introduced (2005) and could allow the structural information to be incorporated into the architectural model. The mechanical and electrical versions (Revit MEP) were introduced the following year. This allowed for collaboration between consultants.

Recently, cloud computing has been introduced to BIM software, where access from anywhere can increase the collaborative ability of the software. The Autodesk website[5] refers to ‘BIM 360 Glue’, which is a ‘Cloud based BIM collaboration software’, aimed specifically at collaborative efforts from different locations. This will allow for true collaboration between CPOs.

It is difficult to anticipate what the future holds for building information modelling, but it is likely that faster computer processing time, increased connectivity and software improvements will have a significant impact on the productivity of BIM. Greater efficiency will also be realised as users become more efficient. Hardin

[5] http://usa.autodesk.com/adsk/servlet/pc/index?id=21318325&siteID=123112 (accessed 2013-10-01)

(2009: 26) suggests that the use of technology over time develops, creates and refines tools for users. He adds that technology rarely moves backwards and that BIM will be affected by the blistering pace of technological improvement. He notes the huge strides in BIM technology over the last decade, and the significant rise in users. He refers to a study that indicates a growth of about 1500% in the BIM related job market between January 2005 and September 2008 in the USA. Race (2012: 61) predicts that there will be a growth of professional expertise as BIM advances. A McGraw-Hill survey of BIM users in the US shows how numbers have increased from 17% in 2007 to 49% in 2009 to 71% in 2012 (Nanalytics: 2012). This trend suggests that BIM will soon replace CAD as the software used by the majority of the industry.

It can be seen that the technological platform for efficient IPD is a recent phenomenon. Schumpeter (1962: 83)[6] introduced the economic theory of creative destruction, which shows how new technologies tend to replace old technologies. He suggests that the capitalistic or free market environment is constantly evolving and destroying the systems or structures that are being replaced. He eloquently states:

> "But in capitalist reality as distinguished from its textbook picture, it is not that kind of competition [price competition based on a similar product] which counts but the competition from the new commodity, the new technology, the new source of supply, the new type of organization (the largest-scale unit of control for instance) - competition which commands a decisive cost or quality advantage and which strikes not at the margins of the profits and the outputs of the existing firms but at their foundations and their very lives (Schumpeter, 1962: 83)[2]".
>
> (Square brackets by researcher, round brackets in original quotation.)

Cox and Alm (2008) discuss the concept of creative destruction and observe that the survival of producers depends on their ability to streamline production by introducing newer and better tools that increase production. Companies that

[6] Original publication was in 1948

do not deliver consumer requirements at competitive prices will lose customers and die.

Egan (1998: 28) suggested that the culture of the industry needs to be addressed, followed by improved processes and then finally applying the technology. This is echoed by Chinowsky (2011: 15), Smith and Tardif (2009: 35) and Rogers (2009: 35). However, Rogers suggests, seemingly contradictorily, that improved building information will help shift the adversarial climate. Krygiel (in Hardin, 2009: xiii) suggests that improved workflows, better building metrics and improved analysis will change the way that the industry currently communicates. The new technology will improve the processes.

When Egan compiled the industry report in 1998 (Rethinking construction), the BIM acronym did not exist. Egan could not have anticipated that within fifteen years the technology would have improved to the degree that is currently being witnessed. The advent of technology suggests a different path to that recommended by Egan. BIM is currently seen as a tool that is available for organisations that are willing to collaborate. However, it is likely that BIM will be a primary driver of collaboration. The disadvantages of non-collaboration are likely to become increasingly obvious, and organisations that ignore this trend may well be left by the wayside.

2.5 Knowledge gaps revealed by the literature review

It was seen that there is limited research with regard to BIM adoption in South Africa. This may indicate that the advanced use of BIM has not been adequately addressed by the South African construction industry. Reasons for this need to be established, and the consequences of the 'business as usual' approach need to be considered. These findings potentially address the second, third and fifth hypotheses, listed on page 7.

Current adoption rates of BIM in South Africa are not known, while surveys in other countries have shown increasing adoption. Determining the adoption levels and rates provides a comparison with other countries, and could determine a trend for adoption in South Africa. This is considered by the second, third and fifth hypotheses.

There was also a lack of research that addressed collaboration in South Africa, and the few studies that were discussed showed that the South African construction industry has not focused on IDP arrangements. The literature illustrated the advantages of collaboration and that the industry culture internationally is changing to address adversarial environments. The consequences of apathy need to be evaluated. The first and fourth hypothesis address this.

2.6 **Conclusion**

The literature review has illustrated the adversarial nature of the traditional construction industry and how collaboration may result in a less antagonistic culture. A collaborative environment will also encourage knowledge sharing between organisations, which can lead to innovation within the industry. The literature that refers to acculturation indicates that knowledge flows are required for successful acculturation and how new collaborative technologies can assist with knowledge flows within the team. The new technologies that are currently emerging are reaching the point of technological maturity that can drive the processes and create such an environment for CPOs. CPOs need to be aware of this trend in order to remain competitive. A link was established between increased communication, trust, knowledge transfer and increased innovation and how these can enhance organisational acculturation between CPOs. It was seen that current processes do not provide a conducive environment for organisational acculturation.

The advent of BIM was examined and current literature shows how the technology provides an environment where information transfer and knowledge sharing are enhanced. Problems that are associated with the construction industry in most cases are due to lack of information or errors in the information and contractual arrangements that encourage risk allocation rather than risk management. A single shared source of information can address these.

BIM was shown to be multi-dimensional in terms of analysis and accuracy of information. The advantage of BIM is the information that is inherent in the model and knowledge sharing is enhanced when accessible to all project participants involved in a project.

It was seen that countries with a high rate of adoption have governments that are mandating the use of BIM and industry bodies that actively create awareness and provide information.

The advent of information technology and recent advances in hardware and software capability have enabled an environment where collaboration is easier. New paradigms in technology have challenged traditional methods and forced a new way of working. The literature suggests that new ways of working are not just possible, but organisations that do not embrace the new paradigm will be unable to compete.

Chapter 3 – Research methodology

3.1 Introduction

The previous chapter examined the concepts of collaboration and revealed how communication and trust are required for successful acculturation between CPOs. It indicated that BIM can potentially be used as a mutual information storage and transfer mechanism to assist CPOs to share tacit knowledge, which is a requirement for successful collaboration. The literature explored the increasing awareness of collaborative approaches to construction projects and how they are likely to improve performance. There was an indication that BIM is increasingly being used in the industry, but is not generally being used to aid collaboration.

This chapter introduces the context of the research and bases it within the theoretical framework. The conceptual framework of the research is considered and the research methodology and instruments that are used to examine the concept of BIM being used as a collaboration tool are discussed. The ontological and epistemological settings of the research are debated. The paradigms of the approach to the study are addressed and rationalised. The methods used to design the survey are discussed, and then the procedure that is used to examine a project from a network perspective is evaluated.

3.2 Theoretical framework

Neuman (2006: 74) defines the theoretical framework in research as a general theoretical system with assumptions, concepts, and specific social theories that relate to the topic being examined. The framework places the research in the context of existing knowledge.

In the review of the literature it was seen that there were different modes of acculturation between cultures that interact with each other (Berry, 2011: 2.6). These were assimilation, integration, marginalisation and separation. The preferred mode was seen as integration (Berry, 2011: 2.9). Chinowsky (2011: 51) discussed different modes of interaction between CPOs and how integration was the preferred mode. The other modes were connection, fragmentation and isolation. Chinowsky (2011: 51) showed that the different modes were based on the degree of trust and communication, and that increased trust and communication increased the likelihood of integration. Integration was seen as the preferred mode for the interaction of CPOs and that the central theme was seen as collaboration, which lies at the intersection between acculturation, trust and communication. This is illustrated in Figure 3-1.

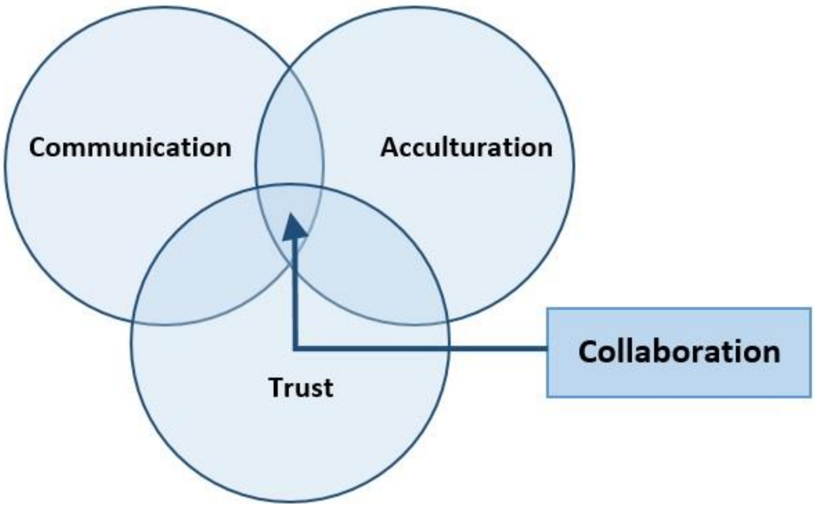


Figure 3-1 Location of the theoretical framework

The literature showed how integration was required for effective knowledge transfer, but that this was unlikely without some degree of trust between organisations. It was seen that effective communications are required to build this trust, and that these were requirements before collaboration could occur.

The research was placed in context by examining existing theory on organisational culture in the construction industry. The work of Walker (2011) looks at this from the perspective of organisational behaviour. Chinowsky (2011) examines the concept of collaboration in construction in the context of organisational behaviour. The concept of acculturation was explored as a construction project involves different parties with separate organisational cultures. A collaborative culture needs to address this.

The body of work that looks at knowledge management (KM) and knowledge transfer was investigated. This was put into a construction perspective by

Anumba, Egbu and Carrillo (2006) who assessed knowledge management in construction organisations. The literature on BIM was surveyed to discover how this can contribute to the concept of collaboration. Pryke (2011) discussed relationships in organisations and the formal and informal networks that exist in construction organisations. A method to measure network relationships is addressed in the social science literature, where methods of network analysis are examined in order to determine their relevance to the research. Precedents for this research method in construction are discussed by Chinowsky (2011) and Pryke (2011, 2012). Figure 3-3 illustrates graphically the broad path of the theoretical framework.

3.3 Conceptual framework

The conceptual framework forms a scaffold for the research methodology and directs the methodological approach. It links the findings of the literature to the procedures of enquiry. The literature review showed how information and knowledge disseminate within and between organisations. Chinowsky (2011: 41) showed that the team is integral to the success of construction organisations, and that solutions need to address the relationships within the networks. It was seen that there are different networks in operation, and that the effectiveness of communication depends on the strength of the networks. In order for collaborating organisations to have effective communications, the information needs to be of better quality and more available, which relies on the interacting networks. The conceptual framework examines the network between the organisations, and is illustrated in Figure 3-2.

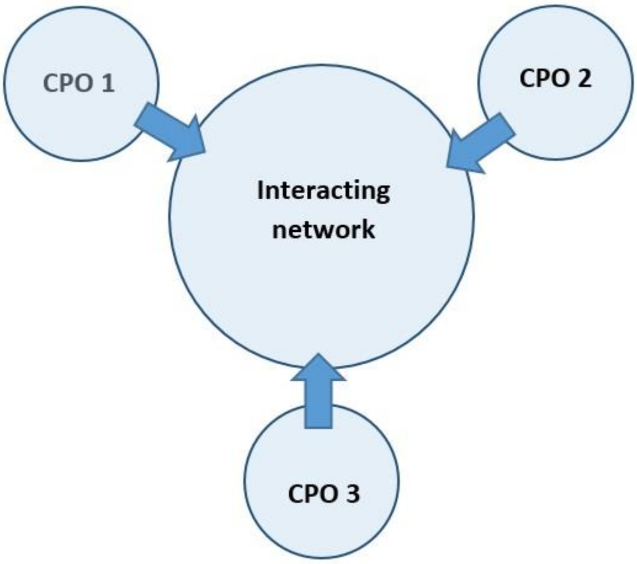


Figure 3-2 The conceptual framework of the research

The concept of the research is to determine the interaction of the networks within a collaborative environment. The literature review showed how BIM can become a central collaborating tool for interacting organisations that enhances the interaction of the networks. The research methodology therefore addresses the extent to which BIM is used within these networks and discusses a method by which the networks within the collaborating environment can be analysed. The relationship between the theoretical framework and the conceptual framework is illustrated in Figure 3-3.

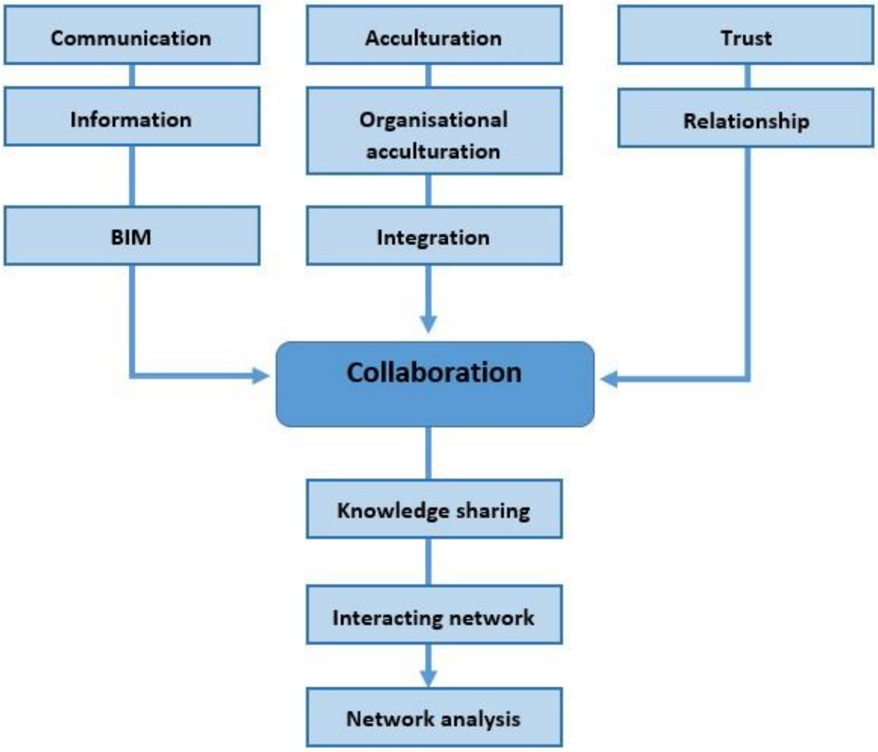


Figure 3-3 Graphical representation of the theoretical framework

The main thrust of this research is to establish whether BIM can be a catalyst for a collaborative culture in the construction industry. It addresses the methods of knowledge exchange during a project. The research problem discussed in Chapter one is restated:

> There is a sub-optimal utilisation of integrated project delivery technologies and a limited culture of collaboration in construction project organisations in South Africa.

The problem is firstly a technical problem, as the research addresses how information technology is currently being used within the industry. However, it is also a social issue, as it addresses the inherent culture of the construction industry. Construction management as a discipline is both a technical discipline as it addresses the technical aspects of erecting a building, and a social discipline, as it manages the organisation of people that are involved with the erection of a building. Typically, the natural sciences measure objective facts and focus on variables (Neuman, 2006: 13), which is defined as the quantitative research approach, while the social sciences construct social reality and cultural meaning by focusing on interactive processes, which is the qualitative approach. However, either approach can be used, both in the natural and social sciences. The chapter is ordered to address the following:

- The ontological and epistemological assumptions of the researcher, which provides a setting for the research;
- The methods that are appropriate to determine how BIM is currently used in South Africa, and the perceptions of architects and contractors of the concept of collaboration on construction projects;
- An exploration of how networks can be analysed;
- Illuminate the weaknesses of traditional construction analysis approaches; and
- Determine and justify a method for examining the problem.

3.4 The paradigms of the research

Neuman (2006: 13) defines research as the use of scientific methods to transform ideas, questions and hunches (hypotheses) into scientific knowledge. He notes that there are two major approaches to social research, being qualitative and quantitative. Although each approach uses specific research techniques, there is an overlap between the type of data and the approach to research (2006: 13). Typically, the quantitative approach is associated with positivism (Nieuwenhuis, 2007: 50), while the qualitative approach is associated with constructivism (2007: 51).

Neuman (2006: 81) describes a research paradigm as a “general organising framework for theory and research that includes basic assumptions, key issues, models of quality research, and methods for seeking answers”. Nieuwenhuis (2007: 47) describes a paradigm as “a set of assumptions or beliefs about fundamental aspects of reality which give rise to a particular world view”. A paradigm addresses fundamental assumptions, such as beliefs about the nature of reality (ontology) and the relationships between knower and known (epistemology). It addresses assumptions about the methodologies used in research (Neuman, 2006: 47 - 48).

3.4.1 Ontology in research

Ontology refers to the nature of knowledge. Nieuwenhuis (2007: 53) defines ontology as the nature and form of reality. Gill and Johnson (2010: 201) state that ontology deals with the essence of phenomena and the nature of their existence. They list two divergent views of ontology, those of realists and those of subjectivists. Realists maintain that social reality exists, and is independent of the researcher's perceptual or cognitive structures. Subjectivists hold that social reality is a creation, or projection of the researcher's consciousness and cognition. The social world is created by perceiving it (Gill & Johnson, 2010: 201). Nieuwenhuis (2007: 53) offers a similar distinction. Realists state that there is one objective reality that can be observed by an enquirer who has little or no impact on the object being observed, while subjectivists state that the external world is real because the observer has constructed it as such, or experiences it in that way. Maree and van der Westhuizen (2008: 31) suggest that realists believe that there is an objective truth that can be discovered, whereas the idealist position is that different observers may experience reality differently. Hammersley (2008: 27) argues that particular methods involve divergent assumptions about the nature of the social world.

Gill and Johnson (2010: 187) comment on how the nature and content of the problem to be investigated and the extent of the available resources influence the methodological approach. However, they suggest that this view is superficial, as when researchers conceptualise what they are trying to investigate and how they are going to investigate it, they tacitly deploy philosophical assumptions that lead them to comprehend and construct the issues in particular ways. They note that the philosophical assumptions made by the researcher entail various approaches to the nature of truth, the nature of human behaviour, the possibility of neutral representation of the facts and the independent existence of the social reality that is being investigated. Gill and Johnson (2010: 188) note that a methodological choice entails taking a philosophical stance and the researcher needs to be aware of the hidden aspects of research. Philosophical commitments need to be made, not by default, but by conscious interrogation of the assumptions that are inevitably in play in undertaking research. These underlying assumptions determine the epistemological approach to research, which is discussed below.

3.4.2 Epistemological assumptions of the research

According to Nieuwenhuis (2007: 55), epistemology refers to how things can be known. Gill and Johnson (2010: 191) refer to epistemology as the study of criteria by which we can know what does and what does not constitute scientific knowledge. Nieuwenhuis (2007: 55) refers to positivists, who believe that knowledge can be revealed or discovered by using the scientific method. He contrasts this with the qualitative, or interpretive approach, where researchers discover reality by exploring the experiences of people. Neuman (2006: 87) summarises the positivist approach as having an essentialist view, that reality is empirically evident. Explanations are nomothetic and advance via deductive reasoning. Research can be verified by replication. According to positivists, social science is objective and value free. Neuman contrasts the positivist approach with the interpretive approach (2006: 95), which is related to constructionism. The interpretive approach is to understand social meaning in context, and to argue that reality is socially constructed. Explanations advance via inductive reasoning. Social science is relativistic with regard to value positions.

Commentators have noted the perceived antagonism between the two main schools of thought. Neuman (2006: 79-80) suggests that the two schools of thought had resulted in one of the more bitter quarrels in contemporary sociology. Gill and Johnson (2010: 191) also discuss the dispute between the two views where the positivist mainstream approach has come under considerable attack. Bergman (2008: 11) discusses the ‘Paradigm Wars’ and the ‘Incompatibility Thesis’ between the positivist and constructionist approaches.

Nieuwenhuis (2007: 48) suggests that the reductionist approach to knowledge, associated with positivism, was questioned by researchers in the field of physics, and new discoveries such as Einstein’s theory of relativity that revealed complex patterns of relationships between diverse observations showed that human observations were relative and that multiple and diverse correlations could be inferred from the accumulated data. Nieuwenhuis (2007: 49) notes that all scientific theories are approximations of the true nature of reality, and that each theory is valid only for a certain range of phenomena. Gribbin (1983: 120) discusses how the Danish physicist, Niels Bohr discovered that the act of observation affects the experiment at an atomic level, suggesting that the observer cannot be independent of the observed, confirming Heisenberg's uncertainty principle. Gleick (1998: 14) comments on how Laplace, the eighteenth century philosopher-mathematician suggested with optimism that the reductionist approach would discover laws in the Newtonian tradition that would apply to the cosmos and the smallest atom. In light of Einstein's relativity and Heisenberg's uncertainty principle, this view, according to Gleick, appeared to be quite naïve. Although scientists acknowledged that measurements could never be perfect, they thought that given an approximate knowledge of a system's initial conditions, they could calculate the approximate behaviour of a system. Western science had assumed that very small influences could be neglected. Gleick (1998: 15-18) discusses chaos theory, which shows how small differences to the initial condition can make large differences to the observed result, a phenomenon known as the butterfly effect. This suggests that the positivist approach is only valid for the scale at which a phenomenon is examined, and is approximate, but it is impossible to examine a subject to an infinitely small or large scale. Babbie (2007: 42) questions whether social life is reflected by rational principles, when viewed in the light of new developments, such as chaos theory, fuzzy logic and complexity. Babbie (2007: 42) claims that all perceptions are subjective, so no observation can be neutral.

Gleick (1998: 12) elucidates the non-linear approach of Edward Lorenz, a pioneer of Chaos Theory. Lorenz acknowledges that systems are deterministic (future behaviour is determined by initial conditions). But observations are always approximations of reality and relate to scale. Capra also refers to how non-linear dynamics and complexity have challenged the purely deterministic view of scientific studies (2003: 74).

However, subjectivists have also been challenged on an epistemological level. Capra discusses how the subjective experience and the perception of free will result from the natural functioning of the brain. He quotes Francis Crick, the co-discoverer of the structure of DNA, who states that consciousness is the behaviour of the vast assembly of nerve cells and their associated molecules (Capra, 2003: 38). Capra points out that Crick does not address the role of non-linear dynamics, or complexity involved in the process. This would suggest that the subjective experience is deterministic, although incredibly complex.

When the role of complexity in research is considered, a paradoxical situation remains, where the reductionist approach is based on subjective observations and the subjective approach is the result of deterministic processes. It is evident that either approach is useful, depending on the nature of the research question.

3.4.3 Pragmatism

Bergman (2008: 13) examines the perceived divisions between qualitative and quantitative research and questions whether such clear distinctions are helpful when considering the complex and compromise-laden process that research entails. He suggests that mixed method research which uses both quantitative and qualitative approaches is being increasingly used in social and behavioural scientific studies (Bergman, 2008: 1). Brannen (2008: 53) refers to mixed methods research as multi-strategy research that uses a number of different research strategies that relate to a complex range of research questions.

Ivankova, Creswell, and Plano-Clark (2007: 263) examine the concept of pragmatism in the light of mixed method research. They trace its origins to the ideas of Dewey, Rorty and Davidson during the late seventies. Pragmatists believe that the truth is derived from 'what works' for understanding a particular research problem. The research questions themselves are more important than the methods used, or the philosophical views that underlie these methods. They argue that quantitative and qualitative methods are compatible and both methods have similarities in fundamental values. When used together, a more complete understanding may be possible. Bergman (2008a: 13) suggests that pragmatic-oriented social-behavioural researchers have joined hands with rationalists. They also link with empiricists who support a real world. Ivankova *et al.* (2007: 263) state that a major justification for pragmatism is that qualitative and quantitative methods are compatible and that pragmatism has been considered as the best philosophical foundation for mixed method research. Gill and Johnson (2010: 206) refer to the 'workability' of a theory and its relationship to the purpose or function for which it is used.

Pirsig (1974: 38) illustrates the concept of the rational/subjective divide using sand as an analogy. A pile of sand could be examined from a number of perspectives, including the shape of the pile, whether it changes over time and where it came from. It can also be examined using a reductionist approach, where the grains could be numerated, or divided up according to a number of different categories, such as shape, size, colour or weight. No view is incorrect – they all reveal different truths using different methods.

When considering how complexity can be viewed at different scales to reveal different truths, the scale of the subject to be examined needs to be identified. In the context of a construction project, this could be the experiences of a single actor in the construction process, or an examination of the construction industry. The specific problems that this research addresses are the extent of the use of technology and how communication and technological processes affect acculturation, or collaboration.

In order to define a suitable instrument, the main research question is reconsidered:

> There is a sub-optimal utilisation of integrated project delivery technologies and a limited culture of collaboration in construction project organisations in South Africa.

The research problem consists of two parts. The first relates to technology. The literature revealed that recent technological advances that are available to organisations within the industry can assist with collaboration (Smith, 2007: 12; Becerik and Pollalis, 2006: 11; Rogers 2009: 35). Limited research has been conducted regarding the uptake of IPD technology in South Africa. In order to compare the uptake with other countries, the research aims to address the question of uptake to gain an improved picture of IPD technology usage in the

South African context. The first part of the problem is related to the degree to which the technology is being utilised.

This is a quantitative problem as it addresses the question: 'How much are IPD technologies being used?' This question can be broken down into the following sub-questions:

- How many organisations are using BIM?
- To what extent are existing users using BIM as a tool for the production of information?
- To what extent are existing users using BIM for analysis?
- To what extent are existing users using BIM to collaborate with external organisations and the design team?

In order to address the sub-questions, the first approach is to conduct a survey of architects and contractors in the industry to determine the extent of BIM usage in South Africa, at what level and to what extent it is used to collaborate with other consultants. Perceptions of the value of BIM and information sharing software as collaborative tools and perceived barriers to implementation can simultaneously be examined.

The second part of the question relates to the culture within the industry. The literature review suggests that a greater degree of collaboration requires a greater degree of knowledge exchange between industry organisations (Chinowsky, 2011: 47-52; Tizani, 2007: 15; Javernick-Will and Hartmann 2011: 25; Senge 2006: 270). Although the 'amount' of collaboration can be determined using quantitative methods, the methods of knowledge exchange are more difficult to determine, as there are usually multiple modes of communication. The question can be examined from different perspectives, and may be viewed differently by the different practitioners that are involved in a project. It is a 'how' question, rather than a 'how much' question. The extent of collaboration and knowledge exchange that occurs can be revealed by examining the communication exchanges that take place during a project. The research is therefore aimed at conducting an in-depth analysis of the communication exchange that transpires during a typical construction project that uses traditional methods of accumulating and disseminating information and that is conducted using traditional contractual arrangements. This can be analysed by examining the relationships within the organisations, using social networking theory. This is discussed in more detail in section 3.6.

The approach taken to address the research question is firstly, to conduct a survey, using a questionnaire, and then to undertake a case study which looks at the relational structure of the organisations that are involved with the project, using a network analysis approach. This is then compared to a hypothetical BIM model to illustrate how BIM can be used as a catalyst for an integrated project delivery culture.

The research methodology is therefore of a conciliatory nature, where different methods are used to examine the research problems. A purely quantitative study is used to gain a broad understanding of current BIM usage in South Africa and perceptions of a collaborative approach to construction projects. For the second part of the study a mixed method approach is used to examine a completed construction project as a unit for research, as this can reveal the extent to which collaboration occurs during a typical construction project. The approach is inductive, as it looks at establishing patterns and relationships from the data, although the data are objective (recorded communications), as they exist historically.

3.5 Survey design

Maree and Pietersen (2007: 155) draw on McMillan and Schumacher (2001) to define a survey as the assessment of current status, opinions, beliefs and attitudes of a known population. They suggest that samples are normally large and that many variables can be tested.

3.5.1 The objectives of the survey

The purpose of the survey is to determine the extent to which IPD technologies are currently being used by the construction industry in South Africa. These results can then be compared to the uptake of these technologies in other countries that have been examined in the literature review. It is anticipated that the survey will reveal:

- Architects and contractors perceptions of BIM
- Architects and contractors use of BIM
- Methods of information transfer between CPOs
- Architects and contractors perceptions of IPD
- Amount of collaboration between CPOs
- Perceptions regarding factors that limit collaboration

Maree and Pietersen (2007: 172) note that probability sampling is required to accurately generalise to the population. The population size of contractors can be estimated from the Construction Industry Development Board (CIDB) register.

In the case of the architects, the number of registered practices can be determined from the regional architect's institutes.

3.5.2 Survey population and sample size

In order to determine relevant sample sizes it was necessary to define the populations and establish the population sizes to be surveyed.

3.5.2.1 Architects

The South African Institute of Architects (SAIA) website gives a breakdown of registered architects in South Africa. However, the research is aimed at organisations rather than individuals. The SAIA website lists eleven different regional bodies, with hyperlinks to the regional websites. Some of the regional websites give details of the individual practices, with contact details, while others do not. After contacting the regional offices, some indicated that they do not give out details of the practices that are registered. The Cape Institute of Architects (CIA) and the Eastern Cape Institute of Architects (ECIA) both list member organisations with contact names and details. The Pretoria Institute of Architects (PIA) does not differentiate between individuals and practices, and does not provide email addresses. The Free State Institute of Architects (FSIA) and Border Kei Institute of Architects provides lists, but these do not contain email addresses. The Gauteng Institute for Architecture (GIFA) and KwaZulu-Natal Institute for Architecture (KZNIA) do not provide lists, in order to protect members and organisations from unsolicited contact. Numerous attempts to contact the relevant organisations were made. Where responses were received, the organisations were unwilling to assist with providing lists of members.

Due to the difficulty of obtaining contact information for architectural organisations, the survey targeted the regions for which contact data were readily available. These were the Eastern and Western Cape, with a combined population of 479[7] architectural practices. Not all listed practices had email addresses and these were discounted. The survey was then sent to the whole population, consisting of 303 practices. The lack of data from other regions represents a weakness in the research. However, a survey conducted in the USA (McGraw-Hill, 2012: 9) showed that BIM use did not vary substantially over different regions within the United States, with no area being more than six percentage points away from the national average.

3.5.2.2 Contractors

The Construction Industry Development Board (CIDB) lists all registered contractors with contact details. The top three grades of contractors in the General Building (GB) category were targeted as these were most likely to have any knowledge of BIM. A previous survey (McGraw-Hill, 2012:10), shows that there is a correlation between company size and BIM adoption. All contractors registered as active[8] were considered and are shown in

Table 3-1. Contractors with no email address were discounted. The survey was sent to all contractors within the top three grades, with a total number of 335 after the removal of invalid email addresses.

Contractor Grading	**Maximum value of projects**	**Registered contractors**
Grade 7	R13 000 000 – R40 000 000	277
Grade 8	R40 000 000 – R130 000 000	92
Grade 9	Over R130 000 000	33

[7] http://www.ecia.co.za/ and http://www.cifa.org.za/ accessed 29 November 2013.
[8] https://registers.cidb.org.za/PublicContractors/

Table 3-1 Contractor grading and population

3.5.3 Method for determining sample size

Bartlett, Kotrlik, and Higgins (2001: 43) suggest that surveys need to generalise about the population from which the sample is drawn. They note two consistent flaws with surveys – disregard for sampling error when determining sample size and non-response bias. They have produced tables, based on Cochran's formulae to estimate a relevant sample size. They note that surveys measure two types of data. The first are continuous data, where a continuous range is measured (such as 'how many employees are there in your company'), and the second are categorical data, where categories are measured (such as 'do you use BIM') (Bartlett, Kotrlik & Higgins, 2001: 44). Sample size is also dependent on the accuracy that is required. The purpose of this research is to gain a broad understanding of BIM use, rather than to accurately chart the number of organisations that use BIM. For a 10% margin of error, sample sizes are calculated as 57 for architectural practices and 55 for contractors for a 90% confidence level using a normal distribution.

3.5.4 Estimation of response rates

Bartlett *et al.* (2001: 46) point out that it is difficult to estimate the likely response rate. In order to ensure that the required sample is obtained, oversampling is usually required. They note four methods for estimating response rates. These are using a pilot study to estimate response rates, doing the survey in two parts, using the first part to estimate the likely response rate of the second part, use the response rates of previous studies on the same population, or estimating the likely response rate. They note that the first three are more likely to give viable estimates of the response rates. In a previous study conducted in the Eastern Cape (Smallwood, Emuze, & Allen, 2012: 145) a survey was sent out to members of the East Cape Institute of Architecture, and seven responses were obtained. The study does not indicate whether all listed practices were part of the sample, or the response rate, but it can be seen that the response rate was small. The authors do not say if they used any methods to try and improve response rates. Baruch & Holtom (2008: 1150) suggest that response rates have been reducing over time, although their research shows that this trend appears to have levelled out. They note that for organisational surveys the response rate is 35.7%, based on a study that examined a number of published papers from different journals. The proposed survey is not conducted within an organisation so the anticipated response rate is likely to be lower.

3.5.5 Addressing response rates to surveys

Porter (2004: 5) mentions the value of surveys for institutional research and suggests that the demand for surveys is increasing in the field of higher academic planning. However, survey response rates have been falling as demand increases. He notes this trend both in the USA and in Europe. Sheehan (2006: 4) also mentions this trend and cites different studies that suggest that this is due to potential respondents being over surveyed. Porter suggests that survey non-response has become a serious problem for researchers.

Both Porter (2004: 6) and Sheehan (2006: 4) mention that low response rates could bias the research results as it may be a certain type of respondent that does not respond. Baruch and Holtom (2008: 1141) note that non-response bias can result from any level of non-response in surveys. They suggest that authors conducting survey research need to make reasonable efforts to increase response rates and address the influence of non-responders. The authors also note some typical reasons for non-response, after a random sample of non-respondents were questioned. They noted that 28% of non-respondents had said that it was company policy to not respond to surveys (Baruch & Holtom, 2008: 1142). They also suggest that a second principal reason for not responding is the failure to deliver the questionnaire to the target population, for reasons such as using the incorrect address. Preparation that addresses the accuracy of the contact data can therefore increase response rates. A third reason is that respondents are away. The timing of the survey could therefore increase response rates, by avoiding conducting the survey during a period when many people are not at work, such as during holiday periods. Sellitto (2006: 151) also notes how timing can have an effect on the population that has been surveyed. He shows how surveys in the wine industry in Australia give lower response rates during critical times of the wine growing period. Timing may have an effect on respondents from the construction industry, such as year-end, or during periods when there are many public holidays.

Wiley *et al.* (2009: 467) observe that pre-notification, follow-up and incentives had the largest effect on improving response rate from a study conducted among students at a large university in New Zealand. They suggest that their results would be valid for other countries and non-university respondents (2009: 261). Porter (2004: 7) suggests that survey administration can improve response rate. He draws on the work of Dillman (2000) and refers to 'social exchange theory', where response rate is related to rewards, costs and trust. The cost to the respondent is generally the time and effort taken to complete the survey. Trust is the expectation that in the long term the rewards will outweigh the costs. Survey design should therefore attempt to minimise the cost to the respondent (time taken to complete the survey) and maximise the reward (incentive to complete the survey). Porter (2004: 8) also suggests that survey responses may be increased by just asking for help.

A small gift that is included with the survey (mail surveys) significantly increases survey response rate, while a reward for completing the survey has little effect unless the reward is significant (Porter, 2004: 13). Due to the financial implications and the anticipated size of the survey, these options are not considered to be feasible.

Wiley *et al.* (2009: 457 – 459) also found that follow up, pre-notification, questionnaire length and incentives increased response rates. They also comment on the visual design, where they note that a more complex design may have a paradoxical effect, due to increased download time. They also recommend that surveys that emanate from a credible institution, with a credible e-mail address (such as from a university) will increase response rate. They also suggest including a privacy statement and personalisation.

Porter (2004: 9-10) suggests that response rates for both mailed paper and internet based surveys are declining. Previous studies do not show a clear advantage for any media. Porter notes that internet surveys have shorter administration times, lower costs and fewer data entry errors. Internet surveys are also easier for potential responders to complete and submit.

3.5.6 Strategy for maximising response rates

The research has indicated that although non-response can be a problem for surveys, there are methods to increase response rates. The following approaches were considered during the design of the surveys and strategy for delivery.

3.5.6.1 Timing

The timing of the surveys needs to take into account periods where participants may be absent, such as during holiday periods, or when they may be particularly busy, such as at the beginning of the year or financial year end. The surveys were conducted during school terms to reduce this effect. They were also sent mid-week as some respondents may have extended their weekends by taking a day's leave either side of the weekend. The time of day may also have an effect, so the three emails sent that contained the link to the survey were sent at different times of the day.

3.5.6.2 Incentive

Respondents were offered the opportunity to receive the completed research results so that they can monitor their performance relative to other organisations within the industry. The survey was composed so that it contained items of interest to the respondent, taking care to not lead respondents before answering questions. Information contained within the survey makes it more interesting to complete.

3.5.6.3 Pre-notification and reminders

The pre-notification emails were personalised, with the name of the respondent and their company's name. The e-mail respectfully requested involvement with the survey, with an opt-out option to not receive the survey or reminders. The survey was only sent to those that did not opt out. Two reminder emails were sent with a reminder that the survey would be closing soon in the last email.

3.5.6.4 Length of survey and ease of completion

The survey length was kept to a minimum to ensure that sufficient data for the study were obtained, with no redundant questions. The questions asked could be easily understood and knowable by the respondent. The questions in the survey were presented following the presentation of information to hold respondent interest, and build a logical sequence to the survey. The survey was designed to take less than five minutes to complete.

3.5.6.5 Privacy

Assurances were given that the respondents would remain anonymous and that the results would not be used for any marketing or commercial purposes.

3.5.6.6 Authority of the body

The respondents were made aware that the survey was not being done for any marketing purposes and that its purpose was for genuine research that is valuable to the industry. The survey was conducted under the auspices of both Nelson Mandela Metropolitan University (NMMU) and the Construction Industry Development Board (CIDB). The email attempted to highlight the importance of the survey and the value of their participation.

3.5.7 Precedents

In order to gather comparable results, the questions were aimed at gathering similar information to that available from other countries. The McGraw-Hill survey has done extended research on BIM use in Europe and the USA.

Three recent precedent studies are relevant to this research in order to compare the South African environment with those of other countries. The first is a survey conducted by the NBS in the UK in 2011 which analysed current BIM use and perceptions of architects. The second is a McGraw-Hill survey that compares the UK and USA markets and looks at BIM use and perceptions, expertise levels and take-up among architects, engineers and contractors, conducted in 2010. A subsequent survey by McGraw-Hill was conducted in the USA in 2012.

3.5.8 Survey questionnaire

The question types that were used in the surveys were generally closed-ended multiple choice questions, although there was also an opportunity for respondents to answer an open-ended question should they have had further information to add.

The survey questionnaires were conducted electronically, with a link to the survey contained in an email. The questionnaires are attached in the Appendices on pages 203 and 211.

The following table (

Table 3-2) presents what the survey expects to reveal, and links this to the appropriate questions within the surveys and the hypotheses presented in Chapter One.

Information sought	**Relevant question in survey**		**Hypothesis**
	Architects	**Contractors**	
Perceptions and awareness of BIM	1.1; 3.2; 3.4	1.1; 3.1; 3.2	1; 4
Methods of information transfer between CPOs	3.3		2; 3
Perceptions of IPD	3.5	3.3	2
Use of BIM	2.1; 2.2; 2.3; 2.4; 2.5; 3.1	2.1; 2.3; 2.4	5
Factors that limit collaboration	3.6	3.4	1

Table 3-2 Relationship of survey questions to information sought

3.6 Case study design

The survey discussed in the previous section was designed to provide an overview of BIM use in South Africa. Its purpose was to establish to what extent BIM is being used in South Africa and to determine awareness and perceptions of collaborative approaches to construction. It provides the context for the research, which addresses the sub-problems and hypotheses. The purpose of the second part of the study is to address how information is traditionally generated and exchanged during a construction project, and the consequences of using the traditional approach. It addresses a qualitative question.

Neuman (2006: 33) lists three main approaches to research: exploratory, descriptive and explanatory. Exploratory research is typically used to explore a new concept or research area. It is often used to provide a setting for further research, or to determine research methods that may be used by future researchers to examine the phenomenon more closely. It examines 'what' questions (Neuman, 2006: 34). Descriptive research aims to describe a phenomenon accurately and determine the specific details of a situation or relationship. It examines 'who' or 'how' questions (Neuman, 2006: 35). Explanatory research tries to answer 'why' questions. It tries to identify the reason why something occurs. It elaborates or tests a theory (Neuman, 2006: 35).

Nieuwenhuis (2008: 71) notes different approaches to qualitative research. He defines a case study as a systematic enquiry into a set of related events, with the aim of describing and explaining the phenomena of interest. Widmer *et al.* (2008: 151) suggest that case study research is one of the most widely used analytical concepts in social science methodology. They note that the normal approach is to apply qualitative data collection and analytical procedures. Quantitative methods are seldom used.

The current study examines how information and knowledge are exchanged, but also tries to explain the link between collaboration and information exchange. The research is therefore both of a descriptive and an explanatory nature. In order to achieve this, the current approach needs to be dissected. Although current approaches to relationships in construction are well understood and procedures are documented, there is a need to compare these to ideal working methods as discussed in the preceding section. This presents a hypothetical situation, as projects are currently not being conducted using the proposed information exchange methods highlighted by this research.

Neuman (2006: 158) suggests that qualitative researchers tend to use a 'case orientated approach', where the case rather than the variables are examined. They examine a wide variety of aspects of one or a few cases. They analyse 'messy' natural settings, and explanations are complex. Widmer *et al.* (2008: 150) suggest that case studies can grasp the complexities of social interaction and allow researchers to investigate a social process in a detailed way. Nieuwenhuis (2008: 75) points out that a case study can be used to describe a unit of analysis, such as an organisation. Widmer *et al.* (2008: 151) also note that case studies deal with organisations as units of analysis. A unit is usually a meso-level entity, such as an organisation, administrative unit or some kind of social process. A case study could also deal with a process, defined as a set of interrelated events. It investigates a longitudinal phenomenon and usually has a diachronic perspective as it investigates an entity over a period of time.

Widmer *et al.* (2008: 150) note that case study research has a long tradition of investigating social processes, as it allows researchers to investigate a social process in a detailed way. They note that a case study can grasp the complexities of social interaction and dynamic aspects of social behaviour. The case study approach has advantages compared to other analytical approaches. They claim, however, that the case study strategy can be weaker than other types of social research. Reasons for this include that they often do not rely on social science theory in an inductive or deductive way.

Commentators have noted that case study research is often criticised as it produces no generalisable evidence (Widmer *et al.,* 2008: 151; Flyvbjerg, 2006: 225). Zainal (2007: 5) lists the main criticisms of case studies as lack of rigour by the researcher, which can result in biased findings. Case studies also generate large amounts of data, which can be cumbersome to manage. The main criticism is that case studies explore a single case, which makes it difficult to generalise. Case studies are nevertheless widely used, even in the natural sciences, such as the study on gorillas which examined their ability to communicate (Tanner, Patterson, & Byrne, 2006). Although only a few gorillas were observed, the findings revealed new knowledge about gorillas in general. Kyburz-Graber (2004: 53) defends case study research as a scientific approach, with quality criteria based on objectivity, reliability and validity. Case studies do not rely on a controlled or artificial environment. They analyse real life situations and their complexity. They are appropriate for the examination of a single phenomenon (Kyburz-Graber, 2004: 54). The following section discusses the case study in the context of the research.

3.6.1 The case study in the context of the research

The case study examines a completed project that is conducted using a traditional approach. For the purposes of this study, this is defined as a project that is documented in an isolated BIM environment and a design-bid-build procurement arrangement (single-stage tender). The project consisted of a multi-purpose community centre. The project is described in chapter five.

Pryke (2006: 208) documents the complexity of construction projects and suggests that the environment within which they operate is non-linear, complex, interactive and iterative. He argues that these are difficult to analyse using traditional methods of analysis, such as structural analysis or process-mapping-based approaches. He proposes that analysing the information exchange networks is part of the solution. Along with contractual relationships and financial incentives, an understanding of the systems in which the project operates is possible by analysing the networks. He suggests that this can lead to a comprehensive understanding of the systems that make up the project and can articulate a social network theory of project coalition activity and effectiveness. Pryke (2006: 213) views a construction project as a network of relationships and suggests that a construction project can be seen as a social network (2006: 217). Chinowsky (2011: 51) also discusses the social networks that are inherent in construction projects and observes that relationships can be analysed between organisations where social and information relationships exist. He observes that network analysis can address coordination and learning within the organisation. By mapping the structure of interactions, the researcher is able to identify channels through which information flows between the nodes of the network. Chinowsky (2011: 41) maintains that research is demonstrating that performance in construction projects is linked to social aspects within the team, including trust, reliance and communication levels. The social aspects are the foundation of the relationships that are developed between team participants. He also observes that successful teams show a high degree of connectivity between team members with a high degree of collaboration (Chinowsky, 2011: 42-43). The traditional perspective of the project team is a group of participants focusing on a project rather than an integrated group of participants within a network. He suggests that social networks play a critical role in determining how problems are solved (2011: 43). Pryke and Chinowsky both endorse social network analysis as a useful tool to examine the effectiveness of a construction project or organisation.

3.6.2 Social network analysis

Marin and Wellman (2011: 11) define social network analysis (SNA) as a set of socially relevant nodes, or network members connected by one or more relationships. Aggarwal (2011: 2) gives a general description of SNA as a network of actors and relationships, where nodes consist of actors and the edges represent interactions between the actors. He suggests that the network consists of information, where nodes could represent either actors or entities and the edges represent the relationships between them. He notes (2011: 4) that social networks can also be constructed from specific kinds of interactions in different communities. Chinowsky (2011: 47) notes two different categories of networks that can be analysed in construction projects. These are information-based networks and social-based networks. Information-based networks consist of communication, information and knowledge networks.

Butts (2008: 13) defines SNA as an interdisciplinary research method that aims to predict the structure of relationships between social entities and its impact on other social entities, while Mayer (2012: 162) proposes that SNA offers a broad range of methodologies to deal with social structures using discursive and visual means.

3.6.3 Origins of social network analysis

Dempwolf and Lyles (2012: 5) claim that all forms of network analysis originate from the graph theory developed by Euler in 1736. During the 1800s, Durkheim compared social systems to biological systems, after Comte’s suggestion fifty years prior that social irregularities were based on the structure of the social environment, comprising of actors. They suggest that Field Theory, which looks at the relationship between social actors and local social orders and Gestalt psychology, be credited as antecedents to SNA (Dempwolf & Lyles, 2012: 5). They cite a study by Jacob Moreno in the 1930s, which used sociograms to depict a network, which came to be known as SNA. Chinowsky, Diekmann, and Galotti (2008: 805), also note that the concept of SNA was introduced by

Moreno in 1934 to represent patterns of interpersonal relationships. He introduced sociograms, with nodes to represent individuals, and links between the nodes to represent relationships between the individuals.

During the 1940s to 1960s, structural approaches mapped actors and relationships as networks, which could be analysed mathematically using graph theory and matrix algebra (Dempwolf & Lyles, 2012: 5). The concept was introduced to the field of group dynamics in conjunction with the concept that groups or individuals exchange information during the course of any activity. Any activity therefore requires that information and knowledge is exchanged. Chinowsky *et al.* (2008: 805) show how the exchange of information can be represented using sociograms. Network information exchange could be analysed mathematically to provide researchers with established measurements for analysing the effectiveness and weaknesses of the group (Chinowsky *et al.*, 2008: 805).

Parise (2007: 370) illustrates how SNA can be used to analyse bottlenecks in the decision making process by using information networks. Schultz-Jones (2009: 595) discusses the effect of the strength of weak ties within a network, where the flow of information depends on three factors: frequency of contact, reciprocity and acquaintance. Moliterno and Mahony (2011: 463) challenge traditional SNA for complicated networks and show how organisations often operate within multiple levels. Typically, within a construction project, this is the case as each party has their established networks with established communication and information dissemination processes.

3.6.4 Social networks in construction project analysis

Chinowsky (2011: 47) discusses information networks which focus on the information and knowledge that is exchanged during a construction project. He notes that these networks are the measureable characteristics that affect project efficiency. He identifies three types of information-based networks. The first is a communication network that examines the informal network within a project or organisation team. These are critical as they are able to activate when unexpected problems arise. The second type is an information network, which takes into account the members that an individual member interacts with to complete tasks. Information is exchanged in two directions in these types of networks. These networks are important as they indicate the efficiency of information transfer within an organisation. The third type is the knowledge network (Chinowsky, 2011: 47). Knowledge networks are an important component of high performance networks and are key to organisations transforming from reactive to proactive processes. Chinowky (2011:48) believes that this level of interaction is difficult to achieve before there is trust and value sharing within organisations. The illustrations (Figure 3-4 and Figure 3-5) based on Chinowskys' sociograms show how these networks vary within the sample organisation, an established engineering firm (Chinowsky, 2011: 48-49).

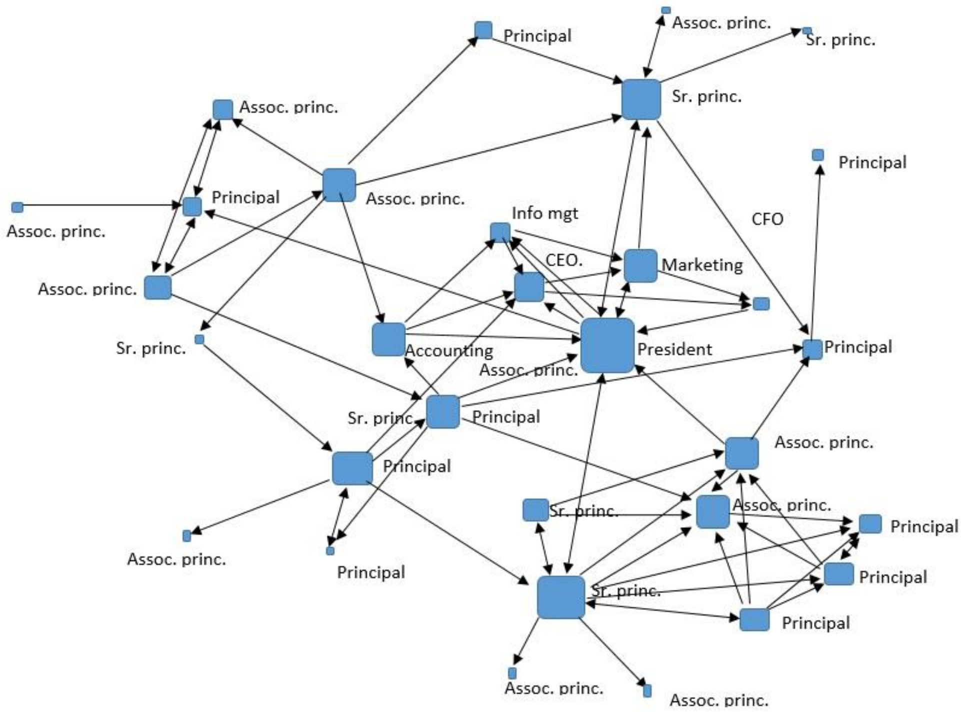


Figure 3-4 Formal communication network within sample organisation (Chinowsky, 2011: 48)

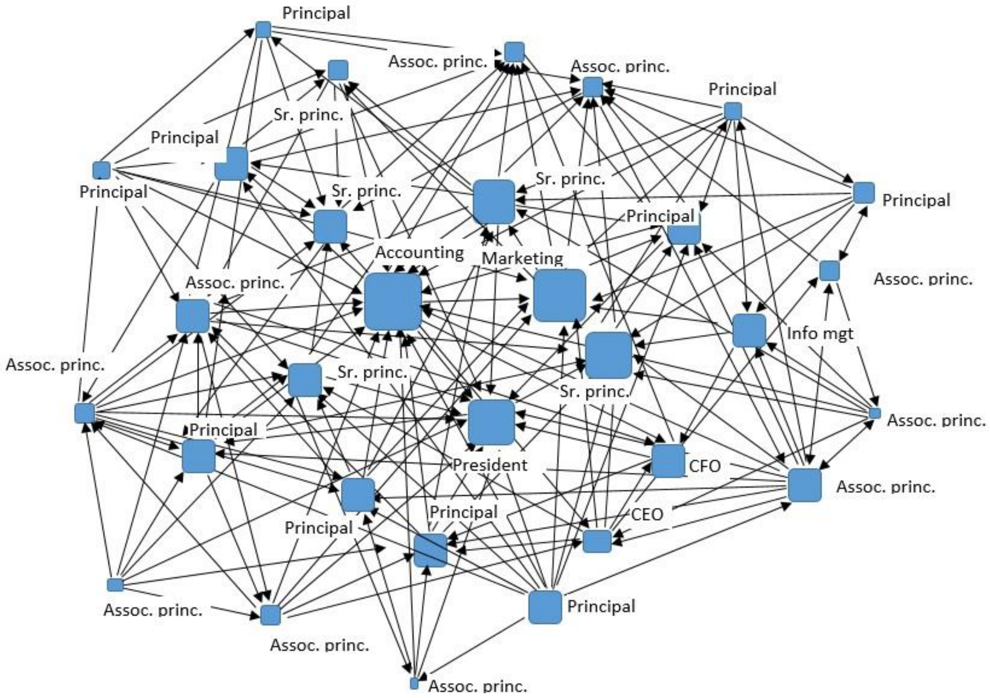


Figure 3-5 Informal networks within the organisation (Chinowsky, 2011: 48)

The first diagram shows the formal communication network within the organisation, showing the centrality of actors by node size. This is compared to the informal communication network within the organisation, where actors were asked whom they went to for help or information required to carry out their work. The second also shows actor centrality by node size and illustrates the importance of understanding the informal network to show how information is disseminated within the organisation.

Pryke (2012: 2) discusses construction supply chains and networks, and illustrates how the contractual and financial relationships in the CPO are different to the knowledge transfer or information exchange network. The illustrations (Figure 3-6 and Figure 3-7) show two different networks for the same project, and show the difference between the contractual relationships and the information exchange relationships. Pryke (2012: 101-211) uses SNA to analyse different network aspects on four construction projects using traditional and partnering relationships. The SNA approach can reveal the advantages of collaborative construction projects.

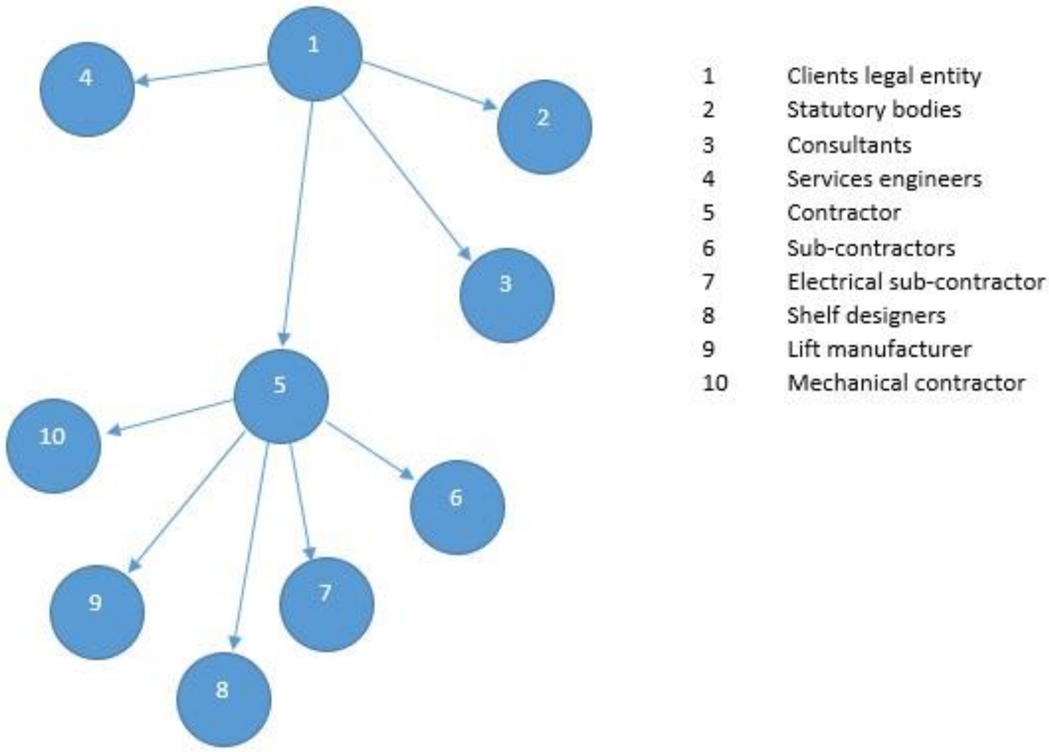


Figure 3-6 SNA between construction organisations - contractual links

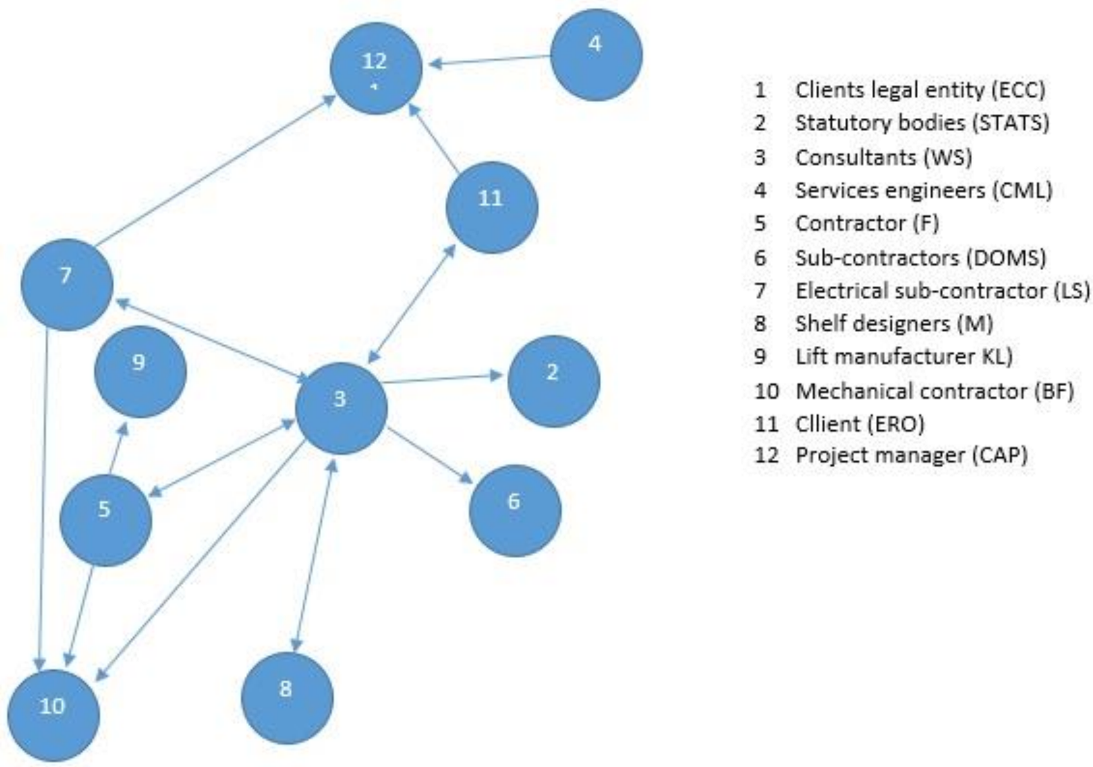


Figure 3-7 SNA between construction organisations - design development network

Radosavljevic and Bennett (2012: 269-270) suggest that construction projects can be analysed by comparing them with a simulated project. Various methods, such as Case Based Reasoning (CBR), which is the process of solving new problems based on the solutions from similar past projects, or agent-based modelling (ABM), which simulates the actions and interactions of agents to determine their effectiveness have previously been used to analyse projects. They also propose that SNA can be used as an analysis tool, and that one method to analyse construction projects is to compare them with a simulated project incorporated in BIM.

Current research in construction using SNA examines relationships from two perspectives. Pryke (2012) examines relationships in the context of inter-organisational relationships, whereas Chinowsky (2011) looks at intra-organisational relationships. However, the networks within construction project organisations are between certain actors from within all the participating organisations. An examination of these relationships may reveal how information flows between the actors within the organisations during a project. This can give an indication of the degree of knowledge sharing.

3.6.5 Research design

The study expects to reveal the information links between the different participants involved in a construction project and, from this, demonstrate how current communications and information exchange affect the project execution. The model can then be compared with a hypothetical model where the information was at a single source and accessible to all relevant participants involved with the project. This will suggest how BIM may have improved the process should it have been used in a partnering relationship.

The study compares a project that uses the full potential of BIM to the same project that uses BIM solely to produce drawings. This can only be done in a simulated environment, as no two construction projects are the same. However, by analysing the communication and information transfer, the study can compare the traditional process with a hypothetical process, where the information and communication is centralised. The analysis should reveal where confidentiality hinders communication during the project. It should also reveal where multiple sources of information have resulted in errors or ambiguities.

The case study will be used to examine a completed construction project by analysing the sources and exchange of recorded data, such as drawings and their subsequent revisions, specifications, communications, requests for information (RFIs) and other data that are available. The source information is traditionally generated by the architectural organisation. An analysis of the communication exchanges during the project is performed and cross referenced with the BIM model where possible. The objective is to compare a traditional project environment and information exchange methods with those that are possible using current practices and technology.

3.6.6 Data collection

The data are sourced from a willing participant, being an architectural practice. The unit of study is a completed (historical) project. The participant provided the electronic information that was recorded for the construction phase of the project. This included the drawing and BIM files, project documentation, communications and schedules.

The research methodology represents one method of analysing a completed project. It is acknowledged that the research can only reveal a part of the communications that occur during a project. The historical data can only reveal recorded information, but during a construction project, other informal communications do occur, such as telephone calls and face to face communications. This may be an area for further research, based on an ethnographic approach, although it would be difficult to record all communications that occur during the lifetime of a project.

3.6.7 Hypothetical BIM model

The hypothetical model used for the comparison of the data (with the historical project) consists of a central database using the available functions that are found in current BIM software. The components within the model are data rich with information that can be used for detailed analysis. The model includes the collaborative functions that are available to other consultants, such as the linking ability to the structural and MEP functions of the software. The model also assumes that the contractor has access to the model and was involved with the compilation of the data.

The reference software for the study is Autodesk Revit. This is due to the researcher's familiarity with the software, rather than an endorsement of the product. Other BIM software has the ability to perform the functions that are contained in Revit. Product information is sourced from the developers' manuals and Autodesk 'White Papers'.

The proposed hypothetical BIM model that is used to compare the data is developed by the architectural team. The model exists in an environment where there is collaboration during the project and the contractor and consultants have first-hand knowledge of the project. The following assumptions have been made with regard to the model.

- The client and selected representatives have access to the BIM;
- Structural, civil, electrical and mechanical engineers all enter their information directly to the BIM and have unlimited access to the model;
- All the construction information is stored in a central place, available to all consultants and the contractor;
- Sub-contractors have limited access to the BIM and are able to enter their data directly;
- The full functionality of the software is utilised, including the ability to produce quantities and pricing data; and
- The model is linked to suppliers self-developed BIM components, such as windows with parametric data (price, thermal, acoustic, light transmitting properties) to allow analysis of the model.

The case study looks at the BIM model to determine how BIM is used in the South African environment. The participant also allowed access to all the project communications, including all email correspondence, formal correspondence, project documentation and the contractor's correspondence with respect to the claims resulting from disputes that occurred during the project. Where relevant, the correspondence is referenced to the model's complexity at that stage.

The BIM model is examined to determine the extent to which the features of BIM have been implemented during the project.

3.6.8 Linking the hypotheses to the methodology

In order to link the methods to the research, the hypotheses are reconsidered, with a view to how they can be addressed using the proposed methodology.

Hypothesis 1: The current South African environment hinders collaboration between CPOs

The survey is designed to reveal the level of collaboration that is currently occurring in South Africa and perceptions of participants as to reasons for lack of collaboration. An in-depth analysis of the project documentation reveals the current linear processes involved with traditional projects and how information exchange is hindered using traditional information transfer routes.

Hypothesis 2: Traditional ownership of project information inhibits knowledge flows between construction project organisations

The case study analysis may reveal where information that was available to parties or individuals involved in the project was not communicated. The withheld information may possibly have led to a delay, or required additional administration to access the information, such as an RFI. However, the information may also have been used to develop an alternative approach to the actions taken, had it been available earlier. This is addressed by analysing the case study communications.

Hypothesis 3: Multiple sources of information lead to errors and omissions in the documentation

The case study documentation is used to reveal the sources of the information and how it is disseminated. The analysis reveals where there are additional sources for similar information and if this led to errors. The correspondence can show where information is missing, or where there is conflicting information due to it being generated multiple times by different actors.

Hypothesis 4: The use of BIM in IPD projects enhances organisational learning and in turn enhances innovation

The SNA and document analysis reveal the methods of information transfer during a typical project. This is then compared with the hypothetical model to establish if innovation was encouraged.

Hypothesis 5: Increased use of BIM in South Africa improves the accuracy of construction project documentation

The project documentation examined in the case study may show how traditional methods for project document creation can be improved by more use of BIM, or by using BIM in a collaborative environment.

3.7 Ethical considerations

Survey respondents were assured that they would remain anonymous. With regard to the case study, full consent was sought prior to any interviews with individual employees and their managers from all organisations.

To ensure that the research is conducted in an ethical manner the following steps were adhered to:

- Authors that are cited in the document are fully acknowledged to avoid plagiarism in the work.
- Consent was obtained from stakeholders or their managers before conducting any interviews.
- Information obtained from stakeholders was treated as confidential, with full assurance given that the sources would remain anonymous. The files containing email addresses of respondents were destroyed once the work was completed.
- Advice was sought where any ethical issues were unclear during the course of the work.
- All efforts were made to ensure that the research did not yield misleading results.

Much of the information that was acquired for the case study was confidential in nature. The information obtained was primarily in electronic format. Precautions were taken to ensure that it did not accidentally enter the public domain by storing all project information on a separate external drive. This was deleted once the analysis was completed. The identity of the case study participants and the project are not revealed in the study.

3.8 Conclusion

The research methodology presented a justification for a mixed method approach to the research and discussed the philosophical assumptions on which the research was based. The survey design was considered and strategies to increase response rates were reviewed. The case study objectives were presented, with a proposal to assess the case study data. Methods to examine the case study BIM model were presented and a method to analyse the project communication was discussed.

The following chapter discusses the results and analysis of the surveys and compares these with surveys that were held in other countries. The findings from the case study are presented in chapter 5.

Chapter 4 – Analysis and discussion of the surveys

4.1 Introduction

The literature review indicated that BIM use in other countries is increasing, but it was observed that its use often replicates that of CAD use, and the full analysis and collaborative power of the software is not yet generally used. This chapter discusses the findings of the survey, where similar practices were observed in South Africa. The survey indicated that BIM use in South Africa is less than that observed for some developed countries. The survey methodology was discussed in Chapter three.

The surveys were set up in an electronic format that could be accessed over the internet. Separate covering emails were sent to contractors and architects, with links to industry-specific surveys. A total of 612 links were sent, after removing the invalid email addresses. 118 responses were received, representing a response rate of 19.3%.

4.2 Contractors' survey

Potential respondents were sent four emails. The first was a notification of the survey, with an option to opt out (appendix 8.1.1, page 199). The second email contained a link with a request to participate (appendix 8.1.2, page 200). A subsequent follow up email was sent to remind potential respondents, again with a link to the survey (appendix 8.1.3, page 201), and a final email notified potential respondents that the survey would close soon (8.1.4, page 202).

Of the 380 emails that were sent, four potential respondents opted out, while a further 41 emails were returned due to the email address being incorrect or invalid, leaving a list of 335 that were sent the survey. The first email returned 22 responses, and the initial findings suggested that contractors were mainly unaware of the BIM acronym. The email did not describe BIM in any way, or convey the significance of BIM. This may have resulted in a lack of interest among potential respondents. The reminder email therefore provided more information to increase interest, without defining BIM. An additional 14 responses were received. The final reminder email returned 16 responses. The total of respondents is thus 52, which gives a response rate of 15.5%.

Contractors were asked to indicate their CIDB grading. The breakdown of contractor respondents is shown in Figure 4-1.

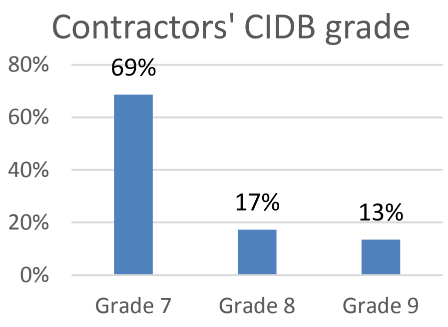


Figure 4-1 Contractors CIDB grade

4.3 Architects' survey

As with contractors, the architects were sent four emails. These are included in the appendices (8.2.1 to 8.2.4, pages 207 to 210). The initial pre-notification email that was sent to architecture practices generated substantial interest, with a number replying immediately that they were keen to participate in the survey. An interested architect phoned to discuss the concept of BIM at length.

Of the 303 pre-survey emails that were sent, three opted out and 23 were returned as undeliverable. The email with the link to the survey was sent to 277 architects. This generated 30 responses. The two reminder emails returned a further 19 and 18 responses each, giving a total of 67, representing a 24.2% response rate.

Architects were asked to indicate the size of their practice. The results are illustrated in Figure 4-2. The majority of respondents were from practices with less than five staff (54%), while 17% were from practices with between five and ten staff members. Respondents from practices with between ten and twenty staff constituted 19% and 8% of respondents were from practices with between twenty and fifty staff members. There were no respondents from practices with more than 50 staff members.

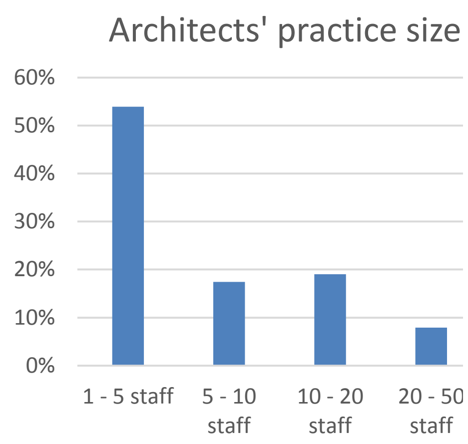


Figure 4-2 Architect's practice size

4.4 Survey findings

The survey results were analysed and the findings are presented below. The survey for architects was different to the contractor's survey, but where relevant, the same questions were asked in both surveys. An initial observation was the substantial difference in the response rates for the surveys, where a similar method of notification and delivery was used. The difference is potentially attributed to the awareness levels of the two different groups, where architects were substantially more aware than contractors of the BIM concept.

4.4.1 Awareness of BIM

The first question addressed awareness of BIM as a concept and was directed at both contractors and architects. During the trial, it was noted that respondents may be aware of or even use BIM software without being familiar with the term 'building information modelling' or the acronym 'BIM'. The survey was adjusted to take this into account by asking the question on a separate page before BIM was described. A 2011 survey conducted in the UK showed that 43% of respondents neither used nor were aware of BIM (NBS, 2011), while only 13% used BIM software. However, a question in the same survey asked respondents about the software they had used, and 25% responded that they had used Graphisoft ArchCAD, Autodesk Revit, Bentley Microstation and/or Nemetschek Vectorworks, all of which are BIM software packages, as their major software. This indicates that the BIM acronym is not recognised by all that use BIM as a tool in their organisations.

The question is presented below with the possible answers. Only one answer could be chosen. The responses are shown in Table 4-1 and represented graphically in Figure 4-4 and Figure 4-3.

How aware are you of BIM?	**Contractors**	**Architects**	**Combined**
Never heard of BIM	73%	21%	44%
Heard of BIM	17%	21%	19%
Have heard of BIM and have a fair understanding of what it means	6%	25%	15%
Are familiar with the BIM concept	4%	33%	21%

Table 4-1 Contractors' and Architects' BIM awareness

It can be seen that there is a substantial contrast between architects and contractors when it comes to BIM awareness, with less than a quarter of architects (21%) not being aware, against nearly three quarters (73%) of contractors not being aware of BIM. 58% of architects consider that they are familiar with, or have a fair understanding of the BIM concept, compared to only 10% of contractors that are familiar with, or have a fair understanding of BIM.

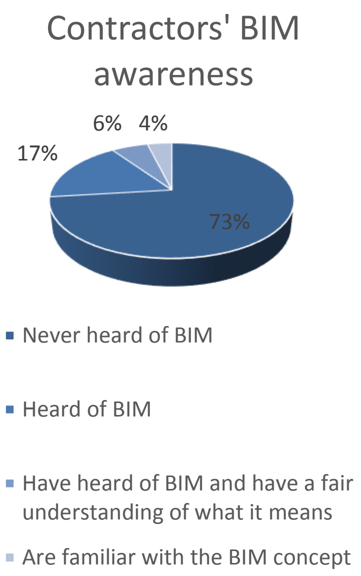


Figure 4-3 Contractors' BIM awareness

The use of BIM by South African architects can be compared to the findings of a survey conducted in the UK in 2011, where 58% of architects were aware of BIM (NBS, 2011: 10). Architects may be more familiar with BIM as they are more likely to use it due to the time savings that BIM offers during the design stage. Contractors may receive 2D drawings from architects that were created in a BIM environment without being aware of the software used to create the drawings. The drawings that they receive are not distinguishable from 2D CAD drawings. Trends for contractor BIM awareness can be compared with a survey conducted in the USA, which showed that contractors are becoming increasingly aware of BIM, with a higher adoption level than architects or engineers (McGraw-Hill, 2012). A survey conducted in Europe in 2010 (McGraw-Hill, 2010: 7) reported that 24% of contractors had adopted BIM in Europe (UK, Germany and France). The survey does not report on awareness of BIM, but it is likely that the figure for awareness of BIM is higher than the adoption rate. The researchers predicted that contractor adoption rates would rise substantially in the following two years, based on the findings of the surveys conducted in the USA.

The results showing BIM awareness were analysed to check if the contractors' CIDB grading or architects' practice size were related to awareness of BIM.

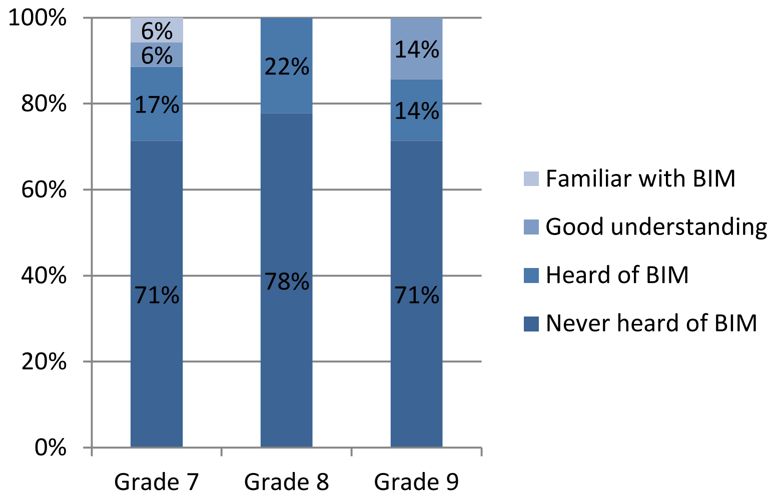


Figure 4-5 Relationship between contractor grade and BIM awareness

The graph (Figure 4-5) shows that there is no correlation between contractor size and awareness of BIM in the upper three groups of contractors. 29% of Grade 7 contractors had some awareness of BIM, 22% of Grade 8's, and 29% of Grade 9 contractors had some awareness of BIM. Surprisingly, Grade 7 contractors scored higher than the larger contractors, with 6% being familiar with BIM. There was, however, a relationship between the size of an architectural practice and BIM awareness (Figure 4-6), with 25% of small practices and 14% of medium size (10-20 staff) practices having no awareness. Respondents from larger practices with over twenty staff were all aware of BIM to some degree.

As noted previously, BIM awareness does not necessarily indicate whether or not BIM software is being used. One of the architects surveyed noted in the comments section that they were not aware of the BIM acronym even though they used BIM.

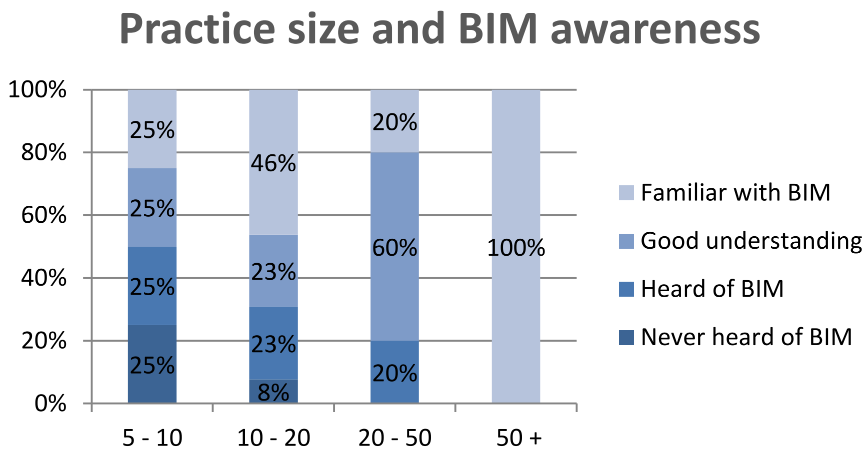


Figure 4-6 Architectural practice size and BIM awareness

4.4.2 Use of BIM

The concept of BIM was introduced in the survey and typical BIM software was named so that respondents who were not aware of the BIM acronym, but still used BIM, could answer the question:

> "Building information modelling (BIM) is a concept that was developed in the late eighties, although computer technology limited its use. The first recognised BIM developer was Graphisoft, who developed Archicad. Building information models are a 3D representation of a building from which drawings and schedules can be extracted. Some current BIM systems include:
>
> - MicroStation/Bentley Architecture
> - Revit (Autodesk)
> - AutoCAD Architecture (Autodesk)
> - ArchiCAD (Graphisoft)
> - Vectorworks (Nemetscheck)"

The second question sought to establish current BIM take-up in South Africa. Both contractors and architects were asked the same question, with one possible answer:

Do you use BIM?	Contractors	Architects	Combined
Not at all	88%	46%	65%
We have used it on one/some projects	10%	16%	13%
We use it on most projects	2%	22%	14%.
We only use BIM	0%	15%	8%

Table 4-2 Use of BIM

The results are presented in Table 4-2 and shown graphically in Figure 4-7 and Figure 4-8. The graphs illustrate that most architects (54%) use some form of BIM, and 15% of architects work exclusively in a BIM environment. This can be compared to the findings of a preliminary study conducted in South Africa (Smallwood, Emuze, & Allen, 2012: 149), which found that BIM implementation and/or adoption was minimal among South African architects, although the authors did not enumerate this.

As with awareness, contractors' use of BIM is limited in South Africa, with only 12% having used some form of BIM and none that use BIM for all projects.

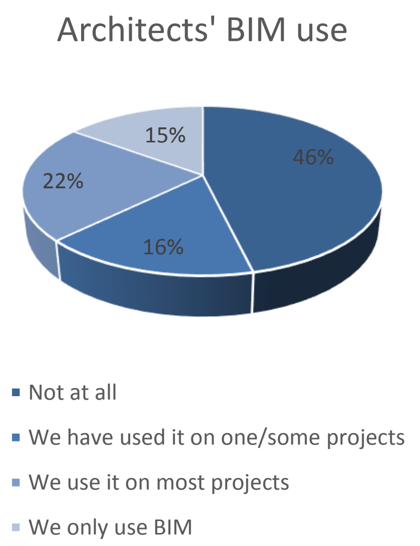


Figure 4-7 Current BIM usage by architects

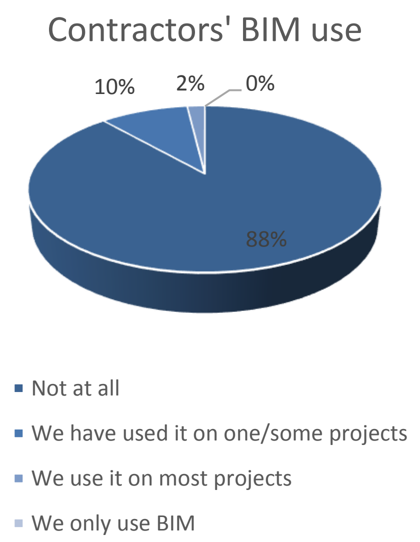


Figure 4-8 Current BIM usage by contractors

The results can also be compared with surveys conducted in other countries. The first is the McGraw-Hill survey, conducted in 2010 (McGraw-Hill, 2010) which compared findings in Europe (France, Germany and UK) with findings from the USA. 36% of the Western European countries' construction industries had adopted BIM (2010), compared to 49% in the USA (2009). This was compared to a prior study in the USA (2007) where there had been a 28% up-take. A further survey by McGraw-Hill (McGraw-Hill, 2012) found that this had increased to 71% in 2012 in the USA, which illustrates how fast BIM is being taken up. Combined BIM use between architects and contractors in South Africa is 35%, suggesting that South Africa is about five years behind the USA and about three years behind Western Europe with respect to BIM adoption.

The second survey was conducted by the NBS group for the Royal Institute of British Architects (RIBA) in 2011 and surveyed construction industry professionals on BIM (NBS, 2011). The professionals that were surveyed included architects, engineers, quantity surveyors and building surveyors, with the majority of respondents involved in architectural practices. Contractors were not included in the survey. The survey did not differentiate between the different professions of the participants and found that 13% of participants had adopted BIM. This contrasts with the findings of the McGraw-Hill survey (McGraw-Hill, 2010) where 36% of the industry had adopted BIM. The reason for this discrepancy is not known, but might be attributed to the fact that contractors were not included in the survey and that the McGraw-Hill surveys did not survey other industry professionals, such as quantity surveyors.

The surveys that were conducted in Europe and the USA compared practice size with BIM adoption and noted that once the smaller practices were discounted, most used BIM. The McGraw-Hill survey (McGraw-Hill, 2012: 10) showed that 91% of larger organisations had adopted BIM, compared to 71% overall adoption. 49% of smaller organisations had adopted BIM. A similar trend is observed in South Africa for architects, where BIM adoption correlates with practice size. An anomaly can be seen in that a small percentage of grade 7 contractors use BIM on most projects, while no grade 8s or grade 9s used it for most or all projects.

It was seen previously that there was no relationship between contractor grade and awareness of BIM. However, for contractors that had used BIM, there was a correlation between contractor grade and the level of BIM use, shown in Figure 4-9. Of the contractors that had used BIM, 9% of grade 7 contractors had used it on some projects, 11% of grade 8s and 29% of grade 9 contractors.

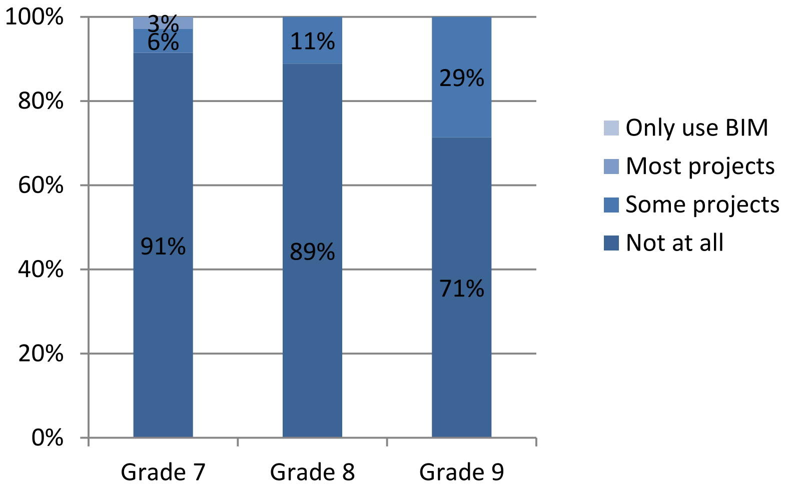


Figure 4-9 Contractor size and BIM use

A degree of correlation between architectural practice size and BIM use can be seen in Figure 4-10. Large architectural practices (50+ staff) used BIM on most projects. No correlation was observed between practice size and 'only use BIM', where a small percentage of all groups surveyed with less than 50 staff used BIM on all projects. There is a correlation between practice size and some use of BIM, although there is an anomaly between practices with 10 – 20 staff and those with 20 – 50 staff, who had a higher count for no BIM use.

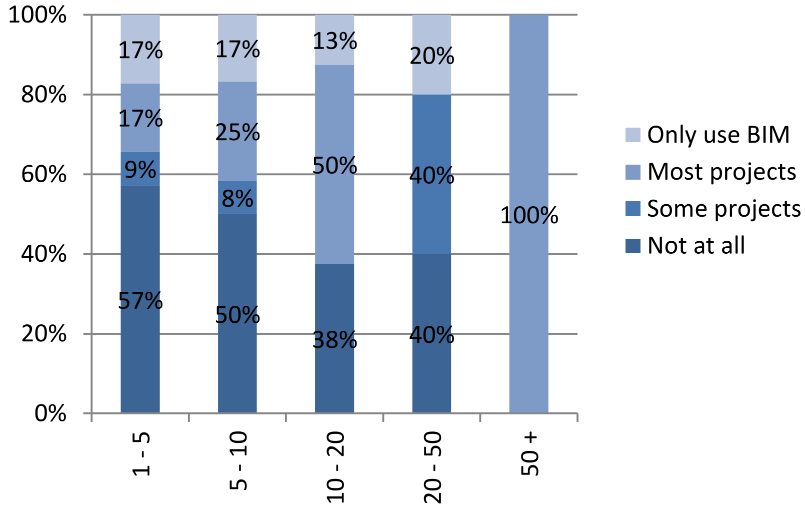


Figure 4-10 Architecture practice size and BIM use

4.4.3 Reasons for not using BIM

The architectural survey asked respondents that do not use BIM why they do not use it. The question and responses are shown below in Table 4-3. More than one answer was possible.

If you have not used BIM, what would be the reason?	
We are comfortable with our current system	46%
BIM is too expensive	15%
The technology is not yet mature	15%
The learning curve is too expensive	15%
The learning curve is too steep	7%
I/we don't consider that it would offer any benefit	0%
Not required for our type of business	13%
We already use BIM	46%

Table 4-3 Why architects don't use BIM

Those that answered that they already use BIM were removed from the dataset. The results are represented graphically in Figure 4-11.

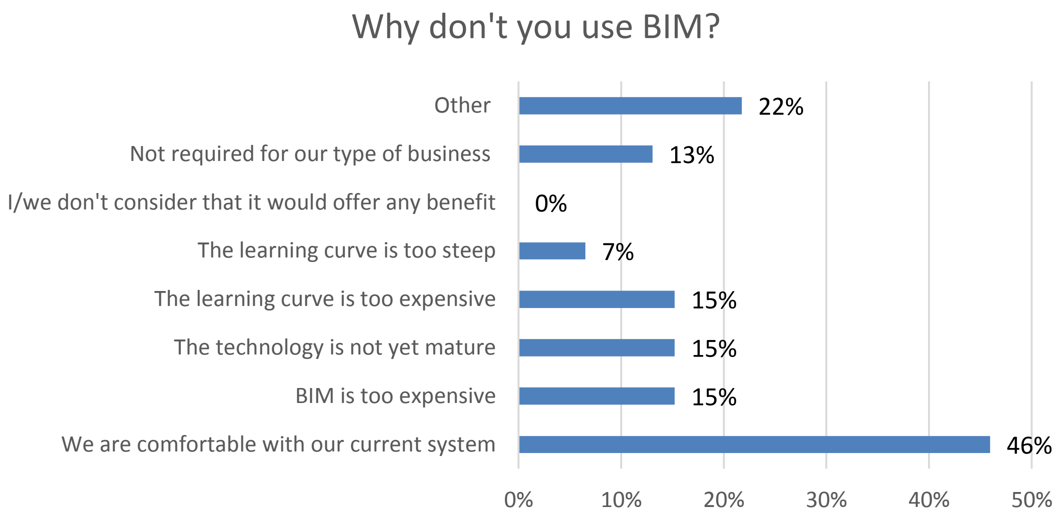


Figure 4-11 Reasons for not using BIM

Nearly half of architects (46%) that do not use BIM perceived that their current methods of working were satisfactory. Nearly one third (30%) of the respondents stated that BIM was too expensive to implement with respect to BIM software and training. The comments section of the survey (see appendices, page 216) revealed other reasons why they do not use BIM. These included:

- Incompatible file formats;
- Resistance to change from staff;
- Too much information is required too early for BIM to work;
- Revit is expensive and complicated – it doesn't make sense to learn it for a small office; and
- Not worth the drawing time for small projects.

The most cited reason was that participants were comfortable with their current systems. This could suggest that they are unaware of the clear benefits that BIM offers. The McGraw-Hill Survey (McGraw-Hill, 2012: 242) showed that the value of BIM is perceived to be greater by respondents that had used it longer, with a greater return on investment correlating with more time using BIM.

The cost of implementing BIM is perceived as a barrier to implementation. The second highest scored reasons for not using BIM were equally for BIM being too expensive and the learning curve being too expensive.

Respondents also thought that BIM was not required for their type of business, with an equal score for the technology not yet being sufficiently mature.

The results suggest that non-users are unaware of the benefits or the power of BIM, although for very small firms the cost of implementation may be prohibitive.

4.4.4 Proposed investment in BIM

Architects that did not use BIM were asked about their intentions to use BIM. Table 4-4 shows the results obtained. One answer was possible. The respondents that had used BIM were removed from the dataset.

If you do not use BIM, would you consider using it in the future?	Architects
No	14%
We may consider it when the technology becomes more mature	64%
We are currently investigating getting BIM	14%
Yes, we are planning to invest in it	8%

Table 4-4 Non-users' intentions to use BIM

It can be seen that a small minority (14%) had no intention of using BIM in the future, while 8% intended to invest in BIM. This can be compared to the BIM survey conducted in the UK (NBS, 2011: 12) where 84% of respondents projected that they would be using BIM on some projects within five years, representing an increase of 55%. The McGraw-Hill survey on BIM use in Europe (McGraw-Hill, 2010: 9) found that 69% of non-users intended to use or evaluate BIM in the future, although this included contractors and engineers.

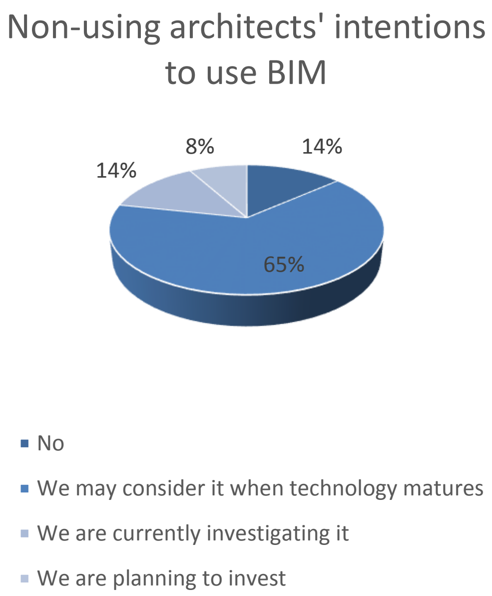


Figure 4-12 Architects' intentions to use BIM

Non-using contractors were asked a similar question, presented in Table 4-5 and graphically in Figure 4-13. Those that use BIM were removed from the dataset.

If you do not use BIM, would you consider using it in the future?	Contractors
No	14%
We are open to exploring its potential value for us	84%
We are actively evaluating it	2%

Table 4-5 Contractors' intentions to use BIM

A similar percentage (14%) of contractors had no intention of using BIM. However, the majority of non-using contractors were open to exploring BIM,

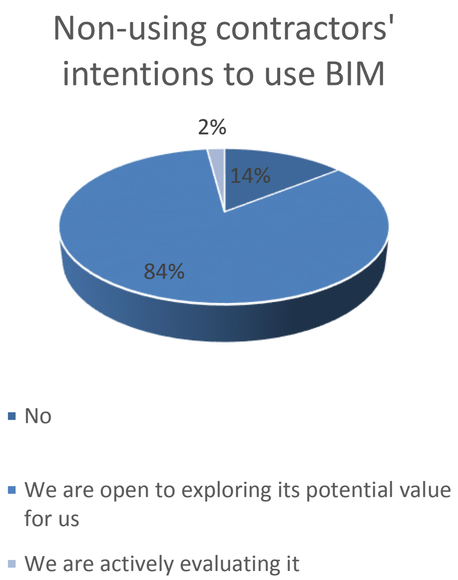


Figure 4-13 Contractors' intentions to use BIM

while 2% were actively evaluating the technology. This appears to indicate that the lack of use of BIM among contractors is not due to resistance to the technology, but rather a lack of awareness. One of the respondents noted that:

> "I believe that more education and information distribution is required for BIM to become an integral part of our industry."

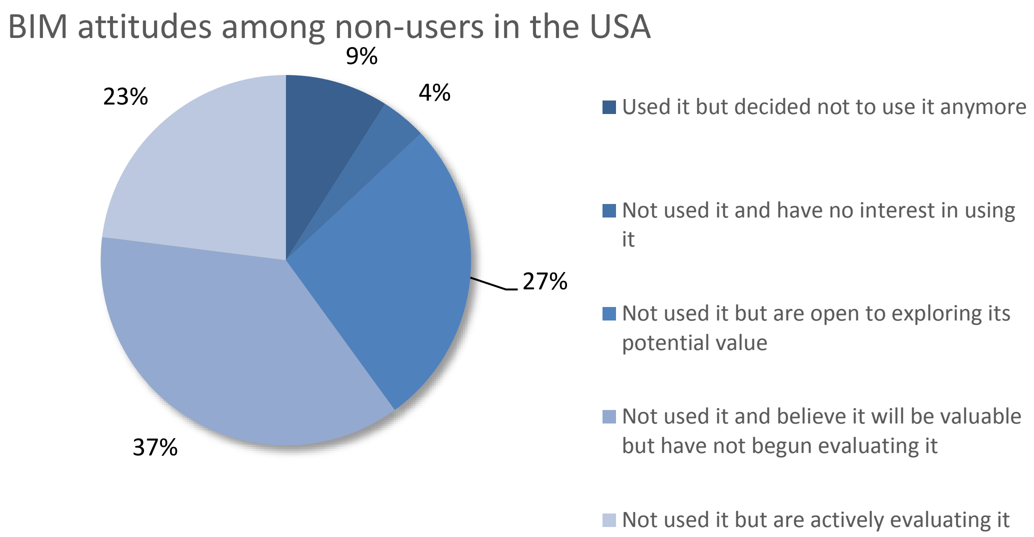


Figure 4-14 Non-users' intentions to invest in BIM (McGraw-Hill Construction, 2010)

The study that was conducted in the USA (McGraw-Hill, 2012) asked non-users if they intended to invest in BIM. The results are reproduced in Figure 4-14. 11% had no intentions of investing in BIM. This is slightly less than in South Africa, although a relatively small part of the industry in the USA does not use BIM.

4.4.5 How long have users been using BIM?

The question was raised to determine how long current users had been using BIM. The results could then be compared to other countries and were also used to determine a trend line of BIM take-up in South Africa.

How long have you being using BIM?	Contractors	Architects
Don't use BIM	**90%**	**48%**
Less than 1 year	**6%**	**3%**
1 – 2 years	**2%**	**6%**
2 – 3 years	**2%**	**8%**
4 – 5 years	**0%**	**8%**
More than 5 years	**4%**	**25%**

Table 4-6 Length of time using BIM

The results are presented in Figure 4-15 and show that a number of architectural practices have been using BIM for more than five years. The results show that there has been an increase in adoption recently. The trend line generated from the data shows how the use of BIM has increased substantially in recent years and compares favourably with other countries. The lines shown for the USA and Europe, obtained from the two McGraw-Hill surveys, were superimposed onto the graph.

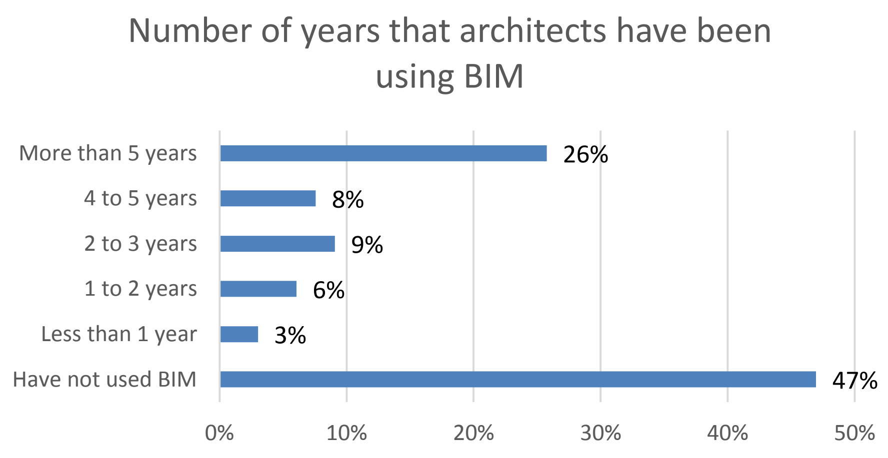


Figure 4-15 Number of years using BIM

Contractors' results are shown in Figure 4-16, but there were insufficient data to reveal a trend with adoption rates. A small percentage of contractors had used BIM for more than five years.

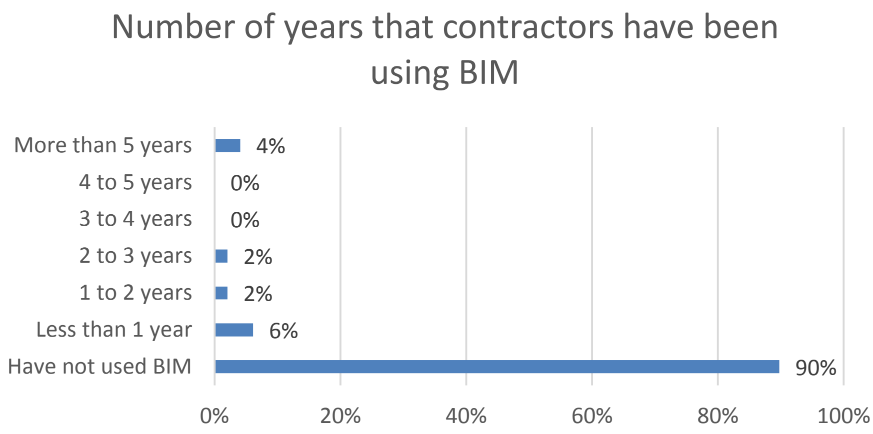


Figure 4-16 Time that contractors have been using BIM

The McGraw-Hill survey was compared with the previous surveys that were conducted to show a trend in adoption rates. Due to the lack of previous research in the South African industry, the survey results could not be directly compared to earlier surveys. However, a question was asked of both contractors and architects as to how long they had been using BIM. From this a trend line was generated to show the rate of take-up in South Africa, and could be used to compare South African adoption with other countries, shown in Figure 4-17.

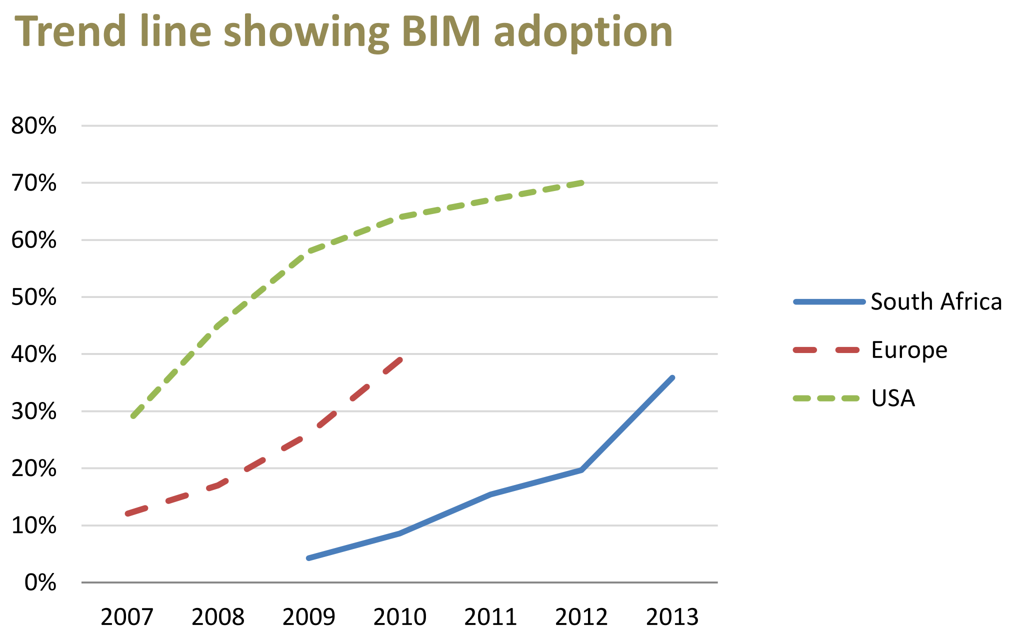


Figure 4-17 Adoption of BIM

It is seen that the adoption curve for the USA is now starting to flatten, which indicates that adoption has reached the late majority stage on the curve shown by Rogers (1983), discussed in section 2.4.10, page 53. Western Europe was in the early majority stage in 2010, while South Africa has now entered the early majority stage. This is illustrated in Figure 4-18.

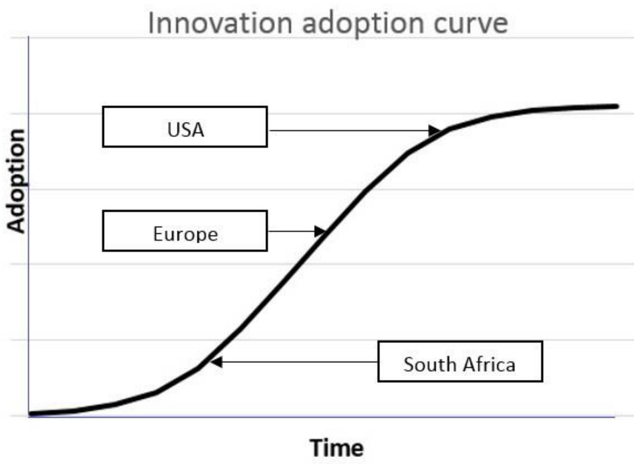


Figure 4-18 South Africa's position on the adoption curve

South African BIM awareness and adoption can be compared with the adoption categories discussed by Rogers (2003) (Section 2.4.8., page 50). The innovation adoption distribution is shown again in Figure 4-19 with BIM awareness and adoption rates plotted on the graph. It can be seen that South African architects fall into the early majority with reference to BIM adoption (53%) and the late majority for BIM awareness (79%). Contractors fall into the early majority with respect to awareness (27%) and the early adoption category for adoption (12%). Rogers (1983: 235) notes that once awareness levels reach about 30%, adoption of the innovation starts to occur significantly faster, and once adoption rates reach 20-25%, the diffusion of the innovation becomes difficult to stop (Rogers, 1983: 235). This suggests that BIM adoption within architectural organisations is well underway and the trend is likely to gain momentum. The awareness rate for contractors suggests that the adoption rates of contractors are likely to start gaining momentum.

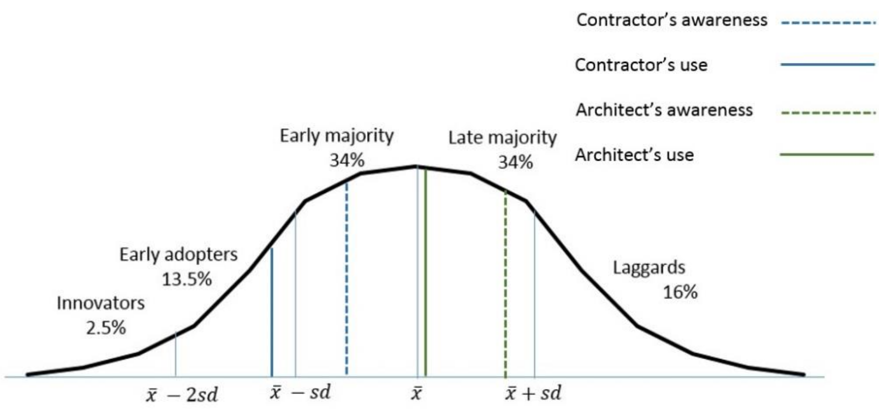


Figure 4-19 Innovation adoption curve (Rogers, 1983)

When the results of the survey are compared with the adoption rate of innovations discussed by Rogers (1983: 247), it can be seen that while the USA is in the late majority stage of adoption, South Africa is in the early majority stage of adoption for architects, while contractors are in the early innovators stage of the adoption curve. The trend seen in the USA suggests that BIM take-up in South Africa is likely to increase and will soon be in the late majority stage for architects and the early majority stage for contractors.

4.4.6 How users rate their skills

Architects were asked how they rated their BIM skills. This could be related to the functions of the software to determine if there was a correlation between perceived user skills and functions used. One answer could be given. The results are shown in Table 4-7 and represented graphically in Figure 4-20.

How do you consider your company's BIM skills?	All respondents	Use BIM
Don't use BIM	48%	
Elementary	12%	24%
Average	15%	29%
Good	24%	47%

Table 4-7 How users perceive their BIM skills

Respondents that did not use BIM were removed from the dataset. The results are illustrated in Figure 4-20 and show that nearly half (47%) of architect respondents that use BIM consider their company's BIM skills to be 'good'.

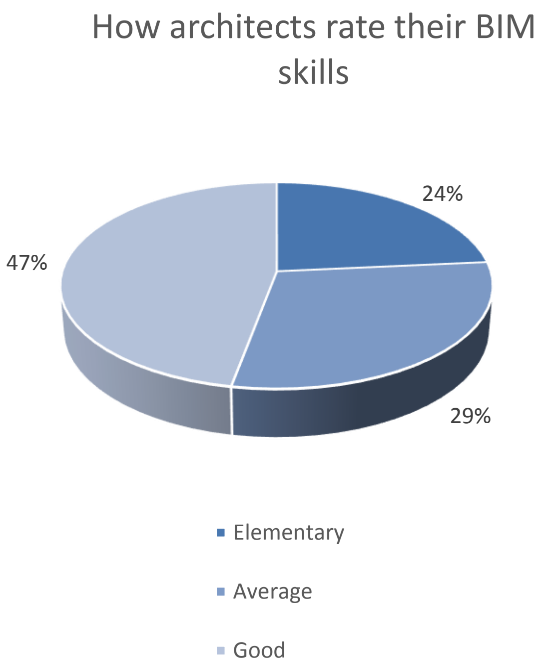


Figure 4-20 How architects rate their BIM skills

A correlation can be seen between the length of time using BIM and the perceived skills. Users that had been using BIM for longer (more than four years) perceived their companies' skills as better than those that had been using it for less time (Figure 4-21). New users (less than two years) rated their BIM skills lower. This indicates that users' BIM skills improve as they become more experienced. The next question compares users' levels of experience with the BIM functions that are used.

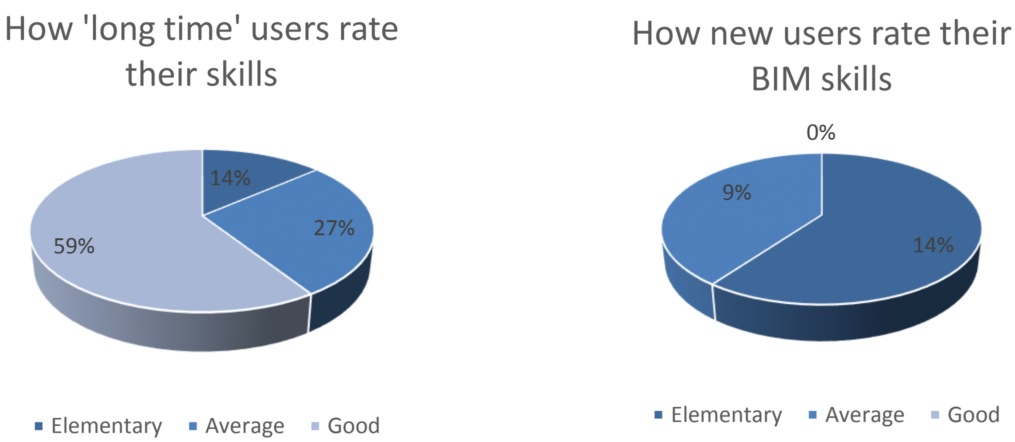


Figure 4-21 Length of time using BIM and perception of BIM skills

4.4.7 What do users use BIM for?

Please indicate what you typically use BIM for on a project	
Conceptual design	39%
Drawing production	46%
Visualisation	42%
Schedule creation	31%
Programming	6%
Quantities/costing	3%
Analysis, such as energy use and acoustic studies	16%
Collaborating with other consultants, such as engineers, using a shared model	33%
Collaborating with the contractor	7%
Do not use BIM	48%

Table 4-8 Features of BIM used by architects

Architects that used BIM were asked about the functions that they used. Architects that did not use BIM were removed from the dataset. The results are presented in Table 4-8 and represented graphically in Figure 4-22. More than one answer was possible.

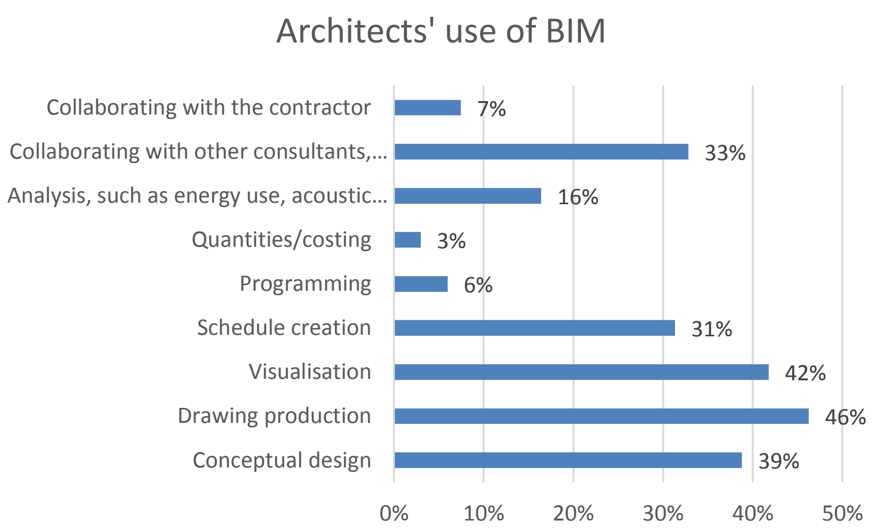


Figure 4-22 What BIM is currently used for

It can be observed that architects use BIM predominantly for its drawing, visualisation and conceptual design functions. A third of respondents indicated that BIM is being used to collaborate with other consultants. 30% of architects use BIM for scheduling while a minority are using it for more advanced features such as analysis, programming, costing and collaborating with the contractor.

The results for users that use only BIM and users that considered their organisations' BIM skills as good were compared. It can be seen that users that perceive that their BIM skills are good use more of the functions of BIM (Figure 4-23).

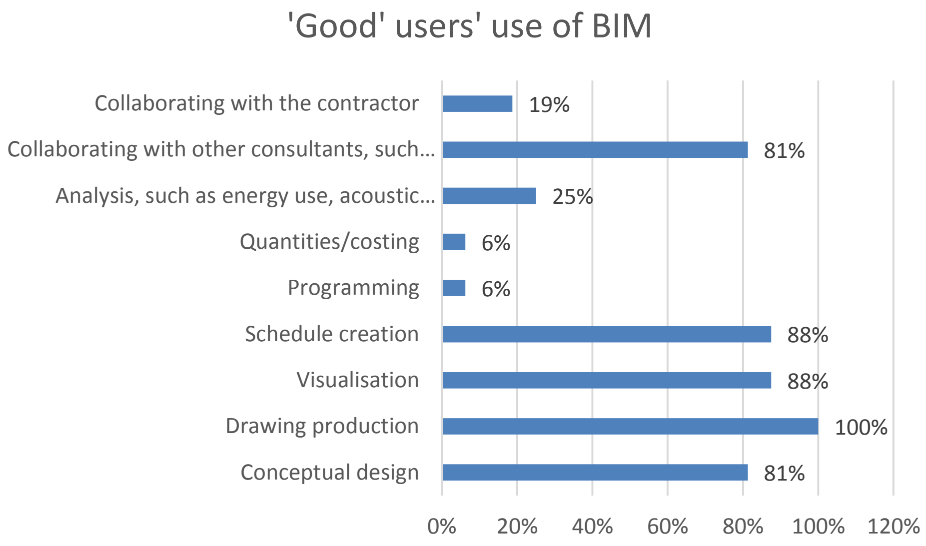


Figure 4-23 How 'good' users use BIM

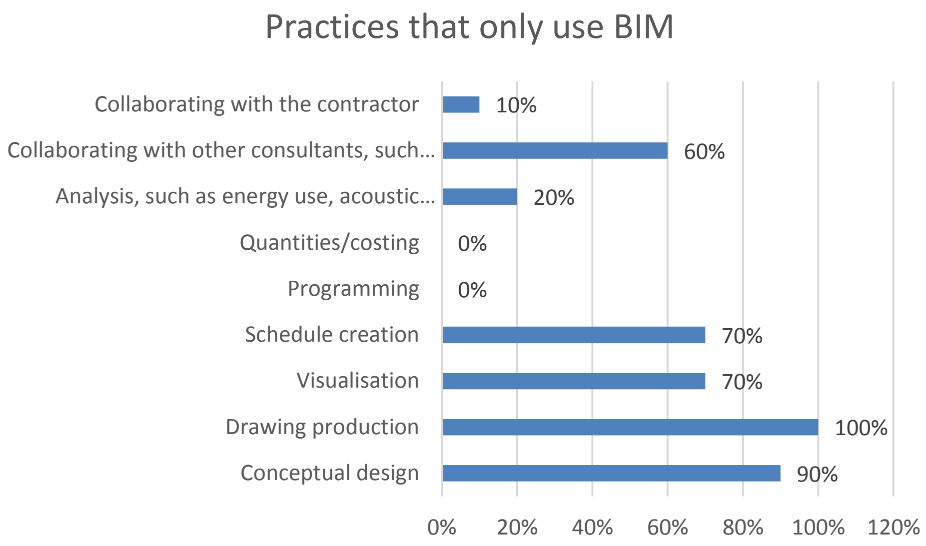


Figure 4-24 Functions used by users that only use BIM

Figure 4-24 shows a similar graph for users that use only BIM. A comparison of the two graphs shows that practices that perceive their skills as 'good' use all of the listed functions more so than architects that used BIM exclusively. The functions used by those that only use BIM echo the findings from other countries, where BIM is used predominantly for drawing production and conceptual design. Visualisation functions and schedule creation functions are also used. Organisations that only use BIM use it to collaborate with consultants to some extent, but use of other functions is limited. A small number (10%) use BIM to collaborate with the contractor, while 20% use the BIM for some kind of analysis. 4D (programming) and 5D (using quantities from the BIM for costing) are not used at all. It can be seen that companies that consider their BIM skills as 'good' still use only a minority of the functions available to BIM users, even in an isolated environment.

4.4.8 Processes that are perceived to be improved by BIM

Architects were asked which processes were perceived to be improved by using BIM. More than one answer was possible. The results are displayed in Table 4-9 and shown graphically in Figure 4-25.

Please indicate which of the following processes in your opinion are improved/streamlined by using BIM over 2D CAD:	
Conceptual design	39%
Drawing production	43%
Visualisation	46%
Schedule creation	36%
Programming	9%
Quantities/costing	16%
Analysis, such as energy use and acoustic studies	24%
Collaborating with other consultants, such as engineers, using a shared model	37%
Collaborating with the contractor	13%
Do not use BIM/don't know	39%

Table 4-9 Architects' view of improved processes

Architects that did not use BIM or did not know which processes were improved by BIM were removed from the dataset.

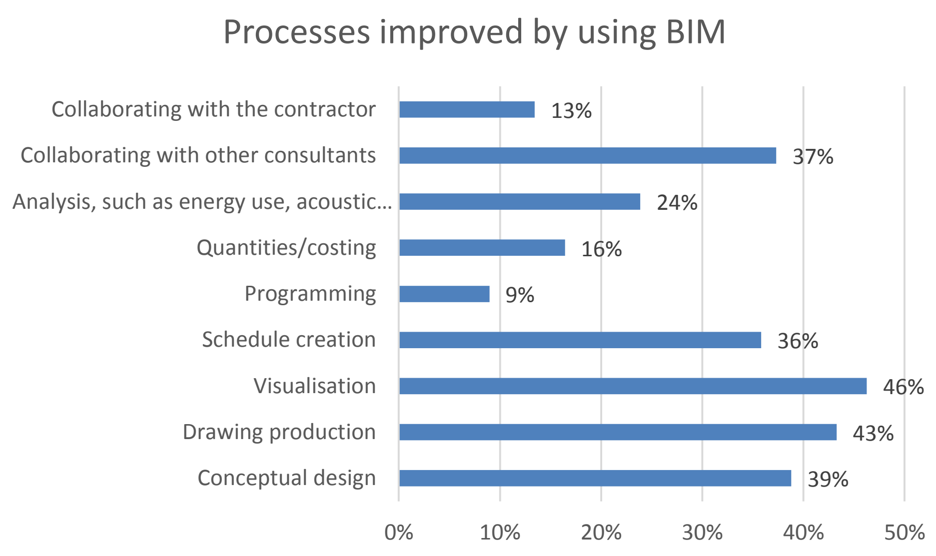


Figure 4-25 Architects' perceptions on processes improved by BIM

The results confirm that BIM is primarily seen to improve early conceptual design, visualisation and drawing production, as has been documented for other countries. However, a substantial percentage believes that BIM will improve collaboration with other consultants (37%). Some architects indicate that collaboration with the contractor is improved by using BIM, while a minority believe the more advanced features, such as analysis (24%), extracting quantities (16%) and project programming (10%) are improved by using BIM.

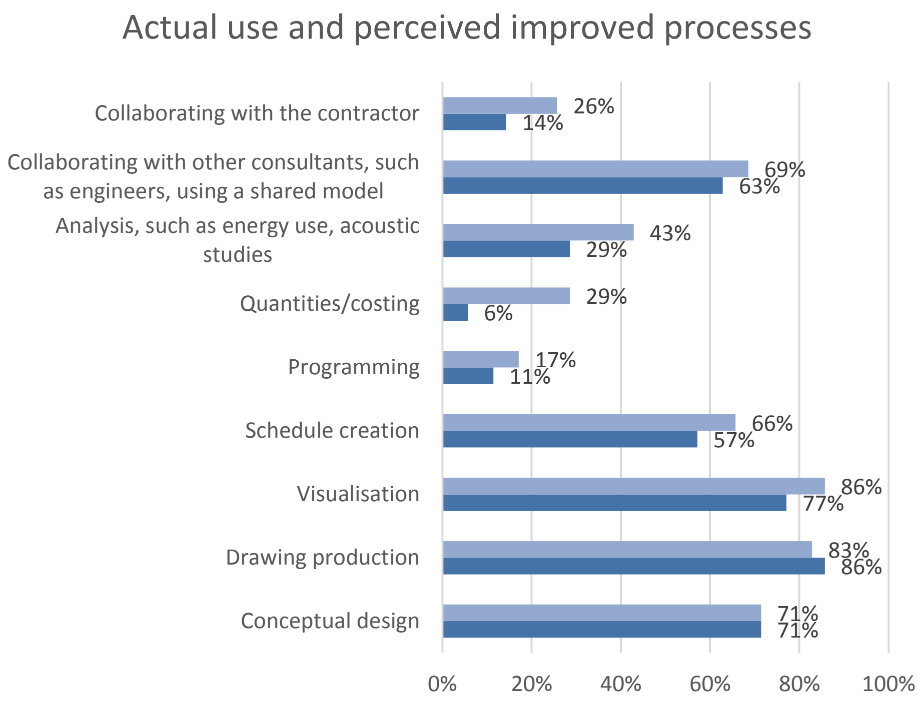


Figure 4-26 Comparison of actual use and perceived improved processes

Figure 4-26 compares architects' actual use (light blue) with their perceptions of processes that are improved using BIM (dark blue). The largest discrepancy observed is with regard to BIM's ability to use the inherent quantities for costing, where 29% of architects believe that BIM can improve the process, while only 6% use this function. However, architects perceive that most of the functions highlighted are improved by using BIM, besides drawing production, where their use of the function exceeds the perception that the process is improved. This may be explained by the fact that most architects that use BIM already use it for drawing production.

Contractors were asked a similar question. Those that answered 'don't know/don't use BIM' were removed from the dataset. One answer was possible. The results are presented in Table 4-10 and displayed in Figure 4-27.

Please indicate which of the following processes in your opinion are improved/streamlined by using BIM over 2D CAD:	
Drawing and schedule production	**10%**
Visualisation	**13%**
Programming	**8%**
Costing	**10%**
Analysis	**4%**
Collaborating with other consultants	**2%**
Do not use BIM/don't know	**79%**

Table 4-10 Contractors' perceptions of processes improved by BIM

Only 21% of contractor respondents that answered this question had an opinion, so it is difficult to give any validity to the results. Of those that answered, most saw BIM as a tool for information production (10%) and visualisation (13%). 10% perceived that it can improve or streamline the costing process, while 8% believed that it can improve programming. The results show that contractors are largely unaware of the advantages that BIM can offer.

The lowest score was for collaborating with consultants (2%), which substantially contrasts with the architects' score (26%). The research indicates that a single data source is one of the most important reasons to use BIM. It can be seen that the South African industry is largely unaware of the concept of BIM as a tool for collaboration.

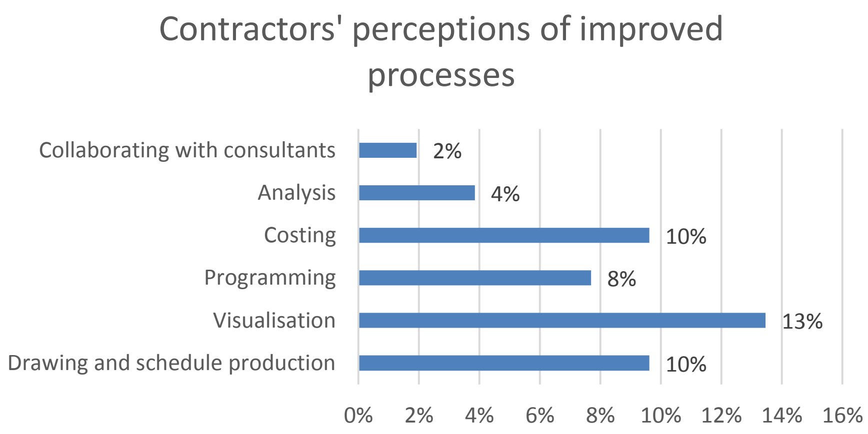


Figure 4-27 Contractors' perceptions on processes improved by BIM

4.4.9 How is information exchanged?

Architects were asked how they exchange information with other consultants. More than one answer was possible. The results are shown in Table 4-11, and graphically in Figure 4-28. The majority (63%) send electronic copies that were produced with traditional CAD software.

How do you exchange information with other consultants such as engineers or quantity surveyors on BIM projects?	
Hard copies generated by hand (drawing board)	7%
Hard copies generated by CAD software, such as AutoCAD	30%
Electronic copies generated by CAD software, such as AutoCAD	63%
Export BIM drawings to a format that they can use, such as DWG	39%
Export BIM model	24%
Allow access to the BIM model over a network	9%

Table 4-11 How information is exchanged

Very few architects exchange hard copies of drawings, showing that the advent of electronic drawings is now ubiquitous within the industry. Most architects that use BIM export the BIM information into 2D drawings for other consultants (39%), and many still distribute drawings as hard copies. To a limited extent, architects are sharing their central model with other consultants.

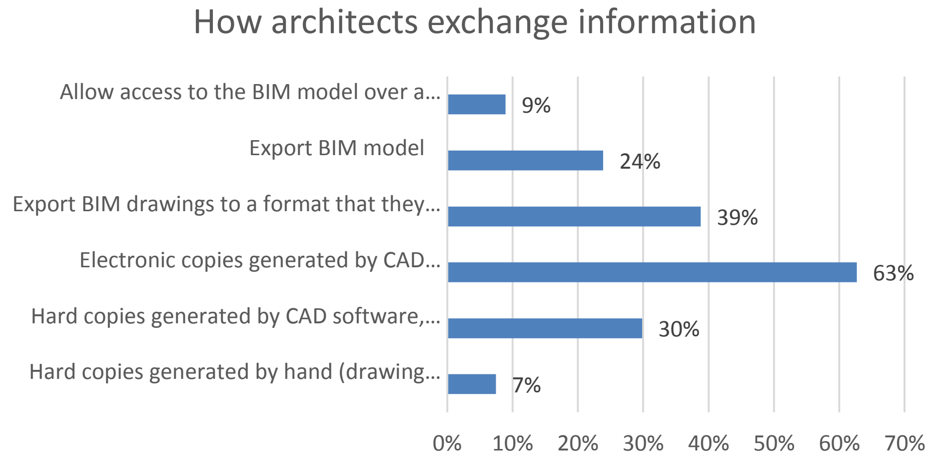


Figure 4-28 How information is exchanged

Although engineers were not surveyed, it can be seen that some architects collaborate with consultants such as engineers by exporting the BIM model or allow access over a network, which suggests that engineers are starting to use BIM to some extent. The McGraw-Hill survey (McGraw-Hill, 2012: 10) shows that engineer adoption (67%) is lower than contractor adoption (74%) and adoption by architects (70%) in the USA, although there is no substantial difference.

4.4.10 Authoring of models by contractors

Contractors that had used BIM were required to indicate who created their models. Although more than one answer could be given, no respondents gave more than one method. The question is presented below with the possible answers:

If you have used BIM who creates the model?	
We receive it from the architect/consultant	**10%**
We create our own model	**6%**
We use a third party to create the model	**4%**
Have not used BIM	**80%**

Table 4-12 Who creates contractors' BIM models?

Contractors that had not used BIM were removed from the dataset. The results are represented graphically in Figure 4-29. Due to the small amount of contractors that use BIM, most respondents could not answer this question.

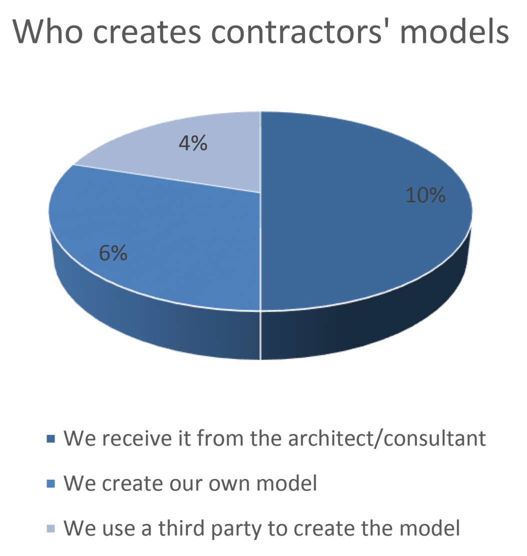


Figure 4-29 Authoring of contractors' models

Figure 4-29 shows that the majority of contractors that do use BIM receive the model from the consultants. This demonstrates that there is a degree of information sharing in South Africa. However, a small proportion (10%) see the value in using BIM even when the consultants do not create a model, or are not prepared to share the model. This echoes findings from other countries, where the value of BIM justifies the creation of a model as a tool during the construction process.

The power of BIM lies in collaboration and the concept that information is produced once. However, some contractors see the value of using BIM even in a non-collaborative environment, without a model produced by the consultants.

A survey conducted in the USA (McGraw-Hill, 2012: 10) noted that construction related activities are more recent applications of BIM, and that contractor adoption is more recent. However, the latest survey shows that adoption by contractors has recently surpassed that of architects in the USA.

4.4.11 Perceptions on shared information

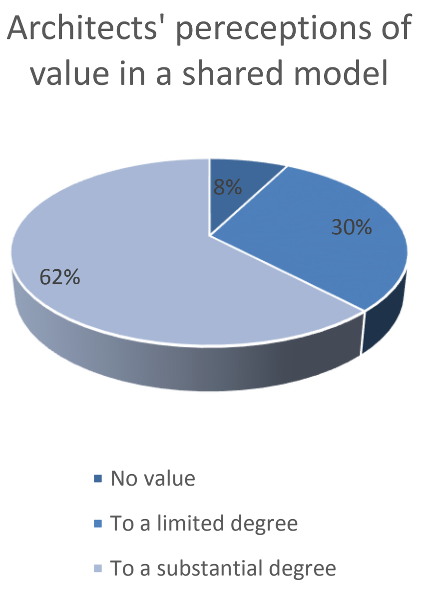
Both architects and contractors were asked if they believed there was value in sharing information from a central source. The question is presented below:

Do you think that there is any value in having a shared central building model that can be accessed by all project participants (partnering)?	Architects	Contractors
No value	8%	24%
To a limited degree	31%	40%
To a substantial degree	62%	36%

Table 4-13 Value of sharing information

More architects saw value in a central source of information that was accessible to project participants, where only 8% perceived that there was no value. This contrasts with the contractors' perceptions, where 24% believed that there was no value. It can be seen that 62% of architects believed that there is substantial value in sharing the model, while only 36% of contractors perceived this.

Although a small minority of the architects surveyed use a shared building model, a substantial majority see the advantage of doing so. The survey question did not differentiate between users and non-users. The number that answered 'no value' is similar to those that 'do not intend to use BIM in the near future', although no correlation between the two was observed.



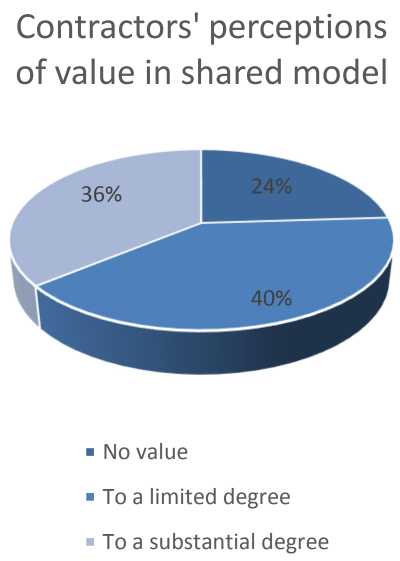


Figure 4-30 Value of shared information source

4.4.12 Advantages of collaboration

Both architects and contractors were asked if they thought that there were advantages to collaboration. The results are displayed in Table 4-14.

Are there advantages to using a collaborative arrangement with contractors/consultants	Architects	Contractors
No advantage	8%	13%
To a limited degree	30%	44%
To a substantial degree	63%	33%

Table 4-14 Perceptions on collaboration

It can be seen that most architects and contractors believe that collaboration has advantages although architects perceive this more so than contractors. More architects (63%) perceive that there is a substantial advantage when compared to contractors (33%), although most respondents from both groups believe that there are at least some advantages.

Most architects see the advantage of collaboration, and when compared to

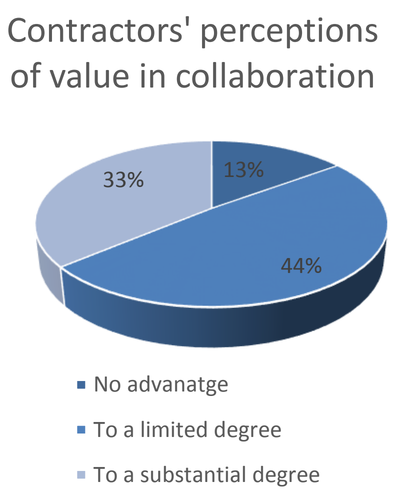


Figure 4-32 Contractors perceptions in the value of collaboration

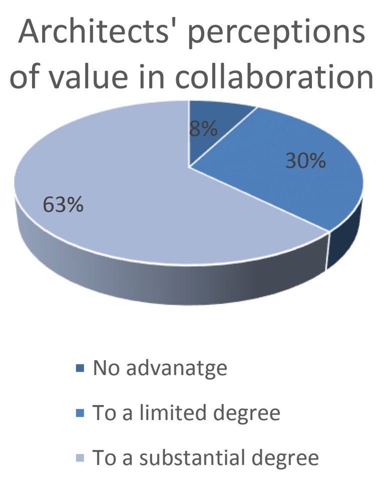


Figure 4-31 Architects perceptions in the value of collaboration

Figure 4-30, more so than sharing information with the contractor. However, contractors that were surveyed perceived more value in collaborating than sharing information. This shows that many architects and contractors do not see a relationship between collaborating and sharing information.

4.4.13 Factors that limit collaboration

The survey sought to reveal the perceptions of both contractors and architects on the limiting factors of collaboration. More than one answer could be given. The question is presented below.

What factors could limit collaboration/partnering on construction projects?	Architects	Contractors
Confidentiality of information	35%	39%
Lack of trust or communication	32%	25%
No clear contractual boundaries	40%	20%
The South African environment makes it difficult	23%	16%
Other reasons	6%	4%

Table 4-15 Perceptions on factors that limit collaboration

Table 4-15 compares the responses between contractors and architects. These are presented graphically in Figure 4-33. Architects perceived contractual boundaries as the main limiting factor, with 40% listing this. Only 20% of contractors saw this as a limiting factor. Contractors (39%) listed confidentiality of information as the main limiting factor, and many architects (35%) also perceived this. The perception that a lack of trust or communication limits collaboration was the second most important factor that limited collaboration for contractors and third most important for architects. Nearly a quarter of architects (23%) and 16% of contractors perceived that the South African environment was a factor that limited collaboration.

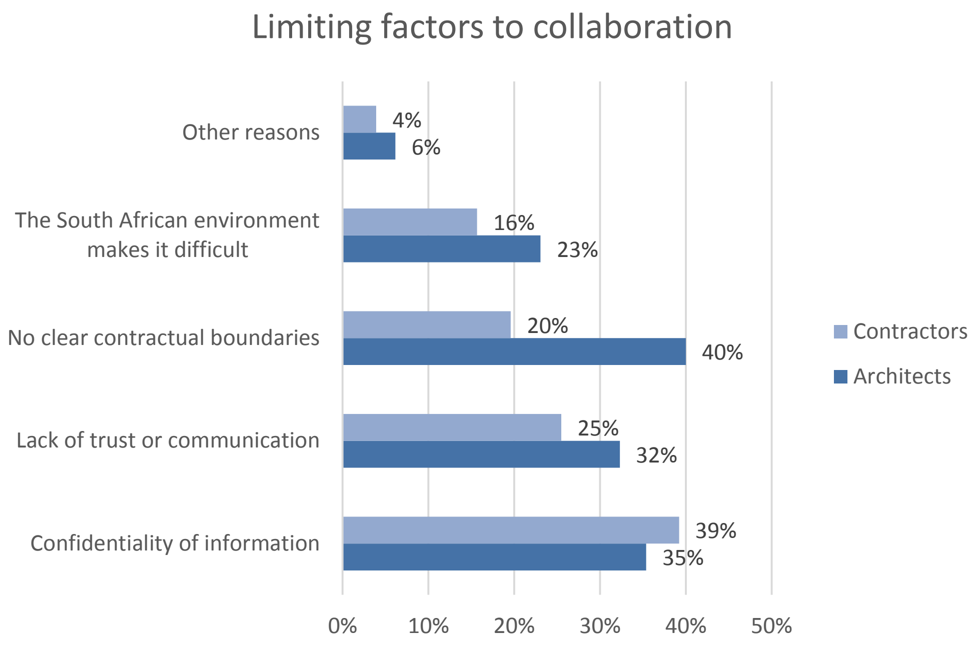


Figure 4-33 Factors that limit collaboration

4.4.14 Respondents' additional comments

A section was included in both surveys for respondents to make additional comments. These are listed in 8.3, page 216, but some are highlighted here. Three architects noted that consultants all use different software, which makes any kind of collaboration during the design phase difficult. Three architects suggested that the cost of the software or training does not justify investing in BIM. A large proportion of architects that commented noted that other consultants or contractors do not use BIM and they are therefore unable to collaborate using a BIM platform. One architect, who was aware of the benefits of using BIM, noted that staff were resisting the use of BIM.

These factors have been addressed by commentators. Smith and Tardif (2009: 38-39) discuss the industry foundation classes (IFCs), where most BIM software supports open-standard data formats. They note that most licensees are not aware of this, or have never attempted to use the IFC data format to exchange data from different software platforms. Architects that noted that other consultants do not operate in a BIM environment do address a current limiting factor in South Africa. However, it was seen from the survey that some consultants do use BIM to collaborate with other consultants.

One contractor said that they do not use BIM because they are not involved in the design process. Another contractor saw the value of using BIM but noted that the architect's model is not complete enough for meaningful costing or scheduling. It was previously shown that contractors in the USA increasingly develop their own models in order to improve the workflow process during the construction phase.

4.5 Summary of survey findings

The survey results show that there is increasing awareness of BIM in South Africa among architects, with trends and usage patterns reflecting the findings of other countries. However, South African contractors are largely unaware of the concept with only 4% of contractors saying that they were familiar with the concept. This varies substantially with observations from other countries, such as the USA where the majority of contractors had already adopted BIM. Early adopters in the architectural category are operating in a BIM-only environment, while none of the contractors surveyed said that they used only BIM. A small minority (2%) of contractors were working in a predominantly BIM environment. When these trends are compared to adoption rates in other countries and the diffusion of innovation theory developed by Rogers (1983), referred to in section 2.4.10, it may be anticipated that architectural adoption will start moving into the late majority phase, while contractors are entering the stage of awareness of the innovation that suggests that adoption rates should start to increase. There was a correlation between architectural practice sizes, but no such correlation was observed for contractors. This may be due to the general lack of awareness of BIM among South African contractors, but might also be attributed to the fact that the three grades of contractors that were surveyed were the three largest groups in terms of company turnover.

The use of BIM in South Africa by architects reflects current practices observed elsewhere, where BIM is used to replicate traditional methods, discussed in section 2.4.4. A minority of architects appear to use BIM in a more advanced way to analyse buildings, prepare quantities, produce schedules, collaborate with other consultants and, in some cases, share information with the contractor. Most architects, including those that use BIM, use traditional methods of information transfer, by printing and mailing drawings, or exporting them to a different format to send electronically to other consultants. Zahiroddiny (2012) notes that resistance to change, which is discussed in section 2.4.4, is a primary reason for this.

The survey also revealed that although BIM use is widespread among larger architecture firms (more than five staff), their use of it reflects findings that have been observed in other countries, where many of the functions that can aid in collaboration have not been used.

Both architects and contractors see the value of having a central information source and collaborating with other parties, although both see confidentiality of information as being a problem. Architects (42%) rated a lack of contractual boundaries as the main limitation to collaboration. A smaller proportion of contractors see this as a limiting factor (20%). Both architects (31%) and contractors (25%) saw lack of trust or communication as a limiting factor. Architects (24%) and contractors (16%) list the South African environment as being a limiting factor. It can be seen that a minority of both contractors and architects list the South African environment as a factor that hinders collaboration. This opinion appears to contradict hypothesis 1, stated on page 7. However, the highest score listed by architects (40%) as a limiting factor was contractual boundaries. Contractual boundaries for public works projects are pre-defined, allowing little scope for alternative contractual arrangements, which is a result of the South African environment.

A minority of both architects (8%) and contractors (24%) see no value in a shared source of information. However the highest score for contractors (39%), and the second highest score for architects (35%) listed as a limiting factor was confidentiality of information. This dichotomy can be addressed by collaborative contractual arrangements, and it was seen in section 2.4.9 that progressive countries are addressing this at a national level.

When participants were asked what processes they thought were improved by BIM the highest score for both architects (35%) and contractors (13%) was visualisation as the main benefit from using BIM. Rischmoller (2007: 90) states that CAD vendors had seen that the visualisation capabilities of new software releases would be the most obvious capability that would increase their market share. Contractors (10%) perceived that drawing and schedule production was nearly as important, while architects saw drawing production as the second most important factor and schedule production as the third.

Only 2% of contractors perceived that BIM will streamline the process of collaboration between contractors and consultants. Architects rated the collaboration ability of BIM as being more advantageous, with 36% perceiving that BIM streamlines collaboration between consultants and 14% believing that it streamlines collaboration with contractors.

The survey shows that architects are more aware of BIM and are largely adopting it. The trend that is observed correlates with that observed in other countries and usage patterns are similar. However, contractor awareness and take-up is substantially behind architects, and substantially behind awareness and adoption in the USA where 74% of contractors have adopted BIM (McGraw-Hill, 2012: 10). Most contractor respondents (79%) did not know what processes were improved by using BIM. The findings suggest that while contractors from other countries are embracing BIM, South African contractors have not yet recognised its potential.

Chapter 5 – Examination of the case study findings

The survey results show that architects do use BIM, although its main function is authoring of documentation. The case study examines a project where BIM is used in a stand-alone environment, which is typical of projects in South Africa where a one-stage tender process is used. The case study illustrates an example of BIM being used to replicate previous working methods in a CAD environment as was noted in the literature review (such as Race, 2007: 109; Davis, 2007: 16).

The project was a public works project to construct a new multi-purpose centre in the Eastern Cape. The projected value of the project was R29 283 243 (06/2010) and the building had a footprint of 2206m², with a total of three floors. Sustainability features were incorporated, including solar water heating, natural ventilation system, rainwater harvesting and day-lighting considerations. The building consisted of a concrete frame, with a steel roof structure and steel cladding support.

The project architect was requested to complete the survey independently so that a comparison could be made with the architectural respondents. The responses of the case study architect are shown below in Table 5-1.

Question from survey	**Case study architect's responses**
How aware are you of BIM?	Familiar with the BIM concept
Please indicate the size of your practice	10-20 staff
Do you use BIM?	Some projects
If you have not used BIM, what would be the reason?	The technology is not yet mature
If you have not used BIM, would you consider using it in the future?	Already use BIM
How long have you been using BIM?	2-3 years
How do you consider your company's BIM skills?	Average
Please indicate what you typically use BIM for on a project	Conceptual design, drawing production, visualisation, schedules, collaborate with other consultants

Please indicate which of the following processes in your opinion are improved/streamlined by using BIM	Conceptual design, visualisation, schedules, quantities
How do you exchange information with other consultants such as engineers or quantity surveyors on BIM projects?	CAD hard copies, CAD electronic copies, export from BIM
Do you think that there is any value in having a shared central building model that can be accessed by all project participants (partnering)?	To a substantial degree
Are there advantages to using a collaborative arrangement with contractors?	To a limited degree
What factors could limit collaboration/partnering on construction projects?	Confidentiality of information, other reasons

Table 5-1 Responses to the survey questions by the case study architect

5.1.1 Analysis procedure

This section analyses the building information model that was created by the architects. This reveals the environment in which the information is created. Typical BIM components are inspected to show how they were created and the level of development (LoD) that was used. The methods of controlling the documents created from the model and their distribution were examined. The model was checked to determine if it could have been used for the more advanced features of BIM, such as analysis or costing.

5.1 The data

The first data set was received from the architect. Due to the large amount of information (66GB, 44 000 items) the data were transferred using an external hard drive. The data were then cleaned to eliminate duplicates, manufacturer's data, pre-construction photos and redundant or superseded BIM models and components. The data were then organised in new files to simplify the codification process. The data file was reduced to below 4GB of data with less than 2 000 items, largely as a result of deleting duplicate and unnecessary BIM data.

5.1.1 Information stewardship

Smith and Tardif (2009: 12) suggest that the three dimensional abilities of BIM are not its main advantage, but rather that it is structured information (organised, defined, exchangeable). Unstructured information is difficult to identify, manage or exchange. If information is difficult to find, it becomes difficult to reuse, and it may be easier to produce it again from scratch.

The information received from the architect was not filed in a manner that it would be easy to extract information at a later stage. Although comparisons have not been made with other companies, this does illustrate the weaknesses of relying on manual systems to file data efficiently.

5.2 The BIM model

The BIM model was analysed from two perspectives. The first was to open the model and to examine the procedures and features that were used in the project. Components within the model were examined so that the component level of development could be determined. The overall level of development of the model was checked to confirm what degree of analysis would be possible and if some of the more advanced features of BIM could have been used. The models and documentation were inspected to confirm how information and documentation were controlled within the project. The second method to analyse the model was to export different versions into a database, where functions used and data within the model could be examined.

5.2.1 Analysing the model

The BIM model was opened using the Autodesk Revit software. Due to the large size of the model (about 270MB), graphics which were unnecessary for the analysis were deleted to make the model more manageable. Redundant components and views were also deleted. The data were then exported from the model into a database programme to analyse the fields. The used and unused fields indicate which of the BIM features had been used.

The opening and examination of the model revealed that the architects had used the BIM software in a manner similar to that documented for other countries. The model had been used to generate drawings and 3D views and, to a limited extent, schedules. It was not used for any of the other functions, such as revision control, or quantities schedules. The approach to these functions was done using methods typical of CAD use, such as unlinked spreadsheets and manually inserting revision data and history on the separate drawings.

Typically, when BIM is used in an architectural practice, the model evolves from a conceptual model to a construction model, with sufficient information for the tender process. Issued drawings are recorded in Portable Document Format (PDF), which provides a historical snapshot of the development of the project. The analysed project did not follow this practice, but instead filed a version of the model that was current at the time of issue. This practice is generally avoided due to the large amount of data that is stored (over 50GB of drawing information was generated and filed for the project). It is not usually necessary to keep versions of the model as it is unlikely that a historical version of the model will again become live and need modification. However, this provided a unique history of the development of the model which allowed analysis that would not have been possible if typical procedures had been used.

In order to make a meaningful comparison, the hypothetical model contains components and systems that are suitable for accurate analysis and costing. The detail levels are based on the 'level of development' (LoD) concept, discussed briefly in 2.4.5, page 46. The American Institute of Architects (AIA) has released a document, known as the E202, Building Information Modeling Protocol Exhibit (2008), which defines the detail that is expected for components for each level of development. These are summarised below:

> LoD 100 consists of overall building massing, with areas, volumes, location and orientation modelled in a representative way, or represented by 3D massing. The model may be analysed based on volume, area and orientation. The model may be used for conceptual costing, based on areas and volumes. The model can also be used for project phasing and to determine an estimate of the likely duration of the project.
>
> LoD 200 consists of components that are modelled as generalised systems or assemblies with approximate quantities. The performance of selected systems can be analysed. Pricing at this level is still conceptual, but includes systems which provide more accuracy than LoD

100. Major elements and systems, such as walls, can be scheduled and time scaled.

LoD 300 contains information that is more detailed and accurate. Model elements are modelled as specific assemblies, accurate in terms of quantity, size, shape, orientation and location. The level of development is sufficient to generate traditional construction documentation and shop drawings. Specific performance criteria can be analysed for selected systems. Cost estimates are based on specific data. The model can show ordered, time scaled appearance of detailed elements and systems.

LoD 400 model elements are modelled as specific assemblies that are accurate, with complete fabrication, assembly and detailing information. Non-geometric information can be included with components. Model elements are virtual representations of the proposed elements. The model can be analysed based on specific model elements and costs are based on the actual cost of specific elements.

LoD 500 represents the 'as built' model and contains information that can be used to operate and run the facility.

The model components could be examined to determine their LoD. Components within the model generally had sufficient detail for LoD 200, as they were mainly symbolic, although some components, such as walls had sufficient detail to comply with LoD 300. An example of a LoD 200 component is shown for a window from the model.

5.2.1.1 Component generation

Figure 5-1below shows the properties for an aluminium window that was used in the model. It can be seen that there are parameters for the height, width and inset (distance from wall face). The component number and manufacturer are included and there are parameters for the glazing and frame materials, which are required for 3D visualisations. Each of the material parameters can be adjusted on many levels for accurate photorealistic visualisations. The 'Wall Closure' parameter determines how the component interacts with its host, which is the wall. Adjusting the ‘Head Height’ parameter changes the window’s vertical position in the wall. The window can be moved horizontally by moving it in the model.

Type: 1800mm x 1800mm

Parameter	Value	Formula	Lock
Construction			
Wall Closure		=	☑
Construction Type		=	☑
Dimensions			
Height (default)	1800.0	=	☑
Width (default)	2500.0	=	☑
IFC Parameters		=	
Analytical properties			
Other			
Material Glass	Glass	=	
Material Frame	Aluminium	=	
Inset	115.0	=	☑
Head Height	2025.0	=	☑
Identity Data			
Model		=	
Manufacturer	Kal-Aluminium	=	
Assembly Code	B2020110	=	

Figure 5-1 Window component from BIM model

The advantages over the traditional CAD systems become apparent. The window’s height can be adjusted by changing a field, and the size can be adjusted. The wall opening adjusts automatically, and all drawings that show the window are updated. The window schedule, if used, will update. The wall area will be updated if these are included in any schedules or material lists.

When the window component is compared with the LoD categories, it can be seen that the window component satisfies level two (LoD 200). Weygant (2011: 80) describes LoD 200 components as primary components. LoD 200 components are representative and are more like symbols than actual components.

However, when the window component is compared with a more detailed component, the true advantages of BIM can be seen. Figure 5-2 shows some of the parameters that are included for a window component that has been developed by a US window manufacturer (Kawneer). The window complies with LoD 400, where the component can be used for document generation, analysis and contains accurate costing information. The BIM component can be downloaded from their website.

The component is data rich and includes properties that are relevant to other consultants and useful information for the contractor. Links are included to manufacturer's documentation and information is included that is used for analysis. Window sizes are predetermined so that the component name corresponds with the component size. The window details shown in Figure 5-1 showed the type of component as '1800mm x 1800mm', whereas the actual width of the components was 2500mm.

The literature review showed that architects typically use BIM for drawing production, and not as a collaboration tool and this can be seen in the South African industry from the survey. A higher degree of data inclusion in the model has benefits for the users. However, to model this level of detail is a time consuming process, and accurate modelling of components requires an advanced skill level by the author. Modelling this degree of complexity may be beyond the skill set currently found in most practices. This reveals a barrier to efficient BIM use in South Africa. In countries that use BIM to a more advanced level, the supply chain supplies information that is useful. The manufacturer produces the components for the model. This makes sense, as the manufacturer in any case knows this level of detail. BIM use in South Africa does not only offer benefits for the architect, but the whole industry. A high level of BIM use will require that the supply chain information can be used efficiently for data-rich BIM use.

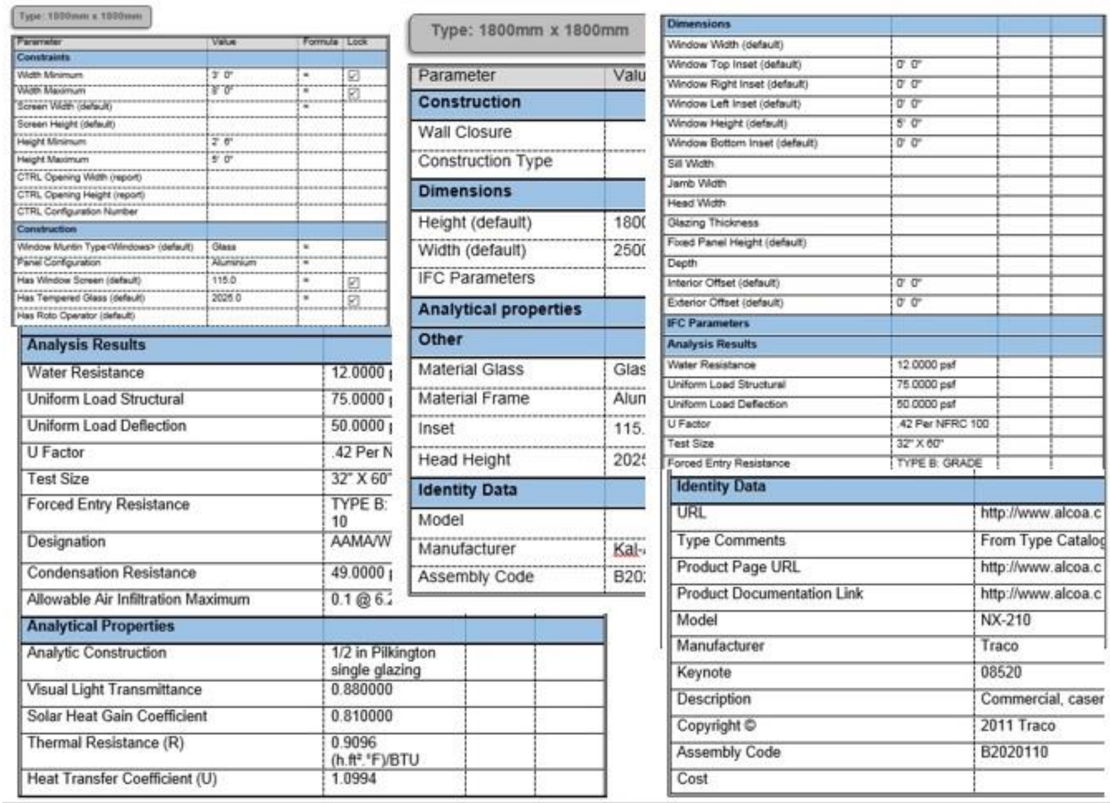


Figure 5-2 Information rich component from supplier

The components that are available from suppliers reveal how BIM is being used in a particular country. In South Africa, a search of window suppliers' websites shows that they provide very little usable data. Most do not even supply CAD details of their products. In the UK, window suppliers provide PDF details and CAD details of their components. In the USA, the supply chain provides BIM components of their products that are data-rich and can be directly inserted into building models.

A case study cited in the McGraw-Hill survey (McGraw-Hill, 2012: 36) quotes John Cross, vice president of the American Institute of Steel Construction (AISC), who discusses how the industry is developing data maps that define the exchange of BIM data within the supply chain and related disciplines. Weygant (2011: 32) shows how manufacturer's components can generate the specification text for inclusion in the project specification. He notes that the process is not currently easy or seamless, but that specification providers are trying to create an interface that allows information to pass between the BIM software and specification document. As BIM use increases this is likely to become more functional.

5.2.2 User ability and the use of parametric functions

The model was analysed to determine the competency levels of the users and how they used the parametric functions that were available.

5.2.2.1 Using project parameters on drawing sheets

Functions exist to include project data on the drawing sheets, which are drawings with a title block and drawing number. Examples of fields include:

- Project name;
- Project number;
- Revision;
- Revision dates;
- Revision history;
- Drawing number;
- Drawing name; and
- Client name and address.

These fields were created on the sheets, but as manual text notes. The authors repeated this information for every new sheet that was created. Although Revit has the capability to do this automatically, the process used replicates the CAD process. When used properly, each field is required to be entered only once for the project. The observed practice is inefficient in three ways. Firstly, the additional text for each drawing sheet increases the size of the file which can slow down the performance of the model. Secondly, a significant amount of time is wasted recreating the information on every sheet. Thirdly, errors are more likely to occur. Using this standard Revit function might have saved significant time that was spent on the BIM and improved consistency within the documentation.

5.2.2.2 Revisions

Revit contains a function for highlighting changes to the drawing sheets, known as revisions. Traditionally, this was achieved by drawing a ‘revision cloud’ around the modified item, and noting the change on the drawing, linked to a revision number. Revit has the ability to produce revision clouds with relevant revision numbers attached to them, such as the revision date, revision number and a note of the change. This can then be recorded in a revision table that can be inserted into the drawing sheet for a revision history. The analysed model showed that revision clouds had been used to highlight changes to the drawing, but the information inherent with the revision cloud had not been used – revision history was added manually. As a result, the revision history did not accurately coordinate with the revisions recorded on the drawings or the drawing issue sheet, resulting in inconsistent documentation.

5.2.2.3 Linked drawings

The BIM model contained 25 referenced drawings, totalling about 48MB. The referenced drawings were generated in AutoCAD, mainly by the structural, mechanical and electrical engineers. Structural sub-contractor drawings were included. Analysing the structural drawings reveals the processes that were used to generate the structural information. The architects generated the layout drawings using the BIM software. These were exported as DWG (native AutoCAD file extension) files from the BIM and sent electronically to the structural engineer. Structural input was then added to these drawings and returned electronically to the architect. These were imported as an aid to update the BIM model with the structural data. The workflow process is illustrated in Figure 5-3. Figure 5-4 shows the process when both engineer and architect use a coordinated model. The comparison illustrates the cumbersome and time consuming methods that are used to communicate information and how these consist mostly of non-value adding tasks. Each manual process has the potential to introduce errors into the documentation.

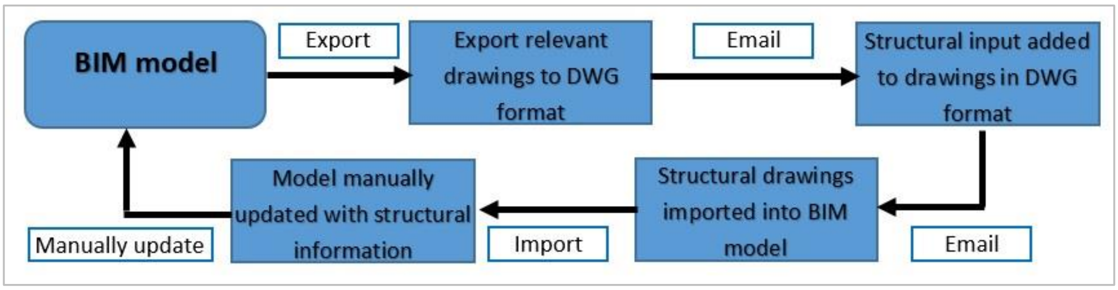
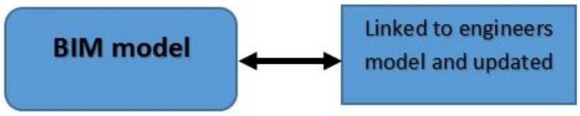


Figure 5-3 Process used to add structural information to the model

Figure 5-4 Desired process for BIM



The software that was used (Revit) has the ability to link to industry specific versions, such as Revit Structures for the structural engineers and Revit MEP for mechanical and services engineers. These versions are used to link to the architect's model and provide coordinated content that can be analysed by the relevant consultant. This practice can save significant time, avoids the manual processes that were observed, and is likely to result in fewer errors.

5.2.2.4 Scheduling

It was observed that the architects had used the BIM to create door schedules and curtain wall components. The use of the scheduling features has many advantages, as the schedule reflects what is happening in the model. An example is where a door is added to the model. All views that show the door are updated. The door schedule is updated with the new door and its parameters. The amount of wall is reduced and this is computed and deducted from the wall schedule or materials quantities where these are used. The software has the ability to create schedules of any of the components or systems that are contained within the model.

The project documentation shows that some of the schedules were created independently in separate software. These included sanitary and room schedules. The disadvantage of this practice is that it takes longer to produce the schedules and they are unlikely to be as accurate, as they are un-coordinated.

5.2.2.5 Building analysis

The model was checked for completeness to determine if analysis could be performed. It was found that the components, such as window components, did not have sufficient detail for analysis. Other components such as walls were accurately modelled in terms of make-up, with layers that represent actual layers in walls. However, details that could be used in energy or heat loss analysis were not included. The wall component details are shown in Figure 5-5 and it can be seen that the fields for thermal resistance (R) and thermal mass are not included. It was also observed that not all rooms were modelled as enclosed spaces and room volumes were not computed, which would have been required for any analyses.

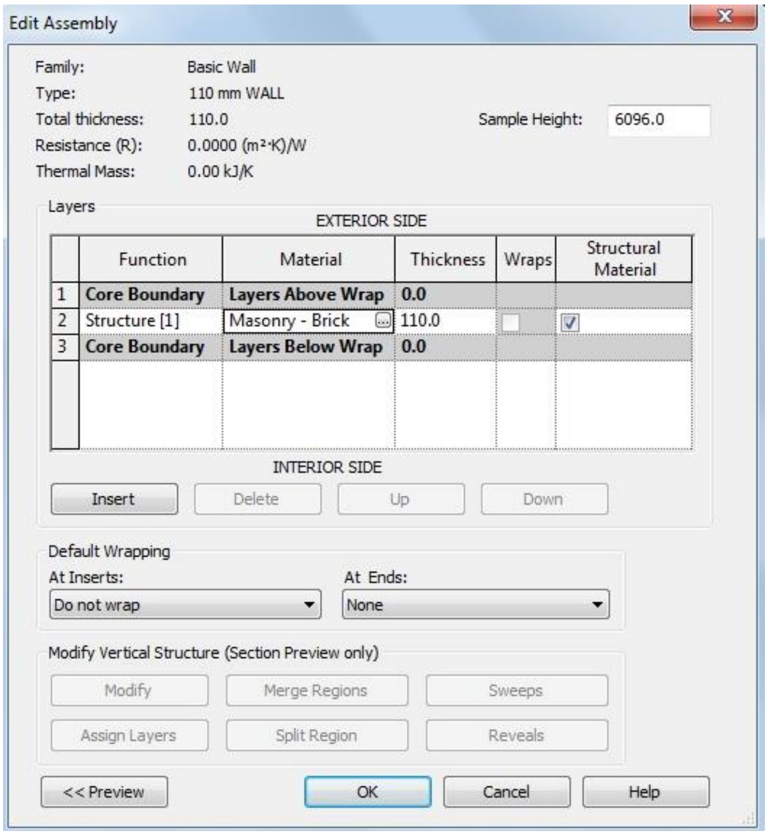


Figure 5-5 Wall component from model

Weygant (2011: 11) emphasises the importance of ‘information’ in the acronym BIM as the main differentiator between CAD and BIM. He stresses that the real value in BIM lies in the ability to analyse the data. He stresses the importance of analysis to improve efficiencies in buildings, such as electricity consumption, and effective heating and cooling systems.

5.2.3 Analysis of the database

Hardin (2009: 224) notes that the BIM is a database. The database is represented by three-dimensional objects, but these consist of data. The BIM can be exported into database software for additional analysis if required. This functionality allowed the BIM model to be analysed using a database programme to quickly check what features of the BIM software were used and if there was sufficient information for an analysis of the building using specialised software. The database analysis can show the Revit fields that were used in the model. Database fields that were not relevant to the building type were deleted, while fields that would have been populated if the full capabilities of Revit had been used were retained. The analysis of the database confirmed what had been seen in the desk-top study. It could be seen that there were few fields that had been used in the model. The database only contained the information that was required to represent the drawings. Components that could have been used for analysis, such as an energy analysis, were not populated. Examples of these were electrical components, which could have been used to analyse the electrical consumption of the building. These fields were not present in the database, and all electrical and mechanical input was input symbolically from the drawings produced by the service engineer. Mechanical systems contained no analysable information.

A comparison of the BIM that had been saved at tender stage was compared to the latest model, which was updated prior to the completion of the project. The latest model did not contain substantially more information, and was not sufficiently detailed or accurate to use as an as-built representation of the facility that could be used to run the building

It can be seen that the processes used to create the BIM model largely replicated previous methods of working using CAD tools. A discussion with the relevant partner showed that the practice is committed to working with BIM and uses it on all new projects.

5.2.4 Comparison of the BIM with the hypothetical model

It was observed that the model that was created by the architect was at an elementary level compared to the hypothetical model that was presented previously. Table 5-2 summarises the findings.

Function	Hypothetical model	Actual model
Production of drawings	All drawings are generated from a single model.	Model was used for drawing production, but only the architect's drawings were generated from the model. Structural input was done by importing the structural engineer's CAD drawings and overlaying these in the model. Details requested in RFIs were often hand drawn sketches and were not generated from the model. Project drawings were created in isolated environments, where each consultant generated their own drawings, using different software. Sub-contractor drawings were done independently. There was no coordination between the drawing sets and the records.
Visualisation	Model is used for accurate visualisation of the finished project, with photorealistic material parameters so that surfaces are rendered accurately.	The model was sufficiently modelled to generate low detail visualisations of the completed project. Material mapping was used for component surfaces, but these did not always accurately represent the actual materials
Schedules	All scheduling is generated by the model.	The model was used to generate door and curtain wall component schedules. Other components were scheduled independently using Excel or Word.

Document control	Full control of documents and revisions recorded in the BIM model.	Document control and recording of revisions was done manually outside the model.
Fields for repeat information	Fields are used to eliminate repeating project information.	Repeating fields added manually as text fields to the model.
Collaboration with consultants	All consultants have access to the model and can incorporate their design information directly.	Model is operated in an isolated environment, where information is extracted from the model, sent electronically to consultants, who maintained a separate set of documents.
Level of development (LoD)	The model has reached a LoD of 400, with components containing sufficient information for accurate analysis of energy consumption, efficiency and sustainability.	Model components are typically at LoD 200, with elementary information contained within components. The components do not contain sufficient detail for any analysis purposes.

4D analysis	Sufficient detail from all project participants is included in the model, with components that represent real world objects. The model can be used to show animated, time related construction scheduling. Clash detection and buildability can be confirmed before the construction of the building starts.	The model does not contain sufficient detail or accuracy for clash detection or scheduling.
5D analysis	The level of development of the model includes components that have accurate supplier cost information. The model can be used to generate quantities of materials with associated costs. The model is potentially used to generate the specification document.	The model has not been used to generate quantities and has insufficient detail or accuracy to do so.

Table 5-2 Comparison of hypothetical and actual model

The analysis shows that the architects used BIM in an isolated manner. This may be anticipated because there was no collaborative working arrangement. It would not have been practical to include information in the model for costing purposes if the quantity surveyor used traditional documentation, which was the case for this project. The architect confirmed that the quantity surveyor required hard copies for estimating and costing to generate the bill of quantities (BOQ). It can be seen that this is a counter-productive practice when using new technology, although it was previously justified as this was the only method by which the quantities could have been determined – by measuring them. However, much of the quantities information exists in the architect's model but was not used. Although components had not been modelled to include any information for analysis, many standard assemblies do not need much detail to generate quantities. An example may be walls, where once they are defined and placed, all the information required to generate quantities is contained within the component, provided that they are accurately drawn.

It has been noted that BIM can be used to increase the sustainability of buildings as the model can be analysed (Weygant, 2011: 132; Hardin, 2009: 229). This is becoming an increasingly important factor, not only to reduce the environmental footprint of the building, but also to save costs during the building's lifecycle. The case study project could not be analysed in this manner, as the building was not sufficiently modelled and did not contain data that could be used for such analysis. A desk-top study was done by an external consultant to determine how the energy consumption could be reduced, but the recommendations were based on 'rule of thumb' conventions rather than an analysis of the building. Recommendations included using solar water heating, as this is independently known to have a reasonably short return on investment. Other possibilities that were mentioned by the consultant included photovoltaic panels, but no accurate information could be provided to determine the economic viability without any analysis of the likely consumption.

Rogers (1983: 224) discusses how the adoption of an innovation is influenced by previous methods, which can negatively affect the adoption rate. An innovation is often initially used as a substitute for the preceding method. He cites an example of a diffusion study in a Columbian rural community, where fertiliser was introduced as an alternative to the manure that they had previously used for their potatoes. Initially the users used the fertiliser in a similar manner by spreading it over the base of the plant as they had done with the manure. This damaged the plants and subsequently retarded the adoption rate of the technology. A similar observation is evident with the advent of BIM, where traditional working methods, such as manually inserting text fields that were already provided for by the software and using external Excel spreadsheets for scheduling information, are used to generate documentation. This tends to nullify some of the advantages that are inherent in the software. An increased awareness of the functionality of the software and knowledge of how to use it would significantly increase productivity, even when BIM is not being used for collaboration.

5.3 Communication analysis

The literature review revealed that successful collaboration requires increased trust and communication. Increased communication exposes the participants to the knowledge within the network that is a requirement for learning organisations and innovation. Traditional contractual arrangements discourage the transfer of information because the release of the information implies liability for the author and is considered to be their intellectual property.

The project documentation was obtained from the case study architect. This included written correspondence (in electronic format) and email communications. Hard copies of the correspondence relating to claims were also included in the dataset. The project information was analysed so that it could be used to visualise the communication flow during the project. The analysis looks at the recorded communications during the construction phase using a network approach. The information consisted of emails, letters, meeting minutes, claims, certificates and other documents that are typical of construction projects. The flow of information can be seen in the email record, as the formal correspondence (such as meeting minutes and drawing issues) was transmitted by email.

5.3.1 Codifying the correspondence

The email fields were exported into a spreadsheet, with links to the attachments and the email contents using a macro in the email software. This allowed for easy access to the attachments that were recorded in a separate file. The architect was defined in the contract as the principal agent (PA). The architect's email archive therefore recorded the correspondence between the PA, consultants and contractor, although the completeness of the archive could not be verified. The project architect left the employ of the architect during the construction of the building and the project was subsequently taken over by a different architect.

The case study project was based on the JBCC Principal Building Agreement contract edition 5.0, which is a standard contract used for a single-stage tender agreement. When the project started on site, the completion date was November 2012, but delays caused the practical completion date to be postponed to May 2013. The late completion date resulted in claims for compensation by the contractor. The correspondence reveals the reasons for the claims. Disruption due to civil action and inclement weather led to delays, and late payment by the client led to claims for interest, but the contractor attributed a large portion of the claim to delays due to late information.

An examination of the email correspondence highlights some important factors with respect to information delivery. The methods of information dissemination can be compared with the survey question asked of architects on how information is exchanged. The most efficient method is to allow access to the BIM model, while the survey found that the most used method of exchanging information was for 2D drawings to be sent electronically. The project email correspondence contained an agreement that all consultants' drawings would be delivered to the architect's office as hard copies for collection by the contractor. It was noted that the contractor did not require any electronic copies of the drawings. The architect's drawings were created in a 3D BIM environment, exported as CAD drawings from the model, printed out as hard copies, and communicated to the contractor via email that the drawings were ready for collection.

The project suffered from many of the problems that commentators have associated with traditional contractual arrangements in construction projects. Disputes arose during the construction period, and had not been resolved at the time of completing this research. The project was completed late. The project architect commented that mal-administration by the client had resulted in late payments, for which substantial interest was claimed.

However, an examination of the project communications revealed additional problems that were encountered during the project, with a separate claim relating to the supply of information required for the manufacture and erection of the structural steel components for the roof. The contractor states in their claim documentation that prior to the event they had been ahead of schedule, but the late information delayed them substantially. This led to the late completion of the project.

5.3.2 Analysis of email correspondence on case study project

The codified emails were used to analyse the communication flows during the project. Due to the large amount of emails, project participants were selected that had had substantial involvement in the project. Suppliers and sub-contractors were not included in the analysis. This allowed a clearer representation to emerge. The project participants are shown in Table 5-3.

Participant	Abbreviation
Architect 1	AR1
Architect 2	AR2
Structural engineer 1	SE1
Structural engineer 2	SE2
Main contractor	MC
Client 1	CL1
Mechanical/electrical engineer 1	ME1
Mechanical/electrical engineer 2	ME2
Quantity surveyor 1	QS1
Quantity surveyor 2	QS2
Client 2	CL2
Civil engineer	CE

Table 5-3 Key to project participants

Table 5-4 shows the email density between the participants. Darker colours represent higher densities. The table shows both sent and received emails.

From	To	AR1	SE1	MC	CL1	ME	CE	QS	QS2	SE2	ME	AR2	CL2
SE1		45		7	2	5	6	15	5	1	0	32	0
MC		87	12		60	16	52	88	18	20	1	247	0
CL1		13	0	7		0	12	15	1	0	1	48	0
ME		6	0	0	0		0	0	1	0	0	15	0
CE		9	2	13	4	0		10	0	0	0	29	0
QS1		20	1	0	3	0	13		1	1	0	75	0
QS2		15	0	6	0	1	1	8		3	0	73	0
SE2		4	0	11	0	0	1	3	1		0	36	0
ME2		0	0	0	1	1	0	2	0	0		3	0
AR1			19	16	37	24	58	72	23	13	1	148	0
AR2		7	0	1	1	0	0	4	0	0	0		0
CL2		18	0	0	0	0	0	0	0	0	0	0	

Table 5-4 Communication density

Pryke (2012: 84) discusses the concept of connectivity between network actors, which shows how connected they are to other members of the network. Chinowsky (2011: 42-43) suggests that high performance teams are characterised by a high degree of connectivity within the network. Figure 5-6 illustrates the degree of connectivity between the actors. Actors closer to the centre interact more.

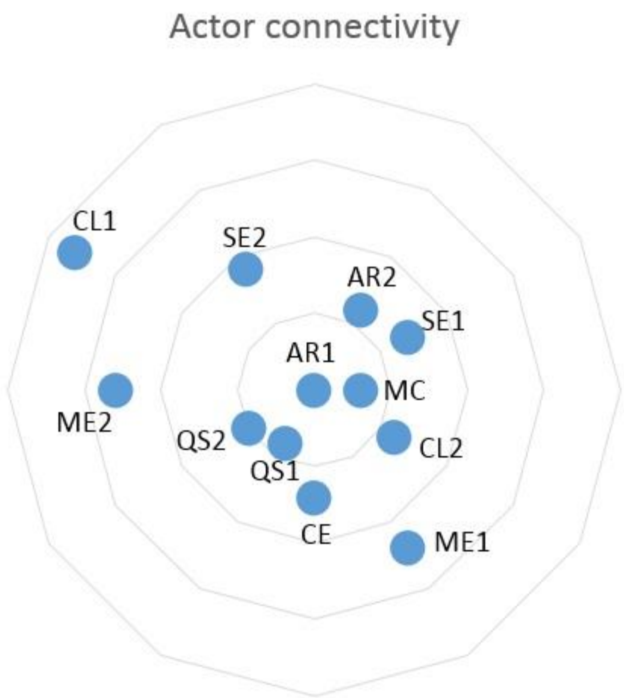


Figure 5-6 Actor connectivity

Table 5-4 can be depicted in a sociogram which shows the participants' centrality in the network. Actor centrality can be seen by the size of the node and its position in relation to the centre of the diagram. This is shown in Figure 5-7.

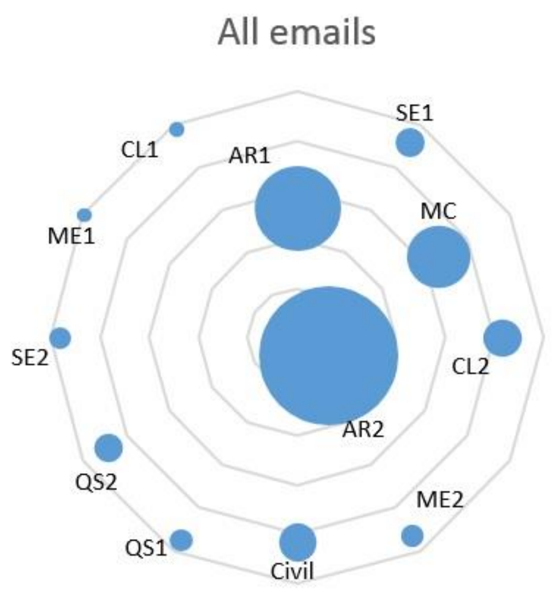


Figure 5-7 Actor centrality

It can be seen that the project architects were the most central actors in the communication network. Two architects are shown on the network. Architect 1 was the project architect until he left the organisation and the project. Architect 2 had also been involved with the project and took over as project architect after the first architect left. Both architects were very central, but architect 2 was even more prominent in the network. The contractor was the next most central actor.

Chinowsky (2011: 45) notes that centrality shows the number of incoming and outgoing links that exist for an actor. One of the factors that works in conjunction with centrality is power. While centrality measures the total number of relationships, power reflects the influence that an actor has in the network (Chinowsky, 2011: 46). Individuals that send or pass on more information have high power. Individuals that mainly receive information may be central in the network but have lower power, as they do not influence the actions taken by others.

The sociogram showed previously was then separated into 'communications received' and 'communications sent' to show the power of individuals within the network. These are shown in Figure 5-8, and show that although architect 2 was very central in the network, he had little influence within the network, and with regard to providing information, was on the periphery in terms of centrality, indicating low power within the network. It can also be seen that the contractor is not a central actor when the received communications are considered, while the contractor is the most central actor when the sent communications are considered.

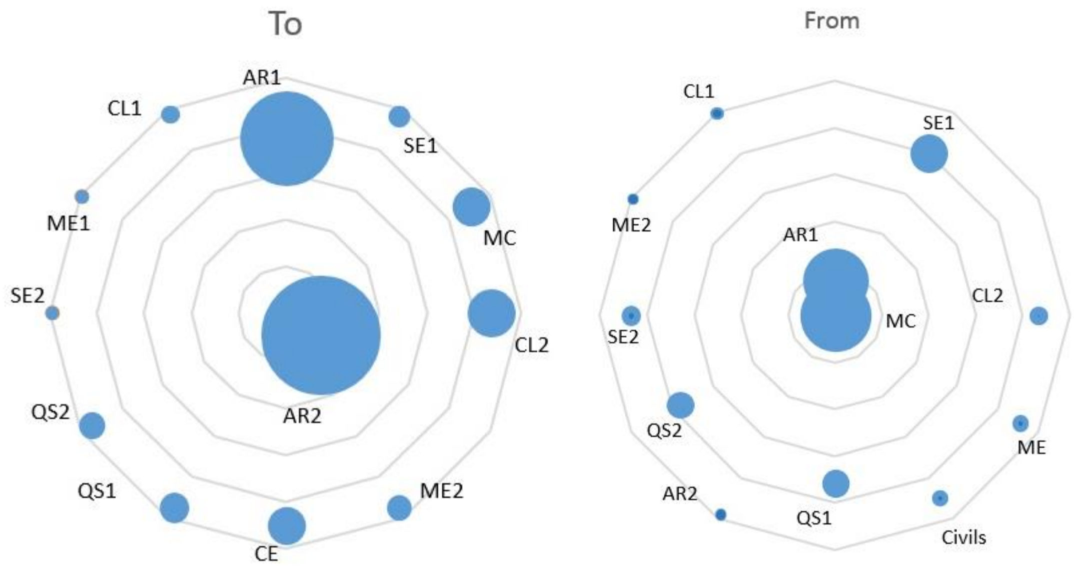


Figure 5-8 Actor centrality based on received (left) and sent (right) emails

Butts (2008: 15) discusses different methods to display relationships. The illustration below (Figure 5-9) shows a symmetrical, or dyadic relationship between two actors, where there is no distinction between sender and receiver (top). These are known as undirected graphs. He compares these to directed graphs, which are known as digraphs (bottom). Digraphs distinguish between sender and receiver (2008: 15). Schultz-Jones (2009: 594) refers to these respectively as symmetrical, or reciprocal ties and asymmetrical or directed ties.

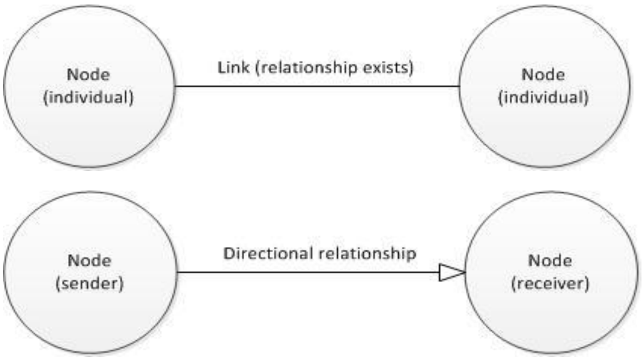


Figure 5-9 SNA showing undirected (top) and directed (bottom) relationships

The sociogram showing actor centrality (Figure 5-7) was then configured to show directional relationships. From this it can be seen that architect 2 received more of the project communication than the other actors, but did not send much communication during the project. This is shown in Figure 5-10. The strengths of relationships are indicated by the width of links between actors.

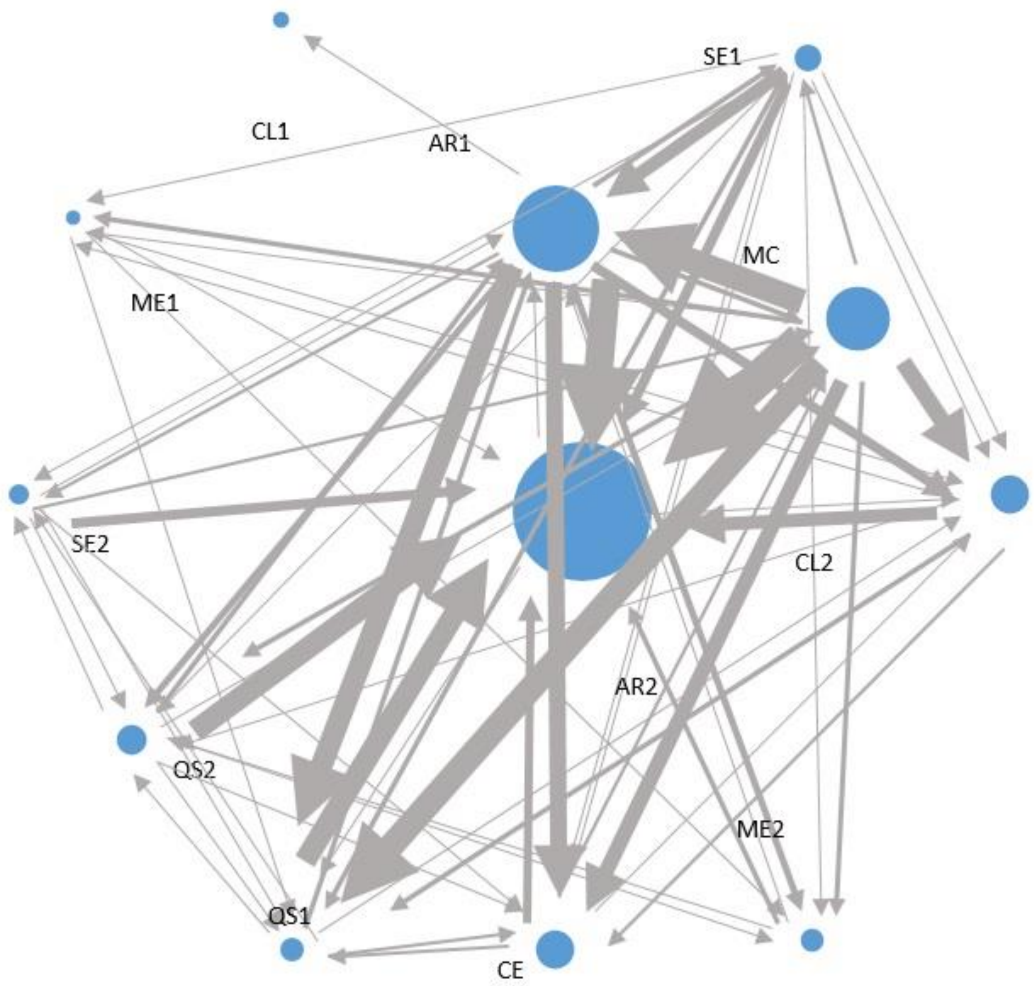


Figure 5-10 Directional graph showing relationships during the project

The sociogram indicates how information was exchanged during the project. The communications between the contractor and other participants are mostly from the contractor. This may suggest that the contractor was providing substantial information during the project, but when the contents of the emails were examined, it was seen that many of the emails from the contractor were informal requests for information or clarification. The client representative (CL2) received many emails and Figure 5-8 (To) shows that the client was very central, with only the architects being more central with respect to receiving emails.

It can be seen that the quantity surveyor (QS1) received a high density of communications from the contractor and the first architect, and sent more emails to the second architect. The second architect also received many emails from the second quantity surveyor that was involved in the project (both quantity surveyors were from the same organisation). High density links may indicate problems and this suggests that these emails reflected problems that occurred during the project. Much of the communication from the contractor to the architects was related to a lack of information, inconsistent information and late information and requests for clarification. An email from the client to the architect also reflected the effect of late information from consultants on the project.

The diagram illustrates one of the weaknesses of traditional contractual relationships, where much of the correspondence relates to clarification or additional information. Pryke (2012: 75) notes that design consultants in collaborative relationships experience lower centrality in information networks, when compared to traditional relationships, where the sociograms for the project show high centrality for the architects.

A central source of information, where project participants all have access to the information, allows the project information to be more accessible. Observability of knowledge is required for it to become tacit knowledge. Egbu *et al.* (2004: 209) comment on the difficulty of transferring tacit knowledge. Information networks that transfer only explicit knowledge limit participants' ability to contribute to innovation and project success (Egbu *et al*., 2004: 209).

It can be seen that the observed relationships were not conducive to trust. The contractor compiled a claim document, consisting of over 200 pages for a single claim (claim 12) relating to information required for the manufacture of the structural steel components. The document reiterated much of the previous correspondence. The document included a letter from the architect, who stated that "… it is not immediately clear how practical completion has been delayed by the 'late issue' of structural steel information". The claim was for 65 working days, although the contractor claimed that the information was 139 days late, but did not necessarily affect the critical path. A more transparent relationship with greater trust would potentially have made the effects of the late information apparent earlier. This can be compared with the integration matrix presented by Songer and Chinowsky (2011: 17) shown in Figure 2-2 (page 17). Although there was a significant amount of communication, levels of trust were low. This suggests that the level of integration was at the fragmentation stage on the matrix, equating to Berry's (2011: 2.9) separation mode in the acculturation mode matrix (Figure 2-1, 17). Berry sees this as a negative mode of acculturation, while Songer and Chinowsky state that integration is the mode that is preferable for acculturation.

The analysis of the project communication flows confirms observations from other countries. Although the architect has used BIM for a number of years and the analysed project was documented using BIM software, the communication flows followed traditional information exchange mechanisms. The weakness of traditional project information exchange mechanisms becomes apparent, while the model endorsed by this research would suggest that problems that occurred during the project could have been resolved earlier through improved communication and information sharing. Access to the BIM by all the project participants may have led to a greater availability of information at crucial stages of the project. Although only one project was analysed in any detail, current contractual arrangements are likely to yield similar results, as has been documented for other countries.

5.4 Comparison of findings with hypotheses

The hypotheses that were presented in chapter one are reconsidered to establish how they relate to the findings of the research.

5.4.1 Hypothesis 1

The current South African environment hinders collaboration between CPOs

The survey results presented in chapter 4 show that there is a lack of collaboration between CPO's in South Africa, with only a small minority of both contractors and architects that currently collaborate. The results show that 7% of architects use BIM to collaborate with the contractor. However, perceptions among both groups showed that most architects and contractors believed that there were advantages to both collaboration and sharing of information. It was seen that 64% of contractors and 92% of architects that were surveyed see the value of sharing information.

It was seen from the survey that architects are adopting BIM despite the lack of drive from industry bodies or the government. This may be because of the other advantages that BIM offers, such as quicker and coordinated document production. When contractor awareness of BIM in South Africa is compared to that of other countries it is seen that there is an alarming lack of awareness. It was shown that in the USA, 74% of contractors have adopted BIM in their work processes, while in the South African industry a similar amount (73%) of contractors are not even aware of BIM and only 12% have used BIM in some way.

Both contractors and architects were asked in the survey what factors they believed were limiting collaboration in South Africa. Neither group perceived the South African environment as the main limiting factor, with a minority of 16% of contractors and 23% of architects indicating that this was a limiting factor. Architects did perceive that contractual boundaries were a limiting factor. 'No clear contractual boundaries' received the highest score (40%) from architects, while only 20% of contractors perceived this. This is related to the South African environment, as major clients such as the government specify the contractual arrangements.

The literature review showed how governments in many other countries are driving collaborative approaches, with a commitment in the UK for all public projects to be implemented in a BIM environment. It was shown that the industry bodies in South Africa, such as the CIDB and the SAIA, do not promote BIM or collaboration in any way, while there is substantial information in other countries with regard to using BIM and partnering agreements.

It was seen that the current tender process that is required for all public works projects happens through a one-stage tender agreement using a traditional tender process. Each organisation that is involved with the project needs to tender independently, so there is no real scope for collaboration on projects. During the case study, the client's representative noted that it should be possible to use a partnering arrangement for the project, but that he had not heard of this happening for any government or municipal work. He noted that a limiting factor was the requirement for any public works projects to be conducted in compliance with current BBBEE (broad based black economic empowerment) legislation. He did not know of a mechanism whereby the BBBEE status of different organisations could be combined to be representative of the collaborating partners.

The research has demonstrated that there are tangible advantages to both the cost and quality of new facilities that are realised using collaborative arrangements and a single database, but projects conducted in South Africa are not currently benefiting from these advantages.

It can be seen that there are reasons why partnering arrangements are limited in South Africa. These are identified as a lack of knowledge or awareness by government bodies and a lack of drive by industry bodies such as the CIDB and the SAIA. The engineering, construction management and QS industry bodies' websites do not promote the use of BIM or collaborative arrangements. The hypothesis is therefore supported by the findings.

5.4.2 Hypothesis 2

Traditional ownership of project information inhibits knowledge flows between construction project organisations

The literature review identified that ownership of information can limit collaboration and that information exchange is required for knowledge transfer. Two reasons were identified. The first is that the project information constitutes intellectual property. Hassan and Ren (2007: 279) note how the design team face unavoidable problems, such as accessing sensitive information and sharing of their own intellectual property.

The second reason is that the author is liable for the information that they release, which means that information is only released when it is required. Collaborative arrangements where all parties are responsible for the information address this current limitation by making all parties responsible for the information.

Chinowsky (2011: 47-52) discusses information based networks in organisations. He notes that knowledge networks are required for high performance results, and that organisations need to have social networks with trust and value sharing before this form of knowledge transfer can occur. This was not witnessed in the case study.

Egbu and Robinson, (2005: 41) show that project success is related to knowledge transfer but that this exposes the organisation's knowledge to other parties. This would suggest that organisations that operate in long-term collaborative partnerships would have an advantage, as knowledge is transferred over time, while it is still held within the collaborating CPOs. The surveys showed that there is a perception that confidentiality of information is a limiting factor for increased collaboration for both architects (35%) and contractors (39%).

When the contractor was asked for recorded emails he was reluctant to share this information. There were unresolved disputes, some of which were due to late supply of information from consultants.

The case study project clearly demonstrates that there was limited information exchange, and in this case, led to delays in the project. Additional costs were incurred on the project and a dispute arose between the contractor and the architect as a result of late information. A higher degree of collaboration may have avoided this.

The survey showed that the contractors' highest score (39%) for perception of factors that limit collaboration and architects' second highest score (35%) was for confidentiality of information. This perception may be a factor that inhibits information flows. The literature study indicated that knowledge flows were related to the degree of communication.

While the findings of the research give credence to the hypothesis, and these are supported by the findings in the literature review, the research cannot conclusively support the hypothesis. The hypothesis is therefore only partially supported by the research.

5.4.3 Hypothesis 3

Multiple sources of information lead to errors and omissions in the documentation

The analysis of the model in the case study showed that the project information was generated and communicated using different software packages. The documentation generated by the architect was done using software other than the BIM software used to generate the project model, whereas much of the documentation could have been done in the BIM software and that would have ensured coordination of the documentation. The different organisations produced documents independently, using different software packages. The communications that occurred during the project confirm that there were errors and omissions in the documentation.

Examination of components within the BIM shows how traditional CAD processes are being used by firms that do use BIM. Current BIM usage by the industry (consultants and supply chain) is limited and does not foster an environment for efficient information exchange. Although the architects had used BIM software to streamline the process of drawing production, the overall process replicates that of traditional document exchange.

The hypothesis is therefore partially supported by the findings, although there was not comprehensive proof that the errors were due to using multiple sources.

5.4.4 Hypothesis 4

The use of BIM in IPD projects enhances organisational learning and in turn enhances innovation

The case study network analysis showed that much of the information required had to be requested rather than being easily accessible. Weygand (2011: 156) shows how the design phase of projects can be streamlined by contractor input as this minimises the research that is required to make appropriate decisions.

Pryke (2006: 70) shows how social participation is at the heart of organisational learning. Greater contact with experts in their practice area allows knowledge to develop. Chinowsky (2011: 47-48) notes that knowledge networks are the strategic component for achieving high performance results. Teams need to focus on sharing knowledge, rather than information. The communications revealed that information was provided on a ‘just in time’ basis and revealed how a lack of information led to delays and increased costs.

The research tentatively suggests that knowledge sharing is improved by collaborative approaches, although a link to how this could lead to greater innovation within the industry could not be shown.

5.4.5 Hypothesis 5

Increased use of BIM in South Africa improves the accuracy of construction project documentation

Both architects and contractors see the value of sharing a central model and collaborating. However, it was seen that the BIM model was at an elementary level that replicated CAD use. It was seen that documentation was not accurate or coordinated.

The blown up detail from the manufacturer's model shows information that is useful to other consultants. Thermal and lighting properties can be used for environmental and energy analysis. Window loading and mass details are available for structural calculations and analysis. The 'Identity Data' section includes hyperlinks to the manufacturer's website, with links to detailed product information. The keynote field links to text files, which refer to standardised specification clauses.

It was seen that in other countries, particularly in the USA, component manufacturers are starting to produce BIM components that can be directly inserted into the BIM. This was compared with a window from the case study model and it was seen that the information contained within the component was insufficient for purposes other than visualisation. The case study also showed how information was produced independently and it was seen that this resulted in errors and omissions that eventually caused the project to be completed late. The contractor also pointed out that there were discrepancies between different consultants' documentation and this could have been prevented if the information emanated from a single source.

Tizani (2007: 21) shows how considerable amounts of data are transferred for each design stage with the traditional CAD based process. He notes that the different software platforms do not necessarily allow seamless transfer of data between disciplines. High levels of iterative processes result in reworking. This results in a compartmentalised design process that allows paper based or rigid information to be transferred across boundaries. The data transfer results in degradation of the data integrity.

A similar process was observed and documented in the case study findings where the process of including structural information into the BIM was seen as a problem.

The cumbersome methods used with this project show that information exchange is inherently difficult. Typically, the process of issuing a drawing consisted of the following steps:

- Export copies of relevant drawings from the BIM model into CAD and/or PDF format.
- File a copy of the extracted drawings into a unique folder, with the date of issue and the recipient. Multiple issues of the same drawing result in multiple copies of the drawings being filed.
- Issue the extracted drawings to the intended recipients electronically by email.
- Manually record the issue on the drawing issue register.
- In the case of drawings issued to the contractor, hard copies were printed, with an email notification sent to the contractor to collect the drawings from the architect's offices.

These steps show the amount of administration that goes into issuing a drawing and the processes used to record the transfer in case of future queries relating to the drawing. In an information-sharing, collaborative environment, many of these processes could have been eliminated, as the information recipients would have had direct access to the information. Smith and Tardif (2009: 10) suggest that obstacles to improved efficiencies in the construction industry are not primarily technical, but rather the lack of reliable, timely information that inhibit efficient behaviour and decision making. The research supports hypothesis 5.

5.5 Discussion of the findings

The literature review illustrated how knowledge transfer requires effective communication and trust. However, the culture of the industry is typically fragmented, and the different organisations involved with the design and construction of the built environment do not act as a team with a common goal. The trust and communications required for effective knowledge transfer to take place in turn require acculturation between construction project organisations. Knowledge transfer is a requirement for innovative and learning organisations. It was also observed that new technologies which are currently achieving the maturity required for effective collaboration are available and that these software and hardware advances are likely to change the way in which construction documentation is transferred between organisations. It was seen that in some other countries the BIM phenomenon is reaching the late majority adoption stage and can be used to predict trends for other countries. The literature review also showed how BIM is still being used in other countries to replicate the manual CAD processes and that many of the more advanced and collaborative functions available are not being used. Similar processes are being used in South Africa. The weaknesses of current contractual arrangements were observed and an alternative two-stage tendering agreement was proposed.

The results of the survey show that uptake of BIM by South African architects is increasing. Comparing these results with growth in other countries indicates that uptake in South Africa is likely to continue to increase. The survey results also show that consultants that use BIM are using it in an elementary way, which replicates the findings for other countries that were revealed in the literature review (for example, Davis, 2007: 16; Suermann, 2009; 37). BIM is being used for more accurate and quicker compilation of documentation, but the true power of BIM is not being used in any meaningful way. The concept of collaboration has not been linked with the BIM concept in South Africa and South African contractors are largely unaware of BIM. An industry-wide embracement of BIM needs to occur before meaningful change can occur, but the research suggests that improving technology will increasingly drive collaborative processes, as has been observed in other countries.

The case study was used to compare a project executed using traditional contractual arrangements and information exchange methods. An analysis of the BIM model, which determines the functions that were used, confirms the findings in other countries. The components have the minimum amount of information included to display correctly in the drawings and visualisations. The model is not sufficient for any kind of analysis, and there is insufficient detail for accurate quantities and pricing to be performed. The project communications showed a project network where communication between the participants was not easily achieved and the architect performed a gate-keeping role, which limited the flow of information. There were claims for delays on the project due to the late supply of information by the consultants, which led to a dispute, reflecting the practice of antagonistic relationships during construction projects as documented in the literature review.

The review of the project communications revealed events that occurred during the project and reflected the weaknesses of traditional documentation methods that were highlighted in the literature review. Correspondence revealed that the engineer reminded the architect to keep them updated with the latest drawings for coordination. A similar reminder was sent from the architect to the engineer for updated information. The contractor received drawings that were marked 'for information' (as opposed to 'construction'). A previous correspondence had suggested that 'for information' drawings were not to be used for construction. These communications reveal the inherent problems with the current manual methods and cumbersome information exchange mechanisms. At one point during the project, the contractor requested a separate meeting with all consultants to establish if issued drawing registers were updated and if the drawings that were received were the latest, as there was a lack of coordination. A separate meeting was requested to discuss the discrepancies between the architect's and the electrical consultant's drawings. These were non-value adding tasks, which took time to resolve.

The analysis of the communications also revealed how details were often resolved 'just in time' with the contractor reminding the consultants that the late supply of information could potentially lead to delays. The methods illustrate the typical process of preparing for the bid process with outline detail to the project, with further details being supplied in time for construction. There were many occasions where the resolved details affected the cost of the project. The contingency sum that had been allocated for the project was used up before the end of the contract.

Due to the tedious process of updating a detail between consultants, this was observed to be done manually, where the steel sub-contractor requested details from the engineer. The information was supplied using a sketch with the detail and dimensions drawn in manually. This information would have been difficult to subsequently add to the BIM model and the as-built model was similar to the model at tender stage. The as-built model would not have sufficient detail and accuracy for any post-construction use, and would have been insufficient for any nD functions that were discussed.

The late supply of information led to a claim for compensation by the contractor. The contractor highlights in the covering letter to the claims documentation that drawings had been required for the manufacture of the steel roof structure by the start of March 2012 and design changes were still being received in September 2012. The contractor believes that this was the main cause of the delay to the project which was only completed in May 2013. The original agreed completion date had been in November 2012. Although other factors had contributed to the delays, such as rain, strike action and civil disruption, the main reason for the delay was blamed on the consultant’s late supply of information.

Chapter 6 - Recommendations and conclusion

The research sought to establish typical information and communication flows that occur during the life-cycle of a project and how BIM is currently being used in South Africa.

6.1 Research aims

The aim of the research was to establish the extent to which BIM is being used in South Africa and to provide a comparison with other countries. This was examined to determine the context of information and communication sharing and how this is enhanced by the use of BIM.

The research sought to examine the concept of collaboration in the context of information exchange and determine why the concept is gaining little support in South Africa.

6.2 General findings from the literature review

The literature review showed how the traditional construction process limits the information exchange that is required for knowledge transfer and increased innovation in the construction industry. Current processes used during the design phase replicate the previous processes that were used using CAD technology. It was seen that multiple platforms are being used to generate and transfer information, resulting in errors, omissions and repetition, and non-value adding tasks are accepted as a necessary toil.

Recently evolving information technology has opened a path to efficiently create, transfer and reuse information in a knowledge sharing environment that has the ability to vastly reduce both time and resources, and increase the value of the information.

The research suggests that the construction industry will face substantial changes to current processes. The construction industry is going through a world-wide transition, and this has already been seen in other countries. There is a perception that BIM will improve the design and documentation phase of projects. The technological advancement is likely to continue regardless of the industry culture. The increasing functionality of both hardware and software is likely to change the process of information transfer and communication. The collaborative functions that are incorporated, along with increased accessibility of the model resulting from increased connectivity will facilitate this. It was observed that contractors in other countries are increasingly using BIM, and will author the model themselves if they are not provided with a model. Current processes will increasingly become redundant. New specialities will be required and some current specialities are likely to become marginalised.

New specialities include modelling competency to use BIM to a more advanced level on projects, and modellers will be required by the supply chain to develop detailed components that can be used in the BIM. Knowledge management will become increasingly important, and it is likely that future construction projects will employ a knowledge manager to control the BIM and control the flow of information and access to the BIM.

Quantity surveyors may be positioned to fulfil this role. The traditional estimating role of quantity surveyors is becoming redundant as the BIM model provides increasingly detailed quantities with accurate pricing information.

There needs to be a concerted effort from government – the drive in the UK has resulted in more awareness and the government itself is driving this by requiring that public works projects are done in a collaborative and BIM environment. Kumar (2012: 192) notes the requirement that the use of BIM on all UK public sector projects will be mandatory by 2016. The governments of countries that use BIM more are aware of BIM and have mandated it at national level. This may offer a substantial advantage to these countries in a globalised market, where improved processes allow them to become more competitive and threaten local markets that have not adopted the new technology.

The current drive of government via the CIDB is to create jobs, with guidelines for tendering on public works and the BBBEE requirements for tenderers. Discussion of these concepts is beyond the scope of this study, but there is a need for more awareness of new ways of working by major clients, including the government itself. There needs to be a drive from government to encourage collaborative environments and recognition of the advantages of using BIM for all parties involved in construction projects. This approach can result in better quality buildings with more economical solutions. The approach to this transition can be guided by the experience gained in other countries.

6.3 General findings of the survey and case study

The survey data revealed that there is an increasing take-up of BIM in the South African construction industry. However, the current processes that architects use for producing information still replicate those that are typical of CAD use, and follow the trends that have been observed in Europe and North America. The survey indicates that South Africa is still behind leading BIM-using countries, although the trend lines indicate that this is a relatively short period.

The analysis of the BIM model used in the case study augments the findings in other countries, showing that the BIM model was used for the generation of drawings and 3D visualisations. Features that could have been used for collaboration between the design team and quantity surveyor were not used. This limits information flows between the organisations, as information has to be requested. Full access to all the project information by all participants, allows for a better understanding of the project, where potential problems can be identified earlier. Full access to all of the project information allows for knowledge sharing, which can enhance innovation. This provides credence to hypothesis four, which suggests that BIM can increase organisational learning. Current practices with regard to ownership of information discourage sharing of information, and procedures were documented for how the information was to be released. The architect’s drawings contained a standard note stating the author’s copyright, lending support to the second hypothesis. The BIM model has tools to accurately record drawing revisions and issue control. These functions were performed manually. There was no use of the functions that would provide quantities and costing. This was achieved independently by the quantity surveyors using printed hard copies of the drawings. Inaccuracies and contradicting information were observed in the contract documentation, where drawing numbers shown on the drawings did not correlate with their listed numbers. Contradicting information on engineers and architects drawings reveal the weakness of having the information emanating from different sources, as suggested by hypotheses three and five.

The survey revealed perceptions and involvement with collaborative efforts in the South African context. The findings reveal that there is little collaborative involvement in South Africa and awareness of the concept is behind other countries, particularly amongst contractors. It was seen that industry bodies are not driving processes, as was witnessed in other countries. The South African construction industry body websites provide no information on either BIM or IPD, whereas websites from other countries provide comprehensive information on both of these subjects. It was seen that there is a drive at a national level to change the current adversarial relationships that have been typical of the industry. New forms of collaborative contractual arrangements are encouraged, due to the confirmed efficiencies that have been documented. The South African government and the Construction Industry Development Board (CIDB) have not yet addressed these. These findings confirm the first hypothesis.

6.4 General conclusion

Collaboration using a single information source offers tangible benefits to the construction industry and current technology offers methods to improve the functionality of buildings and to ease the design and construction process. From a design perspective, BIM streamlines the production of information, where buildings are designed in a three-dimensional environment and all documents are sourced from a single database. The model can be analysed from a number of perspectives before construction begins. From a construction perspective, the building can be accurately priced, using complete information before the building is built. The model can be imported into supporting software for programming and scheduling, so that the construction process is fully understood before construction starts. Buildability can be checked by using clash detection software.

Chapter one hypothesised that there was limited use of technologies that improve accuracy and allow for advanced analysis. These technologies facilitate collaboration, as a single source of information is available to all project participants.

It was seen that the benefits of BIM are realised once all project participants use the same information source. This eliminates errors and ambiguities in the information, and allows all participants to contribute to the information source and extract information. Early contractor involvement has advantages for both knowledge sharing and for allowing the contractor to gain a complete understanding of the building before it starts on site.

The research reveals that there is limited use of BIM in South Africa, discussed in section 4.4.2. Antagonistic relationships that have been observed in other countries are also seen in South Africa In order to experience the full benefits of both partnering and BIM, the whole industry needs to address this – clients, architects, contractors, engineers, sub-contractors, manufacturers and suppliers.

The concept of organisational culture is gaining more recognition internationally, with commentators noting that the culture of the industry can be correlated with poor performance by the industry, even when measured using traditional indicators, such as time, cost and quality. More recent indicators of performance measure additional metrics, such as waste, environmental, safety, whole life cost to run the building and team satisfaction.

The study shows how the current environment and practice inhibit collaboration in South Africa, while many other countries are making an effort to address this. An integrated approach using currently available technologies will allow the construction industry to align with other industries and countries. The resulting paradigm shift will result in an increasingly productive and innovative construction industry.

The literature showed how the current culture of disputes hinders knowledge sharing and current technological use is not yet mature. The survey showed (section 4.4.13) that a similar environment exists in South Africa, and both architects and contractors see the confidentiality of information as a barrier to collaboration in South Africa.

The research confirms that BIM use in the analysed project is limited, discussed in section 5.2. A follow-up session with the model authors revealed that they were unaware of many of the features available within a BIM environment, or did not know how to use them. The survey results augment these findings, where architects see the main value of BIM in drawing production and visualisation.

The research shows the increasing productivity and complexity of BIM and reveals how traditional CAD based approaches are likely to become increasingly redundant. The methods for information production and communication are changing radically, but current contractual arrangements are not aligned to these new methods. In order for the South African construction industry to remain competitive, the industry needs to recognise the trends taking place internationally. Cultural changes require a multi-directional drive within the industry that needs to be driven by large clients, such as the government. More information on BIM and its benefits needs to be supplied by industry bodies, such as the CIDB, to increase awareness, particularly with the larger construction companies. The productivity gains that collaboration can bring to the industry should be recognised, and the advantages of centrally accessible information exchange mechanisms need to be explored and implemented to realise the full benefits of BIM.

The opening page of the introduction to the research showed how Egan (1998) suggested that the culture of the industry needed to be addressed before technology could offer any advantages. However, the statement from Egan may be viewed from a different perspective – technological change will not wait for the culture of the industry to change – it is likely to be a key driver of change. The increasing use of BIM will illuminate the inefficiencies of current systems and working methods. The current South African industry culture, which reflects that previously observed in other countries, will be challenged by the advances of technology. Internationally, a transformation in the way that buildings are erected is being realised, resulting in a more coordinated approach.

New approaches can encourage knowledge sharing, innovation and facilitate higher quality buildings that are increasingly more cost effective. Figure 6-1 illustrates this. Multi-directional information flows within the industry can foster a culture of organisational learning, grounded in a collaborative environment.

Increasing use of BIM will be a catalyst for organisational change within the industry.

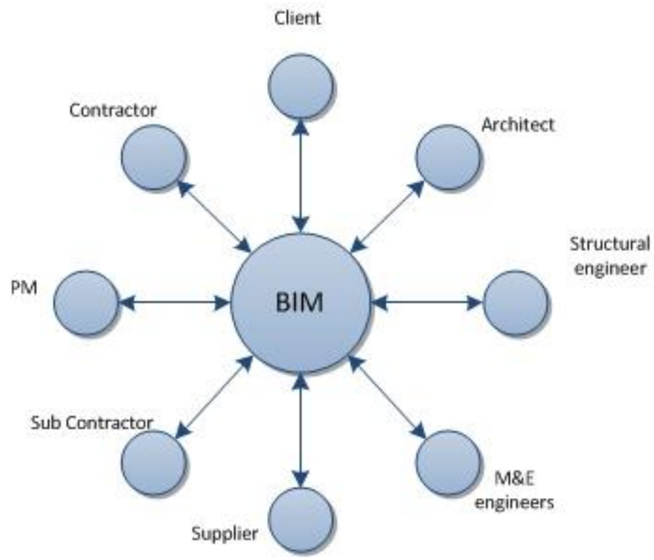


Figure 6-1 A single source of information for a construction project

The BIM phenomenon has gained significant presence within the design sector of the construction industry and although South Africa is still behind with BIM take-up compared to the USA and Europe, a similar trend of increasing use is recognised. When awareness and adoption rates were compared with the diffusion of ideas concept, suggested by Rogers (1983), it was seen that architects were already in the 'early majority' phase and adoption rates were likely to increase in line with other countries. This was illustrated in section 4.4.5. There is less awareness of BIM among contractors, but trends in other countries suggest that this will increase, as contractors are now in the 'early adopters' phase, with sufficient awareness to suggest that BIM adoption will start gaining momentum. Overall BIM usage is likely to increase its hold in South Africa as its benefits are realised. Continuing software and hardware advancement, along with increasing skills as users gain experience are likely to impose a new form of interaction between CPOs where collaborative working becomes progressively easier. Those that continue with current systems will be increasingly marginalised as the coordinated processes within the BIM environment magnify the inefficiencies of current working methods.

6.5 Contribution to knowledge

The research has demonstrated that there is less use both of BIM and partnering in South Africa, when compared to Western Europe and the USA. The use of BIM by architects in South Africa slightly lags that of other countries, and a trend is identified which suggests that architectural take-up is likely to continue. However, contractor awareness and take-up is substantially behind these countries. This represents a challenge for the industry, as the lack of take-up by contractors is inhibiting the collaborative use of BIM in South Africa.

- **The research showed that only 12% of contractors had used some form of BIM, which contrasts sharply with BIM adoption in the USA where 74% of contractors had adopted BIM.**
- **The research showed that architects are increasingly using BIM, but this is mostly in an isolated environment and the main advantages of using BIM are not being utilised.**
- **The research reveals a potential threat to the South African construction industry in that global companies may become more competitive than local companies. This could negatively affect the local construction industry.**
- **Factors that inhibit partnering and restrict BIM use in South Africa have been identified. These include:**
  - **Lack of awareness by large clients;**
  - **Lack of awareness by the government;**
  - **Lack of awareness by industry bodies; and**
  - **A procurement process that discourages collaborative processes.**
- **The research has provided new primary data and quantifies the degree of BIM use and the rate of take-up in South Africa among architects and contractors. Perceptions on BIM and collaborative arrangements were documented.**

- **An innovative exploratory method was demonstrated to analyse communication data and could be used to visualise potential problems that occurred during the project.**
- **The research showed how innovations are adopted and used this method to estimate future take-up of BIM. This allows the South African construction industry to prepare for the advent of BIM and to anticipate adoption rates.**

6.6 Recommendations

The research has shown that BIM, used in a collaborative environment, has advantages for the whole industry. The following section presents recommendations for individual sectors of the industry in South Africa.

6.6.1 Recommendations for clients

The inherent inefficiencies and non-value adding tasks that have traditionally been part of the construction industry are borne by the client, adding substantially to the cost of the built environment. Inefficiencies include the tender process, where contractors spend considerable time and cost on tendering at risk (Hardin, 2009: 7). The inefficiencies introduced by the competitive tender process are largely hidden. Each tenderer on a project bears the cost of tendering and has only a small chance of selection. Each awarded contract therefore has hidden costs that include covering the tender cost for their unsuccessful tenders. Larger clients and government bodies in other countries are beginning to stipulate that BIM is used on their projects as the advantages and cost savings become apparent.

The research suggests that using BIM results in better buildings, as the rich data can be used for analysis before construction begins. The functioning of the building can be determined beforehand, and the streamlined design and construction process can reduce the costs of buildings. Major clients in the UK are increasingly insisting on a BIM platform for their new facilities, and the UK government is driving the process by funding research and requiring that new public buildings are produced in a collaborative environment using BIM.

The main advantage of BIM is that there is one source of information. The information-rich model provides an important tool for the operation and maintenance of the building once the building is completed. Facility managers can use the BIM and add relevant layers of information to the model (Hardin, 2009: 273), which is an accurate representation of the as-built facility. Hardin (2009: 276) suggests that using the model for management has many benefits for the client. These include reducing the amount of time to get and store information, analysing energy use and addressing health and safety in the facility. Weygant (2011: 163) shows how the facilities manager can use the model for scheduling, systems integration, budgeting or space planning for rented areas of the building. Hardin (2009: 278) identifies how the BIM can be used by facility managers in conjunction with radio frequency identity tags (RFIDs). RFIDs can be placed on the assets in the building and transfer information to editable databases that link to the BIM. This research does not address the facilities management role of BIM, but it can be seen that there are numerous advantages to managers who have access to a single source of information which can be used to run the facility.

6.6.2 Recommendations for architects and consultants

The benefits of BIM have been illustrated in this research, and it can be seen that any level of BIM use by consultants is beneficial. The research also shows substantial advantages for architects that use BIM in a more advanced way. Research in the USA (McGraw-Hill, 2012: 4) showed a strong correlation between user competency and return on investment (ROI). This suggests that higher competencies among BIM users in architectural practices will improve the workflow during the project. A higher degree of modelling will allow analysis of the building that is not currently being done, or is too expensive. Better buildings can be produced. The increased use of BIM will also allow for real collaboration among consultants during the design stage, and facilitate earlier contractor involvement and full partnering relationships.

Smith and Tardif (2009: 18) suggest that leaders of design firms often have grossly inaccurate perceptions of the impact that BIM has had on their firms. They state that this makes it impossible for leaders to make strategic decisions with regard to their BIM use.

Both Davis (2007: 16) and Suermann (2009: 37) note that BIM software is not being used to its full potential. In order to take advantage of the technology, consultants need to train users to a higher degree of competency than is currently observed. There is an opportunity to create training facilities that train users in advanced BIM use. The research shows that BIM is currently being used primarily by architects. The full benefits of BIM and the inherent data and information can only be utilised once there is more collaboration during the project. This may become increasingly obvious as both hardware and software capabilities advance and global connectivity increases.

6.6.3 Recommendations for contractors

Hardin (2009: 108) observes how contractors that work with design teams that still use CAD often choose to create their own separate model based on the 2D drawings. This allows them to increase their efficiencies and have a better understanding of the design intent and how it is to be constructed. However, significant resources are required to accurately model the building and this is possibly beyond the capability of many contractors. Contractors need to address this. The research indicates that only a small minority of South African contractors create their own models, or have them created by a third party.

The lack of awareness and use of BIM by South African contractors contrasts with adoption rates elsewhere, where in the USA there was a 74% adoption rate (McGraw-Hill, 2012) among contractors. The advantages of using BIM have been demonstrated by the research and it can be seen that there are tangible benefits to contractors that use BIM. Clash detection software along with 4D and 5D processes could significantly streamline the construction phase. Contractors need to become more aware of the technology that has now reached maturity and is likely to offer more benefits as hardware and software processes improve.

The research shows that in South Africa both contractors and architects generally see the advantages of collaboration, with a majority of both architects and contractors seeing some advantages to both a shared model and to collaboration. Hardin (2009: 24) discusses the benefits of earlier contractor involvement. The advantage of the BIM is that it can virtually construct, test, change and communicate design intent in a way that was not previously possible. This increases the contractor's ability to determine and anticipate the means and methods of construction beforehand and give their perspective on the design. This allows everyone on the team insight into the actual construction of the project while it is still in the design stage.

6.6.4 Recommendations for industry bodies

The literature review confirmed that BIM is increasingly being used internationally and that programmes are being actively developed by industry bodies and governments in many countries, such as the USA, UK, Australia Finland, Norway and China.

The Chair of the body that is driving BIM awareness in the UK, Dr Barry Blackwell[9] believes that the BIM 'genie is out the bottle' and that innovation will be relatively swift with the new technology. He suggests that countries will not remain globally competitive without embracing the new technology. Countries that do not remain competitive will struggle as global markets increasingly compete for local work using streamlined processes.

Industry bodies, such as those that represent architects, contractors, construction managers, engineers and quantity surveyors, need to become more aware of international trends. A review of these bodies' websites did not reveal any information on using BIM or on collaborative methods of working. The extremely fast pace of change that is being witnessed globally needs to be recognised and embraced in South Africa. The South African construction industry may become increasingly non-competitive and marginalised if the new methods of working are not acknowledged.

6.6.5 Recommendations for the supply chain

Suppliers have an opportunity to introduce unique selling points to their products by providing accurate, information-rich components for a BIM environment. There is currently an opportunity for suppliers to gain an early competitive advantage due to the relative immaturity of the market in South Africa. This will require new competencies in order to both compile the data

[9] www.bimtaskgroup.org Newsletter, 21st edition | Week ending 9th June 2013

and model the components. Training that addresses BIM modelling competencies can provide new employment opportunities. Currently, these competencies are found within consultant organisations, but the study suggests that component modelling competencies are not advanced within the industry.

It was illustrated that in the USA, component suppliers are increasingly supplying BIM components for consultants to include in their models. The supply chain must be made aware of the international trends and prepare for the way that information will be communicated in the future. An early realisation of this will allow component and system suppliers and manufacturers to gain an early advantage over their competitors.

6.6.6 Recommendations for government and legislators

In order to harness the benefits of BIM and partnering, legislators need to create an environment that is more conducive to new ways of working. The current procurement processes emphasise black empowerment issues and are not currently aligned to partnership agreements. This discourages collaborative arrangements. Legislation needs to allow for combined teams (partnerships) to tender for work as a unit. It was seen that in the UK the government has largely driven the process to increase BIM use and encourage collaborative arrangements. Graham Watts, the Chief Executive Officer of the Construction Industry Council (CIC) notes the benefits to the nation as a whole from using BIM. He makes the following statement (HM_Government, 2012):

> "BIM will integrate the construction process and, therefore, the construction industry. But it will also have many additional benefits for the nation. It will enable intelligent decisions about construction methodology, safer working arrangements, greater energy efficiency leading to carbon reductions and a critical focus on the whole life performance of facilities (or assets). Of even greater importance are the benefits for the economy that will accrue from better buildings and infrastructure delivered by the construction industry."

The literature review showed that many countries have adopted BIM at national level as a result of government policies. Takim, Harris and Nawawi (2013:26) discuss how the adoption of BIM happens at two levels. These are industry level and national level. In order for a technology to be adopted at the national level, the government has to mandate or regulate it. This results in policies for national standards and enforcement acts. A policy could be made to make it mandatory for BIM use on public works projects if it can be shown that there are benefits.

6.7 Limitations of the research

Findings from the case study and the examination of the BIM model reveal the methods used by a single architectural practice and do not necessarily show how other architects use BIM. However, the findings are triangulated with the survey information and literature review, showing an absence of advanced competencies or uses of the available features of BIM. Further research into individual models is likely to reveal different use patterns, but these can be compared using the method described in this research.

A second limitation of the study is that the architects' survey was limited to the Eastern and Western Cape, due to the difficulty in obtaining data for the other regions. This is covered in the methodology. However, a comparison of the results for the two regions did not show significant difference between the two areas. Future research may potentially address this limitation to confirm if the results obtained for the two regions are applicable to the rest of the country, particularly Gauteng and KwaZulu-Natal, where there are large metropolitan areas. It was noted from a survey conducted in the USA that there was no substantial regional variation with BIM use, with no regions being more than six percentage points from the national average.

The comparatively low response rate from the survey directed at contractors may introduce a bias into the findings, as non-responders may be more aware of BIM than responders. This cannot be ascertained by the research. Further research is required to verify the findings.

The surveys were addressed to the email address of the contact name given in the contact information for both architects and contractors. This may bias the findings of the research, as the contact person may not have been the most appropriate respondent. Further research may be required to verify the findings.

The SNA analysis looked at one mode of communication during the project, being email correspondence. Face to face and telephonic conversations could not be analysed using the method described. Further research may analyse different modes of communication to give a more complete picture of the project network, although this may not be as objective, as recalling conversations relies on participants' memories.

6.8 Cautionary note

Caution is advised when using this research. The findings are exploratory and are based on a single case study and exploratory surveys.

Bibliography

Ackoff, R., Magidson, J., & Addison, H. (2006). *Idealized Design - Creating an Organizations Future.* New Jersey: Wharton School Publishing.

Adobe Systems Incorporated. (2006). *PDF reference 6th edition: Adobe portable document format - version 1.7.* Adobe Systems Incorporated.

Aggarwal, C. (2011). *Social networks data analytics.* New York: Kluwer Academic Publishers.

AIA. (2007). *Integrated project delivery: a guide.* Washington: American Instiute of Architects.

AIA. (202). *AIA document E202 2008: building information modeling protocol exibit.* Washington: American Institute of Architects.

Ankrah, A. (2007). *An investigation into the impact of culture on construction project performance.* Wolverhampton: University of Wolverhampton.

Anumba, C., Egbu, C., & Carrillo, P. (2006). *Knowledge management in construction.* Oxford: Blackwell Publishing Ltd.

Aranda-Mena, G., Crawford, J., Chevas, A., & Froese, T. (2009). Building information modelling demystified: does it make business sense to adopt BIM? (pp. 419 - 433). Melbourne: Emerald.

Autodesk Revit White Paper, _. (u/d). *Multi-user collaboration with Autodesk Revit worksharing.* Autodesk Inc.

Awodele, O., & Ogunsemi, D. (2010). An assessment of success factors and benefits of project partnering in Nigerian construction industry. *CIB 2010 World Congress.* Manchester: University of Salford.

Babbie, E. (2007). *The practice of social research - 12th edition.* Belmont: Wadsworth.

Bartlett, J., Kotrlik, J., & Higgins, C. (2001). Organisational research: determining appropriate sample size in survey research. *Information Technology, Learning and Performance Journal, Vol 19, No 1*, 43 - 50.

Baruch, Y., & Holtom, B. (2008). Survey response rate levels and trends in organizational research. *Human Relations*, 1139 - 1160.

Becerik, B., & Pollalis, S. (2006). *Computer aided collaboration in managing construction.* Cambridge: Harvard University Graduate School of Design.

Bergman, M. (2008). *Advances in mixed method research.* London: Sage Publications Ltd.

Bergman, M. (2008). Straw men of the qualitative-quantitative divide. In M. Bergman, *Advances in mixed method research* (pp. 11-21). London: Sage Publications Ltd.

Berry, J. (2011). Integration and multiculturalism: ways toward social solidarity. *Papers on social representations*, Volume 20, 2.1-2.21.

Bouchlaghem, D. (2012). *Collaborative working in construction.* Oxon: Spon Press.

Brannen, J. (2008). The practice of a mixed methods research strategy: personal, professional and project considerations. In M. Bergman, *Advances in mixed methods research* (pp. 53 - 65). London: Sage Publications Ltd.

BSI. (2013). *PAS 1192-2:2013 Specification for information management for the capital/delivery phase of construction projects using building information modelling.* London: British Standards Institute.

Butts, C. (2008). Social network analysis:a methodological introduction. *Asian journal of social psychology*, 13 - 41.

Cabinet_Office. (2011). *Government construction strategy.*

Cabinet_Office. (2012). *Government construction strategy: one year on report and action plan update.*

Cain, C. (2003). *Building down barriers: a guide to construction best practice.* London: Taylor and Francis.

Capra, F. (2003). *The Hidden Connections.* London: Flamingo.

Cheng, W., & Cheng, T. (2007). Critical success factors for construction partnering in Taiwan. *International Journal of Project Management*, 475 - 484.

Chinowsky, P. (2011). A network and culture perspective. In P. Chinowsky, & A. Songer, *Organization management in construction* (pp. 41 - 59). Abingdon: Spon Press.

Chinowsky, P., & Songer, A. (2011). *Organizational management in construction.* New York: Spon Press.

Chinowsky, P., Diekmann, J., & Galotti, V. (2008). Social network model of construction. *Journal of construction engineering and management*, 804-812.

Contractor, N., & Monge, P. (2003). Using muti-theoretical multi-level (MTML) models to study adversarial networks. *Dynamic social network and analysis* (pp. 324 - 344). Washington: Office of Naval Research.

Cox, A., & Ireland, P. (2006). Relationship management theories and tools in project procurement. In S. Pryke, & H. Smyth, *The management of complex projects* (pp. 251-281). Oxford: Blackwell Publishing.

Cox, M., & Alm, R. (2013). *Creative destruction.* Retrieved from The concise encyclopedia of economics. 2008: http://www.econlib.org/library/Enc/CreativeDestruction.html

Crossley, N. (2011). Using social network analysis: researching relational structure. In J. Mason, & A. Dale, *Understanding social research: thinking creatively about method* (pp. 75 - 89). London: Sage Publications Ltd.

Dempwolf, C., & Lyles, L. (2012). The uses of social network analysis in planning: a review of the literature. *Journal of planning literature*, 3-21.

Egan, J. (1998). *Rethinking construction: the report of the construction task force.* London: Department of Trade and Industry.

Egbu, C., & Robinson, H. (2005). Construction as a knowledge based industry. In C. Anumba, C. Egbu, & P. Carrillo, *Knowledge management in construction* (pp. 31 - 49). Oxford: Blackwell Publishing.

Egbu, C., Fryer, B., Ellis, R., & Gorse, C. (2004). *The practice of construction management (4th edition).* Oxford: Blackwell Publishing.

Faust, K. (1997). Centrality in affiliation networks. *Elsevier*, 157-191.

Faust, K. (2005). Using correspondence analysis for joint displays of affiliation networks. In P. Carrington, J. Scott, & S. Wasserman, *Models and methods in social network analysis* (pp. 117 - 147). New York: Cambridge University Press.

Fellows, R., & Liu, A. (2006). Culture as a category of risk in construction. *CCIM 2006 Sustainable development through culture and innovation* (pp. 138 - 147). Rotterdam: In house.

Flyvbjerg, B. (2006). Five misunderstandings about case study research. *Qualitative Inquiry*, 219-245.

Flyvbjerg, B. (2011). Case study. In N. Denzin, & Y. Lincoln, *The Sage handbook of qualitative research* (pp. 301-316). Thousand Oaks: Sage.

Fouche, J. (2004). *A normative model for alliance partnering in the South African engineering & construction industry.* Potchefstrrom: MBA dissertation, North-West University.

Gibbs, D., Emmitt, S., Ruikar, K., & Lord, W. (2012). An investigation into whether building information modelling (BIM) can assist with construction delay claims. *Proceedings for the first UK academic conference on BIM* (pp. 35 - 44). Newcastle: Northumbria University.

Gill, J., & Johnson, P. (2010). *Research methods for managers.* London: Sage Publications.

Gleick, J. (1998). *Chaos: the amazing science of the unpredictable.* London: Vintage Books.

Graphisoft. (2013). *Interoperability with structural disciplines.* Graphisoft.

Green, L. (2001). *Communication, technology and society.* London: Sage Publications Ltd.

Gribbin, J. (1984). *In search of Schrodingers cat: quantum physics and reality.* New York: Bantam Books.

Hammersley, M. (2008). Troubles with triangulation. In M. Bergman, *Advances in mixed method research* (pp. 22 - 36). London: Sage Publications.

Hardin, B. (2009). *BIM and construction management - proven tools, methods, and workflows.* Indianapolis: Wiley Publishing.

Hassan, T., & Ren, Z. (2007). Legal issues of nD modelling. In G. Aouad, A. Lee, & S. Wu, *Constructing the future:nD modelling* (pp. 276-286). Abingdon: Taylor & Francis.

HM_Government. (2012). *Building information modelling: industrial strategy, government and industry in partnership.* London: HM Government.

Horne, M. (2007). Role of higher education in nD modelling. In G. Aouad, A. Lee, & S. Wu, *Constructing hte future: nD modelling* (pp. 309-325). Abingdon: Taylor & Francis.

Israel, G. (2009). *Determining sample size.* Gainesville: University of Florida.

Ivankova, N., Creswell, J., & Plano-Clark, V. (2007). Foundations and approaches to mixed methods research. In K. Maree, *First steps in research* (pp. 253 - 282). Pretoria: Van Schaik Publishers.

Javernick-Will, A., & Hartmann, T. (2011). Knowledge management in global environments. In P. Chinowsky, & A. Songer, *Organisation management in construction* (pp. 23 - 40). Abingdon: Spon Press.

Kumar, B. (2012). Building information modeling: road to 2016. *First UK academic conference on BIM* (pp. 192-199). Newcasstle: Northumbria University.

Kurzweil, R. (2005). *The singularity is near: when humans transend biology.* New Yotk: Penguin Books.

Kyburz-Graber, R. (2004). Does case-study methodology lack rigour? *Environmental Education Research*, 53-65.

Latham, M. (1994). *Constructing the team: Final report of the government/industry review of procurement and contractual arrangements in the UK construction industry.* London: Department of the Environment.

Lee, A., Wu, S., & Aouad, G. (2007). *Constructing the future: nD modelling.* Abingdon: Taylor & Francis.

Leon, M., & Laing, R. (2012). The review of BIM as an effective tool for collaborative design during the early design stages. *First UK academic conference on BIM* (pp. 109-117). Newcastle: Northumbria University.

Maree, K., & Pietersen, J. (2007). Sampling. In K. Maree, *First steps in research* (pp. 171 - 181). Pretoria: Van Schaik Publishers.

Maree, K., & Pietersen, J. (2007). Surveys and the use of questionnaires. In K. Maree, *First steps in research* (pp. 155 - 170). Pretoria: Van Schaik Publishers.

Maree, K., & van der Westhuizen, C. (2008). Planning a research proposal. In K. Maree, *First steps in research* (pp. 23 - 45). Pretoria: Van Schaik Publishers.

Marin, A., & Wellman, B. (2011). Social network analysis: an introduction. In J. Scott, & P. Carrington, *The Sage handbook of social network analysis* (pp. 11-25). London: Sage.

Mayer, K. (2012). Objectifying social structures: network visualization as means of social optimization. *Theory & Psychology*, 162-178.

McGraw-Hill. (2010). *The business value of BIM in Europe: getting building information to the bottom line in the United Kindom, France and Germany.* Bedford, MA: McGraw-Hill Companies.

McGraw-Hill. (2012). *The business value of BIM in North America: Multi-year trend analysis and user ratings (2007 - 2012).* Bedford, MA: McGraw-Hill Construction.

Moliterno, T., & Mahony, D. (2011). Network theory of organization: a multilevel approach. *Journal of Management*, 443 - 467.

Morris, P. (2006). How do we learn to manage projects better? In S. Pryke, & H. Smyth, *The management of complex projects: a relationshiph approach* (pp. 58-77). Oxford: Blackwell Publishing Ltd.

Mosey, D. (2009). *Early contractor involvement in building procurement: contracts, partnering and project management.* Chichester: John Wiley & Sons Ltd.

Naoum, S. (2011). *People and Organizational Culture in Construction - Second edition.* London: ICE Publishing.

NBS. (2011). *Building information modelling: report March 2011.* London: RIBA Enterprises Ltd.

Neuman, W. (2006). *Social research methods - qualitative and quantitative approaches - 6th ed.* Boston: Pearson.

Ngah, R., & Jusoff, K. (2009). Tacit knowledge sharing and SMEs' organizational performance. *International journal of economics and finance*, 216 - 220.

Nieuwenhuis, J. (2007). Introducing qualitative research. In K. Maree, *First steps in research* (pp. 46 - 68). Pretoria: Van Schaik Publishers.

Nieuwenhuis, J. (2007). Qualitative research designs and data gathering techniques. In K. Maree, *First steps in research* (pp. 69 - 97). Pretoria: Van Schaik Publishers.

Nissen, M., & Lee, J. (2010). Accelerating acculturation through tacit knowledge flows: refining a grounded theory model. *The journal of information and knowledge management systems*, Vol. 40 3/4 312-325.

Nonaka, I. (2007, July - August). The knowledge-creating company. *Harvard Business Review*, pp. 162-171.

Parise, S. (2007). Knowledge management and human resource development: an application in social network analysis methods. *Advances in developing human resources*, 359 - 383.

Perumal, V., & Abu Bakar, A. (2011). The needs for standardization of document towards an efficient communication in the construction industry. *World Applied Sciences Journal 13*, 1998-1995.

Pirsig, R. (1974). *Zen and the art of motorcycle maintenance.* New York: William Morrow & Company.

Porter, S. (2004, Spring). Raising response rates: what works? *New directions for institutional research, no. 121*, pp. 5-21.

Pryke, S. (2006). Projects as networks of relationships. In S. Pryke, & H. Smyth, *The management of complex projects: a relationship approach* (pp. 213 - 235). Oxford: Blackwell Publishing Ltd.

Pryke, S. (2012). *Social network analysis in construction.* Oxford: Wiley-Blackwell.

Pryke, S., & Smyth, H. (2006). *The management of complex projects: a relationship approach.* Oxford: Blackwell Publishing Ltd.

Quintas, P. (2005). The nature and dimensions of knowledge management. In C. Anumba, C. Egbu, & P. Carrillo, *Knowledge management in construction* (pp. 10-30). Oxford: Blackwell Publishing Ltd.

Race, S. (2012). *BIM demystified.* London: RIBA publishing.

Radosavljevic, M., & Bennett, J. (2012). *Construction management strategies - a theory of construction management.* Chichester: John Wiley & Sons Ltd.

Razlim, F., Mustaffa, N., & Yaakob, J. (2010). Legal issues of partnering in construction: an analysis of case law. *RICS COBRA conference.* London: RICS.

Rischmoller, L. (2007). Construction scheduling: a Latin American perspective. In G. Aouad, A. Lee, & S. Wu, *Constructing the future: nD modelling* (pp. 82-97). New York: Taylor & Francis.

Rogers, E. (1983). *Diffusion of inovations - 3rd edition.* New York: Macmillan Publishing Co. Inc.

Rogers, W. (2009). BIM implementation strategies. In D. Smith, & M. Tardif, *Building information modeling - a strategic implementation guide* (pp. 27 - 55). Hoboken: Wiley & Sons.

Sanchez, R. (2004). *"Tacit knowledge" versus "Explicit knowledge" - approaches to knowledge management practice.* Copenhagen: Copenhagen Business School .

Schultz-Jones, B. (2009). Examining information behavior through social networks: an interdiciplinary review. *Journal of Documentation*, 592 - 631.

Schumpeter, J. (1962). *Capitalism, socialism and democracy.* New York: Harper Torchbooks.

Sebastian, R. (2011). Changing roles of the clients, architects and contractors through BIM. *Engineering, construction and architectural management*, Volume 18, pp. 176 - 187.

Sellitto, C. (2006). Improving winery survey response rates: lessons from the Australian wine industry. *International journal of wine marketing*, 150-152.

Senge, P. (2006). *The fifth discipline - the art & practice of the learning organisation.* London: Random House Business Books.

Senge, P., Ross, R., & Kleiner, A. (1994). *The Fifth Discipline Handbook - Strategies and Tools for Building a Learning Organization.* New York: Doubleday.

Serdult, U., Vogeli, C., Hirschi, C., & Widmer, T. (2007). Assessing structure from process: The Actor Process Event Scheme (APES). *4th*

Conference on applications of Social Network Analysis. Zurich: University of Zurich.

Sexton, M. (2007). Technology transfer. In G. Aouad, A. Lee, & S. Wu, *Constructing the future: nD nodelling* (pp. 299-308). Abingdon: Taylor & Francis.

Sheehan, K. (2006, June 23). *E-mail survey response rates: a review.* Retrieved September 21, 2012, from Wiley on-line library: http://onlinelibrary.wiley.com/doi/10.1111/j.1083-6101.2001.tb00117.x/full

Sheehan, T., Poole, D., Lyttle, I., & Egbu, C. (2005). Strategies and business case for knowledge management. In C. Anumba, C. Egbu, & P. Carrillo, *Knowledge management in construction* (pp. 50 - 64). Oxford: Blackwell Publishing Ltd.

Shelbourn, M., Sheriff, A., Bouchlaghem, D., El-Hamalawi, A., & Yeomans, S. (2012). Collaboration - key concepts. In D. Bouchlaghem, *Collaborative working in construction* (pp. 6 - 25). Oxon: Spon Press.

Silverman, D. (2010). *Doing qualitative research* (3rd ed.). London: Sage Publications Ltd.

Smallwood, J., Emuze, F., & Allen, C. (2012). Building information modelling: South African architects' and contractors' perceptions and practices. *First UK academic conference on BIM* (pp. 141 - 151). Northumbria: Northumbria University.

Smith, D. (2007, Fall). An introduction to building information modelling (BIM). *Journal of building information modelling*, pp. 12-14.

Smith, D., & Tardif, M. (2009). *Building information modeling.* Hoboken: Wiley & Sons.

Smyth, H. (2006). Measuring, developing and managing trust in relationships. In S. Pryke, & H. Smyth, *The management of complex projects: a relationship approach* (pp. 97-120). Oxford: Blackwell Publishing Ltd.

Songer, A., & Chinowsky, P. (2011). Leading the modern construction organisation. In A. Songer, & P. Chinowsky, *Organization management in construction* (pp. 7-22). Abingdon: Spon Press.

Statsbygg. (2011). *Statbygg buildding information modelling manual : Version 1.2.* Oslo: Statsbygg.

Suermann, P. (2009). *Evaluating the impact of building information modelling (BIM) on construction.* Florida: University of Florida.

Takim, R., Harris, M., & Nawawi, A. (2013). Building information modeling (BIM): a new paradigm for quality of life within architectural, engineering and construction industry. *AMER international conference on quality of life* (pp. 23-32). Langkawi: Elsevier.

Tanner, J., Patterson, F., & Byrne, R. (2006). The development of spontaneous gestures in zoo-living gorillas and sign taught gorillas: from action and location to object representation. *The journal of developmental processes*, 69-102.

Thomas, G. (2011). A typology for the case study in social science following a review of definition, discourse and structure. *Qualititive Enquiry*, 511 - 521.

Thomsen, C., Darrington, J., Dunne, D., & Lichtig, W. (2010). *Managing integrated project delivery.* McLean: CMAA.

Tizani, W. (2007). Engineering design. In A. Lee, S. Wu, & G. Aouad, *Constructing the future: nD modelling* (pp. 14-39). Abingdon: Taylor & Francis.

Van der Merwe, F., & Basson, G. (2008). Partnering with the design team. *5th post graduate conference on construction industry development.* Bloemfontein: CIDB.

Vanossi, A., Veliz, A., Balbo, R., & Ciribini, A. (2012). Paths between real and virtual environments within a BIM based scheme. First *UK academic conference on BIM* (pp. 254-265). Newcastle: Northumbria University.

Walker, A. (2011). *Organisational Behaviour in Construction.* Chichester: Wiley - Blackwell.

Wang, X. (2012). The new BIM player - China. *Journal of Building Information Modeling*, 27-28.

Wegner, D. (2003). The mind's best trick: how we experience conscious will. *Trends in cognitive sciences*, Cambridge MA.

Weygant, R. (2011). *BIM content development: standards, strategies, and best practices.* Hoboken: Wiley & Sons Inc.

Widmer, T., Hirschi, C., Serdűlt, U., & Vőgeli, C. (2008). Analysis with APES, the actor process event scheme. In M. Bergman, *Advances in mixed method research* (pp. 150 - 171). London: Sage Publications Ltd.

Wiley, J., Albaum, G., Han, V., & Thirkell, P. (2009). Selecting techniques for use in an internet survey. *Asia Pacific Journal of marketing and logistics*, 455-474.

Zahiroddiny, S. (2012). Evaluating and identifying optimal BIM communication patterns within design and construction projects. *First UK acadamic conference on BIM* (pp. 200-210). Newcastle: Northumbria University.

Zainal, Z. (2007). Case study as a research method. *Jurnal Kemanusiaan*.

Appendices

8.1 Appendix 1 Contractors survey

8.1.1 Contractor survey pre-notification email

<COMPANY NAME>

SOUTH AFRICAN CONTRACTORS AND BIM PERCEPTIONS

Dear <Name>

A survey is to be conducted under the auspices of the Nelson Mandela Metropolitan University (NMMU) in conjunction with the Construction Industry Development Board (CIDB) in order to obtain a more complete picture of the use of the technology used by the construction industry in South Africa. The survey, among South African Contractors, aims to be the most comprehensive to date on technology use in South Africa. We would value your input to the survey, whether or not you have used BIM.

The survey is designed to be as short as possible and it is anticipated that completing the survey will take less than three minutes of your time. Respondents will receive the results of the completed survey, which will allow them to compare their practice and perceptions with other contractors operating in South Africa.

Respondents will remain entirely anonymous and no data will be sent to any other party.

The survey is to be sent out by email on 23rd October 2013, and your participation would be significantly valuable to the outcome of the survey. However, if you do not wish to participate, please return this email and your name will be removed from the list to ensure that you receive no further correspondence with regard to this survey.

Should you have any queries or comments regarding the survey, please do not hesitate to contact me. My contact details are shown below.

Kind regards,

Tim Froise

Department of Construction Management
Nelson Mandela Metropolitan University
Tel **041 504 3214**
Cell **081 270 7576** Email : tfroise@nmmu.ac.za

8.1.2 Contractor survey link email

<COMPANY NAME>

SOUTH AFRICAN CONTRACTORS AND BIM PERCEPTIONS

Dear <Name>

I refer to my email, sent last week regarding a proposed survey. The survey, among South African contractors aims to be the most comprehensive to date on technology use in South Africa. Your input to the survey will be valuable, whether or not you use BIM for your projects.

Respondents will receive a PDF copy of the survey results, allowing them to compare their practice and perceptions with other companies operating in South Africa.

The survey is designed to be as short as possible and should take less than five minutes of your time. Respondents will remain entirely anonymous and no data will be sent to any other party.

Please click the link below to access the survey.

<LINK TO SURVEY>

Your participation would be significantly valuable to the outcome of the survey. However, if you do not wish to participate, please return this email and your name will be removed from the list to ensure that you receive no further correspondence with regard to this survey.

Should you have any queries or comments regarding the survey, please do not hesitate to contact me. My contact details are shown below.

Kind regards,

Tim Froise

Department of Construction Management

Nelson Mandela Metropolitan University

Tel	**041 504 3214**
Cell	**081 270 7576**
Email	tfroise@nmmu.ac.za

8.1.3 Contractors reminder email

Contractor survey reminder

<COMPANY NAME>

SOUTH AFRICAN CONTRACTORS AND BIM PERCEPTIONS

Dear <Name>

BIM is a new technology that is gaining recognition in the construction industry around the world and is increasingly being used in South Africa. It is not a product or brand name.

I would like to thank all those that have responded to the survey, which was sent out last week. If you have not yet responded I would humbly request a few minutes of your time. Your input to the survey will be valuable, whether or not you use BIM for your projects.

The survey is designed to be as short as possible and should take about three or four minutes of your time. Respondents will remain entirely anonymous and no data will be sent to any other party.

Please click the link below to access the survey.

<LINK TO SURVEY>
Respondents will receive a PDF copy of the survey results, allowing them to compare their practice and perceptions with other companies operating in South Africa.

Should you have any queries or comments regarding the survey, please do not hesitate to contact me. My contact details are shown below.

Kind regards,

Tim Froise

Department of Construction Management
Nelson Mandela Metropolitan University

Tel	**041 504 3214**
Cell	**081 270 7576**
Email	tfroise@nmmu.ac.za

8.1.4 Contractors final reminder

Contractor survey reminder

<COMPANY NAME>

SOUTH AFRICAN CONTRACTORS AND BIM PERCEPTIONS

Dear <Name>

I would like to thank all those that have responded to the survey, sent out two weeks ago. Please note that the survey will soon close and I send this final reminder to request those that have not yet responded to spend a short time to complete the survey. Your input to the survey will be valuable, whether or not you use BIM for your projects.

BIM is a new technology that is gaining recognition in the construction industry around the world and is increasingly being used in South Africa. It is not a product or brand name.

The survey is designed to be as short as possible and should take less than three minutes of your time. Respondents will remain entirely anonymous and no data will be sent to any other party.

Please click the link below to access the survey.

<LINK TO SURVEY>

Respondents will receive a PDF copy of the survey results, allowing them to compare their practice and perceptions with other companies operating in South Africa.

Should you have any queries or comments regarding the survey, please do not hesitate to contact me. My contact details are shown below.

Kind regards,

Tim Froise

Department of Construction Management

Nelson Mandela Metropolitan University

Tel	**041 504 3214**
Cell	**081 270 7576**
Email	tfroise@nmmu.ac.za

8.1.5 Transcript of contractors survey

Contractors BIM survey

Page: 1 2 3

This survey is being conducted under the auspices of the Construction industry Development Board (CIDB) and Nelson Mandela Metropolitan University (formerly University of Port Elizabeth). The purpose of this survey is to determine the attitudes and perceptions of South African contractors to BIM, and will be compared with similar studies which have been conducted in other countries. Your participation in this short survey will assist in creating a more complete picture than has been previously created.

1. What is BIM?

During the late part of the twentieth century, computers and software became developed enough to use for draughting. They increased the productivity of the designer and allowed easier storage and transfer of drawings, particularly with the advent of the internet.
As the computer hardware improved, software became more sophisticated, allowing for the development of 3D views. Some view the concept of BIM as the next step in computerisation.

1.1 How aware are you of BIM?

- Have never heard of BIM
- Have heard of BIM
- Have heard of BIM and have a fair understanding of what it means
- I /We are familiar with the BIM concept

Page: 1 2 3

Building information modelling (BIM) is a concept that was developed in the late eighties, although computer technology limited its use. The model is a 3D information rich simulation of the proposed building from which drawings, schedules and quantities can be extracted.
Nowadays, the most common BIM systems include:
• MicroStation (Bentley Architecture)
• Revit (Autodesk)
• AutoCAD Architecture (Autodesk)
• ArchiCAD (Graphisoft)
•Vectorworks (Nemetscheck)

2. BIM use

How much is BIM used?

2.1 Do you use BIM?

- Not at all
- We have used it on one/some projects
- We us e it on most projects
- We only use BIM

2.2 If you have not used BIM, would you consider using it in the future?

- No
- We are open to exploring its potential value for us
- We are actively evaluating it
- Already use BIM

2.3 If you have used BIM how long have you been using it?
Have not used BIM

- Les s than 1 year
- 1 to 2 years
- to 3 years
- to 4 years
- to 5 years
- More than 5 years

2.4 If you have used BIM who creates the model?

- We receive it from the architect/consultant
- We create our own model
- We use a third party to create the model
- Have not used BIM

Contractors BIM survey
Page: 1 2 3

How is BIM used?

3. How is BIM used?

Typically drawings are created using 2D CAD software, with separate documents for schedules. Drawings are printed out for the contractor.

3.1 Please indicate which of the following processes in your opinion are improved/streamlined by using BIM over 2D CAD.

- Drawing and schedule production
- Visualisation
- Programming
- Costing
- Analysis
- Collaborating with consultants
- Don't use BIM /don't know

3.2 Do you think that there is any value in having a shared central building model that can be accessed by all project participants (partnering)?

- No value
- To a limited degree
- To a substantial degree

3.3 Are there advantages to using a collaborative arrangement with the consultants?

- No advantage
- To a limited degree
- To a substantial degree

3.4 What factors could limit collaboration/partnering on construction projects?

- Confidentiality of information
- Lack of trust or communication
- No clear contractual boundaries
- The South African environment makes it difficult
- Other reasons

3.5 Please indicate your CIDB grade

- Grade 6
- Grade 7
- Grade 8
- Grade 9

3.6 Please indicate your region.

- Eastern C ape
- Free State
- Gauteng
- KwaZulu-Natal
- Limpopo
- Mpumalanga
- North West
- Northern Cape
- Western Cape

3.7 Do you have any other comments on BIM or collaboration?

3.8 Please provide an email address if you would like a copy of the results.

<< Previous Page Submit Questionnaire

8.2 Architects BIM survey

8.2.1 Architects pre-notification email

Architectural survey

<COMPANY NAME>

SOUTH AFRICAN ARCHITECTS AND BIM PERCEPTIONS

Dear <Name>

A survey is to be conducted under the auspices of the Nelson Mandela Metropolitan University (NMMU) in conjunction with the Construction Industry Development Board (CIDB) in order to obtain a more complete picture of the use of the technology used by architects in South Africa. The survey, among South African Architects, aims to be the most comprehensive to date on BIM use in South Africa. We would value your input to the survey, whether or not you use BIM in your practice.

The survey is designed to be as short as possible and it is anticipated that completing the survey will take less than three minutes of your time. All respondents will receive the results of the completed survey, which will allow them to compare their practice and perceptions with other practices operating in South Africa.

Respondents will remain entirely anonymous and no data will be sent to any other party.

The survey is to be sent out by email on 23rd October 2013, and your participation would be significantly valuable to the outcome of the survey. However, if you do not wish to participate, please return this email and your name will be removed from the list to ensure that you receive no further correspondence with regard to this survey.

Should you have any queries regarding the survey, please do not hesitate to contact me. My contact details are shown below.

Kind regards,

Tim Froise BArch, MSc Arch

Tel 041 504 3214
Cell 081 270 7576

8.2.2 Architects survey email

Architectural survey

<COMPANY NAME>

SOUTH AFRICAN ARCHITECTS AND BIM PERCEPTIONS

Dear <Name>

I refer to my email, sent last week regarding a proposed survey. The survey, among South African Architects, aims to be the most comprehensive to date on technology use in South Africa. We would value your input to the survey, whether or not you use BIM in your practice.

All respondents will receive a PDF copy of the survey results, allowing them to compare their practice and perceptions with other practices operating in South Africa.

The survey is designed to be as short as possible and should take less than five minutes of your time.

Respondents will remain entirely anonymous and no data will be sent to any other party.

Please click the link below to access the survey.

<LINK TO SURVEY>

Your participation would be significantly valuable to the outcome of the survey. However, if you do not wish to participate, please return this email and your name will be removed from the list to ensure that you receive no further correspondence with regard to this survey.

Should you have any queries regarding the survey, please do not hesitate to contact me. My contact details are shown below.

Kind regards,

Tim Froise BArch, MSc Arch

Tel **041 504 3214**
Cell **081 270 7576**
Email tfroise@nmmu.ac.za

8.2.3 Architects reminder email

Architectural survey

<COMPANY NAME>

SOUTH AFRICAN ARCHITECTS AND BIM PERCEPTIONS

Dear <Name>

I would like to thank all those that have responded to the above-mentioned survey, which was sent out last week. If you have not yet responded I would humbly request a few minutes of your time. Your input to the survey will be valuable, whether or not you use BIM for your projects.

The survey is designed to be as short as possible and should take about three or four minutes of your time. Respondents will remain entirely anonymous and no data will be sent to any other party.

Please click the link below to access the survey.

<LINK TO SURVEY>

Respondents will receive a PDF copy of the survey results, allowing them to compare their practice and perceptions with other companies operating in South Africa.

Should you have any queries or comments regarding the survey, please do not hesitate to contact me. My contact details are shown below.

Kind regards,

Tim Froise BArch, MSc Arch

Tel	**041 504 3214**
Cell	**081 270 7576**
Email	tfroise@nmmu.ac.za

8.2.4 Architects final reminder

<COMPANY NAME>

SOUTH AFRICAN ARCHITECTS AND BIM PERCEPTIONS

Dear <Name>

I would like to thank all those that have responded to the survey, sent out two weeks ago. Please note that the survey will soon close and I send this final reminder to request those that have not yet responded to spend a short time to complete the survey. Your input to the survey will be valuable, whether or not you know what BIM is. If you have completed the survey, please ignore this email – I will send the results to respondents once the analysis is done.

BIM is a new technology that is gaining recognition in the construction industry around the world and is increasingly being used in South Africa. It is not a product or brand name.

The survey is designed to be as short as possible and should take less than three minutes of your time. Respondents will remain entirely anonymous and no data will be sent to any other party.

Please click the link below to access the survey.

<LINK TO SURVEY>

Respondents will receive a PDF copy of the survey results, allowing them to compare their practice and perceptions with other companies operating in South Africa.

Should you have any queries or comments regarding the survey, please do not hesitate to contact me. My contact details are shown below.

Kind regards,

Tim Froise BArch, MSc Arch

Tel	**041 504 3214**
Cell	**081 270 7576**
Email	tfroise@nmmu.ac.za

8.2.5 Transcript of architects survey

Page: 1 2 3

This survey is being conducted under the auspices of the Construction industry Development Board (CIDB) and Nelson Mandela Metropolitan University (formerly University of Port Elizabeth). The purpose of this survey is to determine the attitudes and perceptions of South African architects to BIM, and will be compared with similar studies which have been conducted in other countries. Your participation in this short survey will assist in creating a more complete picture than has been previously created.

1. What is BIM?

During the late part of the twentieth century, computers and software became developed enough to use for draughting. They increased the productivity of the designer and allowed easier storage and transfer of drawings, particularly with the advent of the internet.

As the computer hardware improved, software became more sophisticated, allowing for the development of 3D views. Some view the concept of BIM as the next step in computerisation.

1.1 How aware are you of BIM? (Could only choose one option)

- Have never heard of BIM
- Have heard of BIM
- Have heard of BIM and have a fair understanding of what it means
- I /We are familiar with the BIM concept

1.2 Please indicate the size of your practice (Could only choose one option)

- 1 – 5 staff
- 5 – 10 staff
- 10 - 20 staff
- 20 – 50 staff
- More than 50 staff

1.3 Please indicate your region (Could only choose one option)

- GIFA
- PIA
- ECIA
- CIFA
- KZN

Page: 1 2 3

2. BIM use

Building information modelling (BIM) is a concept that was developed in the late eighties, although computer technology limited its use. The first recognised BIM developer was Graphisoft, which developed Archicad. ArchiCAD could combine 3D and 2D information from the same model.

Nowadays, the most common BIM systems include:
• MicroStation/Bentley Architecture
• Revit (Autodesk)
• AutoCAD Architecture (Autodesk)
• ArchiCAD (Graphisoft)
• Vectorworks (Nemetscheck)

2.1 Do you use BIM? (Could only choose one option)
- Not at all
- We have used it for one/some projects
- We use it for most projects
- We only use BIM

2.2 If you have not used BIM, what would be the reason?
- We are comfortable with our current system
- BIM is too expensive
- The technology is not yet mature
- The learning curve is too expensive
- The learning curve is too steep
- I /we don't consider that it would offer any benefit
- We already use BIM
- Not required for our type of business
- Other

2.3 If you have not used BIM, would you consider using it in the future?
- No
- We may consider it when the technology becomes more mature
- We are currently investigating BIM
- Yes, we are planning to invest in it
- We already use BIM

2.4 How long have you being using BIM? (Could only choose one option)
- Don't use BIM
- Less than 1 year
- 1 – 2 years
- 2 - 3 years
- 4 - 5 years
- More than 5 years

2.5 How do you consider your company's' BIM skills? (Could only choose one option)
- Don't use BIM
- Elementary

- Average
- Good

Page: 1 2 3

3. How is BIM used?

Nowadays, most architectural practices use different software to document the project. Typically, working drawings are done using CAD, such as AutoCAD, 3D image created using software such as Sketchup, while schedules are created in Excel. Architects that do use BIM use it for a portion of their work.

3.1 Please indicate what you typically use BIM for on a project

- Conceptual design
- Drawing production
- Visualisation
- Schedule creation
- Programming
- Quantities /costing
- Analysis, such as energy use, acoustic studies
- Collaborating with other consultants , such as engineers , using a shared model
- Collaborating with the contractor
- Do not use BIM

3.2 Please indicate which of the following processes in your opinion are improved/streamlined by using BIM over 2D CAD

- Conceptual design
- Drawing production
- Visualisation
- Schedule creation
- Programming
- Quantities /costing
- Analysis , such as energy use, acoustic studies
- Collaborating with other consultants
- Collaborating with the contractor
- Do not use BIM /don't know

3.3 How do you exchange information with other consultants such as engineers or quantity surveyors on BIM projects?

- Hard copies generated by hand (drawing board)
- Hard copies generated by CAD software, such as AutoCAD
- Electronic copies generated by CAD software, such as AutoCAD
- Export BIM drawings to a format that they can use, such as DWG
- Export BI M model
- Allow access to the BI M model over a network

3.4 Do you think that there is any value in having a shared central building model that can be accessed by all project participants (partnering)? (Could only choose one option)

- No value
- To a limited degree

- To a substantial degree

3.5 Are there advantages to using a collaborative arrangement with contractors? (Could only choose one option)

- No advantage
- To a limited degree
- To a substantial degree

3.6 What factors could limit collaboration/partnering on construction projects?

- Confidentiality of information
- Lack of trust or communication
- No clear contractual boundaries
- The South African environment makes it difficult
- Other reasons

3.7 Do you have any other comments on BIM or collaboration?

____

3.8 Please provide an email address if you would like to receive a copy of the results (won't be used for any other purposes).

____

8.3 List of comments

The following are the comments that were received from the survey. Comments from the architectural survey are listed first, followed by those from the contractor survey.

8.3.1 Architect's comments

We would invest when a project suitable to carry cost if initiation is available

Although I do not currently use BIM, it remains an exciting toll for the building industry and is of benefit to all who use it, including building contractors. I believe that more education and information distribution is required for BIM to become an integral part of our industry

Collaboration requires all participants to ideally have the same program, say, late edition AutoCAD. Many participants have old editions, others have different CAD programs. Sharing is generally possible but requires having to save in a particular format, (older AutoCAD, DXF format, etc) on one occasion both for one contract. This has serious logistic problems of keeping each format up to date. As regards REVIT, which we use, not a lot of consultants or contractors will have this. A specialist, say mechanical engineer may have an appropriate Revit but not the architectural. I have not found any QS using BIM documentation for measuring quantities or costing.

We have BIM packages in our office, but have enormous resistance to the use thereof by our staff due to the learning curve involved. BIM is a fantastic step forward, but the cost thereof (both in terms of time investment and actual cost of acquisition) is prohibitive.

not yet using BIM to collaborate. Also, mostly working on smaller residential scale projects

Consultants we work with are not in BIM environment yet and surprisingly do not use our model if they are expensive, internet too slow for colab

I believe too much information is required too early on in the project for BIM to work efficiently. I think it would not be great for alterations and smaller jobs.

Most projects involve working with consultants who do not use BIM to the degree which we do, which can sometimes slow / complicate the coordination.

THE REST OF THE INDUSTRY ARE RESISTING CHANGE

Not always worth the drawing time on small projects like residential

There are different programmes available and consultants generally use one that is different to the one you use & tends not to be compatible. Contractors are generally not technologically up to date and prefer paper copies. Revit, for example is complicated and expensive for small practices - it doesn't make sense in terms of time out to learn it.

ArchiCAD has not got Agreema Certificate SA yet and this has hindered the full usage of the software to do energy efficiency calculations.

We have had a recent experience of the consultant team using a shared model for all drawing coordination and it was a bad experience. It was using REVIT. Im not sure what the issue is... perhaps not all users were fully skilled and capable (that seems to be a necessity), perhaps there wernt enough clear protocols and boundaries of who does what and perhaps the person managing the model (the crucial position) was not best suited. I do think that there are opportunities but, after a few short experiments, our office has agreed to limit our computer drawings to basic AUTO CAD LITE that are then email able to other consultants.

one of the challenges are to convince consultants and contractors to switch over and make use of this facility. too many different software packages used in the market and costs for consultants to convert to applicable software too costly.

Very few of the other professions use BIM

South African Engineers and Contractors are not yet ready to operate on BIM platform

i was not aware of the term bim even though using the software

It is a must for being competitive and efficient

BIM is great but the lack of skill and software amongst other consultants is frustrating. At this stage we are only able to benefit in our own practice.

8.3.2 Contractor comments

our apologies for not being able to give a more meaningful input but the only 3D views of details used to date have been in partnership with Tasmanian Consultants to give us a better understanding of intricate details

BIM from the definition, seems like a revolutionary system, that will save time(which equal costs).

Often the construction process is running just ahead of design so consultants may not have a 3D model ready or may be scared of showing the contractor how little the design has been developed. Sharing of the model for information even if not fully developed is useful but does not make a massive difference. If there was a fully developed model it would be much more useful as it can produce quantities of materials and the details of connections and intersections could be examined and understood which would speed up construction. A lot of these details are developed by the Engineers and I have not seen any 3D models that incorporate the Engineers design.

Not really aware of BIM

We are a construction company which tender on the open market and is therefore not involved in the design process. I think the contractor can play an important role in the design process because of his practical experience. Question is how do you manage the process in practise ? It can work where the contractor is also the developer.