WITS UNIVERSITY

THE COEVOLUTION OF AEC PROFESSIONAL WORK PRACTICES WITH TECHNOLOGY: COLLABORATIVE DELIVERY FRAMEWORK MODELLING FOR BIM PROJECTS

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A thesis submitted to the Faculty of Engineering and the Built Environment, University of the Witwatersrand, Johannesburg, in fulfilment of the requirements for the degree of Doctor of Philosophy (PhD).

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DECLARATION

I declare that this thesis is my unaided work. It is being submitted for the Degree of Doctor of Philosophy to the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination to any other University.

Adeyemi Akintola

18TH DAY OF APRIL 2018

Abstract

Despite BIM's potential to alleviate persistent construction industry challenges, its use does not guarantee results. Therefore, it was argued and established from a theoretical and practical standpoint that the implementation of BIM, an evolving technology, within pre-BIM organisational and project team work practices (as activity systems), induces their evolution through dysfunctions created in the systems and their resolution. A multi-stage\multi-method research design involving a study of BIM implementation cases, documents analysis, swimlane modelling and multi-domain-mapping (MDM) of pre-BIM and BIM-enabled project delivery processes was employed. This was to develop an understanding of how construction professional work practices evolve with the implementation of BIM. The findings show that evolutionary change of work practices within organisations precedes that of project teams. The findings further suggest a link between organisational attitude towards BIM as a method of working and success at implementing it. Using activity theory, a novel conceptual analysis of BIM induced change in professional work practices aided a theoretical understanding of the implications of implementing BIM on construction professional work practices. The theory provided a basis for analysing historical and future change patterns in professional work practices with BIM and indeed similar work mediating tools. An in-depth conceptualisation and new theoretical insight were developed on the phenomenon of new role legitimation, establishing that new BIM role takers are legitimated to exercise authority within project teams and organisations mainly because they leverage knowledge as a strategic resource. By implication, they will remain legitimate only as long as the constraint or dysfunction prompting their creation subsists. Furthermore, using swimlane and MDM modelling methods in complement, the BIM change impact on pre-BIM workflows was modelled. An objective evaluation of the BIM change impact at the pre-construction phase showed that the BIM-enabled project delivery workflows structure, compared to the pre-BIM is more connected and integrated.

Keywords: *Building Information Modelling, Activity Theory, Multi-Domain Mapping Matrices, Change, Roles, Professional Work Practices*

Dedication

To God

Acknowledgements

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List of key abbreviations

SACI	South African Construction Industry
IT	Information Technology
IS	Information Systems
CAD	Computer Aided Design
2D	Two Dimensions/Dimensional
3D	Three Dimensions/Dimensional
4D	Four Dimensions/Dimensional
5D	Five dimensions/Dimensional
6D	Six Dimensions/Dimensional
BIM	Building Information Modelling
DSM	Design Structure Matrix
DMM	Domain Mapping Matrix
MDM	Multi-Domain Mapping Matrices
BAST	BIM Authoring Software Tool
EIR	Employer's Information Requirements
PIIP	Project Information Implementation Plan
TIDP	Task Information Delivery Plan
MIDP	Master Information Delivery Plan
CDE	Common Data Environment/platform
RFI	Request for Information
RCF	Research Concept Framework
AT	Activity Theory
AEC	Architecture Engineering and Construction

1 BACKGROUND TO THE STUDY

1.1 Introduction

Construction projects are complex undertakings that require the participation of multiple and diverse natured stakeholders (Fang and Marle 2013). They are characterised by multiple interdependent components, people and processes (Antoniadis *et al.* 2008). Complexity has both technical and socio-cultural dimensions and is characterised in many aspects of projects, including organisation structure, procedures, technology among other things (Antoniadis *et al.* 2008; Fang and Marle 2013). Vidal *et al.* (2011) identified the sources of project complexity as size, variability, uncertainty, interdependencies and context (i.e. cultural and environmental configuration). Moreover, Baccarini (1996) stated that this complexity influences the management capabilities of project stakeholders regarding project team selection, planning, coordination and selection of procurement arrangements, making them perhaps one of the most complex endeavours for any industry or economic sector. Therefore, understanding and managing complexities are essential to achieving satisfactory performance of construction projects (Gransberg *et al.* 2013).

The construction industry has continued to contend with fragmentation, which is intrinsic in its structure, and also a product of the separation between design and construction (Howard *et al.* 1989; Nawi *et al.* 2013). It is also attributable to the continued specialisation of industry practices into more specific fields of operation (Nawi *et al.* 2013; Yates and Battersby 2003). This trend is a result of the evolution of practices in the construction industry. Over time, there has been a shift from master craftsmanship to splitting the responsibility for design and construction project delivery processes. Recently, there are indications of a drive back towards more integrated practices. This change in pattern is mutually shaped by the demands of the prevailing industry culture, and of projects (Diekmann 2007). It may thus be deduced that fragmentation contributes to project complexities. Furthermore, it inevitably leads to inefficiencies in project delivery processes while also impairing communication (Howard *et al.* 1989; Sharp and

McDermott 2009). By implication, construction industry fragmentation impacts the performance of projects.

These issues (of project complexities and fragmentation) are global and are therefore not alien to the South African Construction Industry (SACI). They are two of the most prominent construction industry challenges identified by both Latham (1994) and Egan (1998) in two government-sponsored reports on achieving improved project outcomes on UK construction projects. In the SACI context, project delivery problems are inclusive of inconsistent, inefficient and inappropriate systems and procedures (CIDB 2006). Current challenges likewise include poor definition and coordination of process and product quality, inadequate documentation and knowledge transfer, and the poor interface between multidisciplinary design teams (Pretorius *et al.* 2012). Therefore, addressing these issues remains essential.

Consequently, there has been a drive globally to improve the overall efficiency and effectiveness of project delivery processes through innovative research on how the integration of multiple project stakeholders' work processes can be achieved across disciplines and teams (El-Gohary and El-Diraby 2010). Integrative approaches to the delivery of projects have been advocated in different countries and jurisdictions. Howard *et al.* (1989) had suggested a shift from traditional open competition procurement practices to integrated design and construction. This is supported in successive reports by Latham (1994) and Egan (1998) respectively. Notably, achieving optimal project outcomes, a seemingly elusive pursuit of the construction industry is tied to making radical changes in the process through which projects are delivered (Egan 1998; Latham 1994). Furthermore, the use of information technology (IT) has been argued and demonstrated to be capable of providing the impetus for this change (Ahmad *et al.* 1995; Fischer and Kunz 2004; Sun and Aouad 2000). Thus, solutions are being sought both regarding changes to the delivery process and the application of the right kind of information technology.

In the late eighties to early nineties, the unprecedented changes faced by organisations stemming from globalisation, demand for the transformation within organisations and rapid developments in information technology brought about the emergence of business process reengineering (BPR) (Kettinger et al. 1997). Some of the early ideas on implementing BPR required the 'obliteration' of existing processes through radical or revolutionary change and starting from a clean slate (Kettinger et al. 1997; Martinsons 1995). Martinsons (1995) was critical of Hammer's (1990) ideas in the sense that Hammer (1990) perhaps "naively" proposed that a BPR methodology requires starting afresh as opposed to the position put forward by Davenport (1993). Notably, methodologies that focused on starting afresh were not always successful (Sharp and McDermott 2009) and weren't typically practised (Kettinger et al. 1997).

Kettinger (1997) described BPR as a form of organisational change involving the transformation of interrelated organisational subsystems. This description is similar to Ranganathan and Dhaliwal's (2001) description of it as a management tool for coping with rapid technological and business change occasioned by changing economic environments. BPR was claimed to be a tool for organisations to reduce waste in time and costs by at least 75-80 percent (Ranganathan and Dhaliwal 2001). Acknowledging their high failure rates, however, Ranaganathan and Dhaliwal (2001) posited that when executed appropriately, with relevant information technology, BPR projects are capable of producing significant gains in performance through improvements in operational efficiency and customer service within organisations. This position is allied to Davenport and Short's (1990) earlier position that work process improvements must employ the capabilities of information technology as both are natural partners. It is also supported by Kim (1994). There is thus a recursive relationship between information technology capabilities and business process change which raises questions on how IT can support business processes and how a business process can be transformed using IT (Davenport and Short 1990).

Putting these in the construction industry context, although the use of information technology (IT) in the construction industry before recent times has been largely discrete, there is sufficient evidence in the literature showing its usage has progressed. From the use of basic capturing and storage technologies to integrative and collaborative technologies (Ibem and Laryea 2014). There has been a shift towards process automation applications, computer-aided design (CAD), knowledge integration, web-based services and virtual reality among others. These innovations have created opportunities for reaping fairly high returns on investment in the technology employed in the construction industry. One of such avenues is the implementation of Building Information Modelling (BIM) which has its roots in CAD (Crotty 2012; Deutsch 2011; Elmualim and Gilder 2014). BIM is a digital representation of the physical and functional characteristics of a facility such that it creates a shared knowledge resource for information about a facility among team members and also forms a reliable basis for their decisions throughout the facility's lifecycle (NIBS 2007 p. 12). Once modelled, BIM models contain a wealth of data about the designed entity and are useful for representing several views of project data. These include two-dimensional (2D), three-dimensional (3D), four-dimensional (4D, schedule), five-dimensional (5D, cost), six-dimensional (6D, operations and maintenance) views (Arayici *et al.* 2012; Love *et al.* 2011b).

BIM facilitates a departure from traditional CAD challenges of ambiguities in design detail, non-specificity in design documentation, inaccuracies, and lack of interoperability (Crotty 2012). Furthermore, its implementation has gained prominence in the last decade, particularly so in the United States of America (USA), United Kingdom (UK), Scandinavia (Wong *et al.* 2010). Also more recently in Australia (Alabdulqader *et al.* 2013) and Asia (Cao *et al.* 2015) for both public and private sector projects. Furthermore, the primary drivers of BIM adoption have been its benefits. These benefits are widely acclaimed in research and practice. They include faster delivery processes, improved coordination, and better project outcomes (Crotty 2012). These promises appear to account for the yearly increase in adoption levels (BIM report by the National Building Specification, UK) (NBS 2014).

Nonetheless, BIM does not produce guaranteed results. Indeed, despite the foregoing, there has been limited research efforts to objectively measure the benefits of BIM (Lu *et al.* 2013a). Returns on investments in BIM have also been shown to vary significantly between projects (Giel and Issa 2013). Notwithstanding, cases from industry applications have shown that it is beneficial to the achievement of project objectives, albeit with attendant challenges and demands (Crotty 2012; Deutsch 2011). The challenges of BIM implementation revolve around the process, people and technological issues. However, even in the literature (Rekola *et al.* 2010), it is difficult to separate BIM issues and challenges into these three distinct categories, as they often take on more than one dimension.

As typical of Information Systems (IS) implementations, one of the most significant challenges associated with implementing BIM is its requirement for changing existing work practices and workflows (Martinsons and Cheung 2001; Vaast and Walsham 2005; Yeh and OuYang 2010). There is substantial evidence from existing literature that supports the notion that BIM implementation requires changes in existing workflows to achieve success (Jung and Joo 2011; Porwal and Hewage 2013; Rekola *et al.* 2010). Interestingly, while current implementers acknowledge this, even intending adopters have been shown in research to believe a change in the way they practice is essential to implement BIM successfully (NBS 2014). It may, therefore, be propositioned that implementing BIM within existing project delivery practices and procedures will create problems and could further lead to failure in achieving desired outcomes.

Hartmann *et al.* (2012) argued that it is hardly possible for BIM to induce substantial changes in existing construction industry practices, rather that it is more practical to align existing work practices to the demands of implementing BIM. This argument is credible, in that construction professional work practices are well established and difficult to change (Hughes and Murdoch 2001). However, it is failing as BIM does possess the potential to change certain aspects of the industry, project team or organisational work practices, both cognitively and practically (Cavka et al. 2015; Sebastian 2011; Xu et al. 2014; Zhang et al. 2013). Despite literature pointing to the need for changing existing work practices, there appears to be a dearth of nuanced theoretical and practical understanding of how challenges triggered by implementing BIM brings about a transformation of processes, teams and organisation structures (Çıdık et al. 2017; Dainty et al. 2017).

Therefore, the pertinent questions that need answers are; which tasks become redundant or newly created as a result of BIM implementation? How does BIM affect the distribution of roles and responsibilities among project stakeholders? Is there a need for new competencies or roles? How can the work of collaborating teams be best organised for implementing BIM on projects? How exactly is the project delivery workflow structure altered? Hence there is a need to examine construction professionals' work practices against BIM implementation demands. First, this would enable an understanding of how construction professional service providers' work practices are coevolving with new technology (BIM). Second, it would as a result aid the development of a BIM friendly collaborative framework with redefined stakeholder/task relationships and interdependencies.

1.2 Statement of the research problem

Construction projects are not being delivered efficiently due to a high level of complexity, process fragmentation, and inadequate information management. Although implementing BIM can alleviate these challenges, there is currently no theoretical and practical understanding of how it propagates changes through dysfunctions induced in existing professional work practices of organisations and project teams in the South African Construction Industry. Consequently, implementing BIM with the existing professional work practices may lead to failure of the implementation as the interfaces, relationships, roles, and dependencies within existing project delivery workflows that are not supportive of BIM. Though the claims made in the literature about BIM's capability to revolutionise construction industry work practices are not unfounded, it is nevertheless essential to develop nuanced theoretical and practical understandings of such changes, and how they came to be.

1.3 Research aim

The purpose of this study was to develop an understanding of how organisational and project team work practices coevolve with the implementation of new technology (BIM).

1.3.1 Objectives

1. To evaluate the impact of implementing BIM on organisational and project team work practices
    a. To assess how BIM implementation enables organisational and project team work practices
    b. To assess how BIM implementation constrains organisational and project team work practices
2. To elicit and model the structure of pre-BIM project team delivery workflows
3. To model a collaborative framework that is supportive of BIM
4. To assess the differences between pre-BIM project team delivery workflows and BIM-enabled project delivery workflows

1.4 Propositions

- The introduction of new tools into organisational and project team activity systems prompts dysfunctions in the systems which in turn creates demands for change. The resolutions of dysfunctions in the systems are the drivers for change and development (Engestrom 2000; Kaptelinin and Nardi 2006).
- The more construction professionals' work practices align with BIM implementation demands, the more the chances of success of the implementation (Hartmann et al. 2012).

1.5 Scope

- The study focusses on organisational activities (comprising consulting architectural, quantity surveying, services engineering and structural engineering firms) and project team activities. Hence the units of analysis are the organisational activities, project team activities and individual experiences as the case may be;

- The workflow structure includes the interdependencies, relationships, hierarchies, arrangement, and composition of the constituent tasks, roles and information produced by project teams (individually and collectively) while delivering projects at the pre-construction stage only;
- Collaborative work in this study is taken to mean multi-organisational collective work. Therefore, though all multidisciplinary projects are collaborative, the modelled workflows are based on only the design bid and build method of delivery;
- BIM in the context of this study means the process of digitally representing the physical and functional characteristics of a facility in a way that provides a shared knowledge resource for information about the facility and enables its management by organisations and project teams involved throughout the facility's lifecycle, using a system of tools and processes; and
- The number of possible iterations in each cycle of iterative tasks were not considered as this would be project-specific.

1.6 Overview of the research design

This research is qualitative; it is in part exploratory, descriptive and explanatory. It also sought to provide research contributions that may inform professional practice. To address the phenomenon of interest, *change in patterns of professional work practices* after being impacted by new technology (and associated processes), the research design draws strongly from theory to conceptualise the study constructs while also maintaining congruence with related research approaches adopted by authors who have studied similar problems. Such as in the works of Gu and London (2010), Jung and Joo (2011), Porwal and Hewage (2013), Taylor and Bernstein (2009), Sebastian (2011), Hartmann *et al.* (2012), Linderoth (2010), and Barlish and Sullivan (2012). To this end, the research was designed as a multi-method and multi-stage qualitative inquiry involving in-depth semi-structured interviewing, document analysis, structured knowledge elicitation interviewing, swimlane modelling, and multi-domain mapping matrix modelling. The rationale for the multi-method design was to as much as practicable, provide theoretical and practical perspectives of change in work practices. That is, the method is embedded in the argument that human activities are evolutionary and an assessment of change in work practice or workflows upon impact by new tangible and intangible work tools (and processes) requires examining the status quo as a basis for making projections on what the new form of the activities might be.

1.7 Structure of the thesis

This thesis is structured into nine chapters thus:

Chapter 1 introduces the study and provides an outline of the structure of the rest of the study.

Chapter 2 further establishes the research context with a review of the literature. The review begins with an overview of key construction industry challenges in the South African construction industry context followed by an introduction to Information Systems implementation benefits and risks, as the normative literature, which provides context. The chapter also includes a critical review of BIM literature on benefits and risks BIM as well as its impact on construction industry practices.

Chapter 3 provides a review of theory in the BIM literature. Further, it presents the theoretical underpinnings of the study. Mainly in activity theory as a base theory over which perspectives from role theory and theoretical insights on legitimacy, power, and authority (drawn from institutional theory) were built. The chapter concludes with a conceptual model that guided the design of the study, from the key assumptions and arguments, data collection methods, data analysis and to making sense of the findings.

Chapter 4 contains a review of ideas in key social science and management research texts relating to research philosophy and methodologies that informed the research design choices for the study. The chapter, therefore, outlines the specific methodology and methods adopted in this study to answer the research questions.

In ***Chapter 5*** the results of the case analysis were presented. These provided further substantiation for the research problem, presented findings in answer to the first objective, and in part, provided a basis for the workflow remodelling done in the next stage of the study. In this sense, the results also made a case for the need to align construction professional service providers' work practices and workflows to the demands of BIM.

Chapter 6 presents theoretical explanations and sense-making of the data collected through the study of cases of organisations' implementation of BIM. First, a theoretical explanation of legitimacy and power dynamics introduced in project teams along with the creation of new BIM roles, and second, an activity theory analysis of the coevolution of organisational and project team activities with the BIM tool introduction.

Chapter 7 presents the results of a content analysis of documents adopted in this study as exemplars of BIM implementation processes and procedures in delivering a BIM-enabled construction project. These are the bases for the BIM-enabled swimlane and multi-domain mapping (MDM) modelling done and the alignment of existing (pre-BIM) workflows to BIM implementation requirements.

Chapter 8 contains a summary of the key research findings, contributions to the body of knowledge, conclusions and recommendations while ***Chapter 9*** contains the research outputs from this study. *Figure 1.1* further illustrates the links between the chapters.

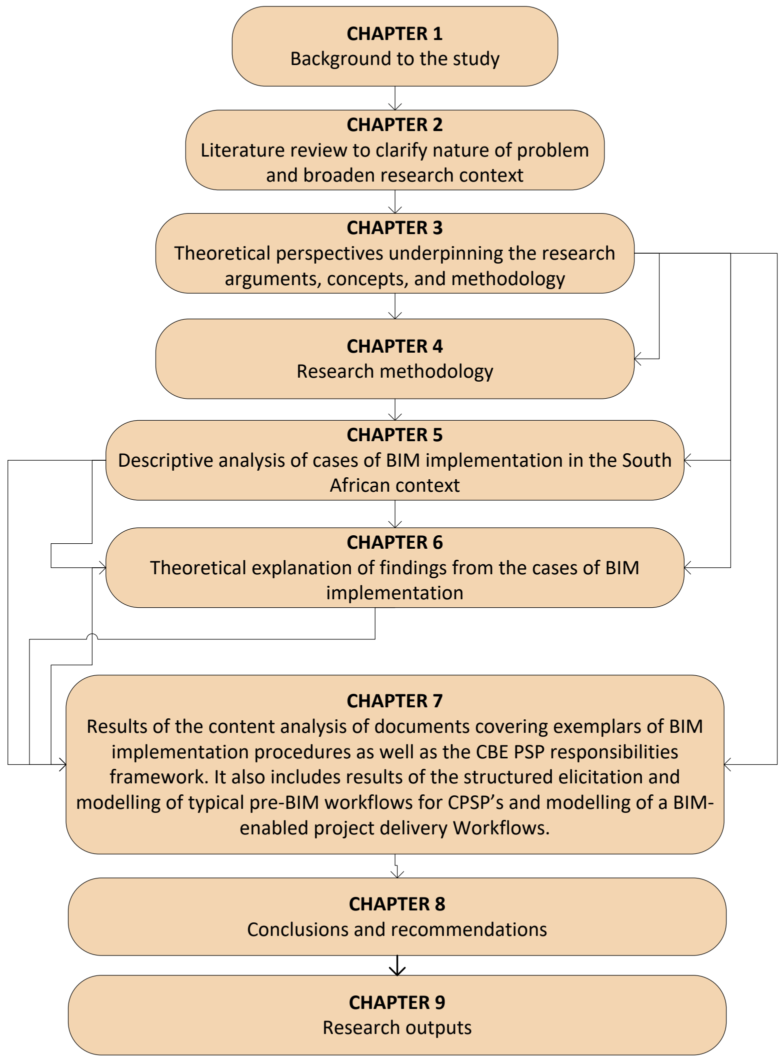


Figure 1.1: Structure of the thesis

2 LITERATURE REVIEW

2.1 Overview

The objectives of this review are to provide context for the study by situating its relevance in the South African construction industry context, introduce the normative Information Systems literature, and also critically review closely related BIM literature as a foundation for the rest of the study.

2.2 The South African construction industry context

The purpose of this section of the review is to situate the research and its purpose in the South African context. It briefly describes South Africa as a country with indicative demographic statistics, the country's infrastructural needs and spending, and lastly, it provides a summary of the reviewed literature on current challenges impeding the optimum performance of projects in meeting the nation's infrastructural development goals as well as the construction industry's at large. These put the South African construction industry in the community of those for which new or innovative technology is required to alleviate persistent challenges.

2.2.1 Infrastructural needs and strategic policy-driven investment

South Africa has since the democratic dispensation began in 1994 sought to achieve balanced socio-economic development through extensive capital investment in infrastructure. Evidence of this can be observed in the contribution of the Finance, Real Estate, and Business Services industries, and particularly the increasing contribution of the construction industry to the national gross domestic product (GDP). For instance, the contribution of the construction industry in the last five years rose from 3.83 percent in 2010, to 4.11 percent in 2014 although decreasing to 4.05 percent in 2015 (National Treasury 2016). This is not farfetched as massive capital investments like the Gautrain rapid rail system and the 2010 FIFA World Cup stadia were projected to play essential roles in the nation's economic growth.

To achieve economic growth, public infrastructure expenditure by the government has continued to increase yearly (National Treasury 2016). A sizeable chunk of government spending on infrastructure in this regard has gone into the Transport & Logistics, Energy, Water and Sanitation sub-sectors. In the years 2014/15, 2015/16, 2016/17, and 2017/18 put together, the energy sub-sector is expected to take up about R166.3 billion which is about 20 percent of the entire public sector infrastructure budget for the period (National Treasury 2016). Other sub-sectors benefitting from capital spending by the government include Health, and Justice & Protection services. Indeed, infrastructure investment has been recognised in South Africa as capable and vital for national development (Chihuri and Pretorius 2010; Ofori *et al.* 1996; Othman 2009) through its national agenda to achieve socio-economic transformation (Rwelamila 2002).

A summation of the foregoing could be that whether public or private sector led, the importance of the industry in nation building is not in dispute. However, in spite of these, the construction industry is yet faced with several impediments to fulfilling its purpose (Othman 2012). These are discussed further in the next section.

2.2.2 South African construction industry challenges and performance related issues

The Construction Industry Development Board (CIDB) was established through Act 38 of the year 2000 to drive the development of the industry. Each year, the body conducts and publishes the results of project performance surveys in the industry using clients/employers, contractors and agents as participants. The reports published in the years 2013, 2014, and 2015 show that 12 percent, 16 percent and 18 percent of projects respectively produced either a neutral or dissatisfied perception of performance from clients. The results, as shown in *Table 2.1*, further indicate that the level of dissatisfaction of clients about contractor's performance is growing. Furthermore, a large percentage of contractors were unhappy with the quality of contract documents received from clients (and their agents). The results nevertheless are deemed optimistic against the weight of evidence from empirical research carried out by independent researchers which suggest that the problem might be more pronounced.

Table 2.1: Key performance indicators for South African construction industry in the past three years

Year	Client dissatisfaction with contractors' performance	% of projects with inappropriate levels of defect	% of projects with occurrence of late payment	% of contractors dissatisfied with tender documents
2013	12	8	43	22
2014	16	18	42	22
2015	18	13	60	17

Sources: (CIDB 2013, 2014, 2015)

Findings from a survey of emerging civil engineering contractors who make up the largest percentage of those registered in South Africa report of a 'bleak picture' of the industry (Martin and Root 2010, 2012). The study revealed that a considerably high number of emerging contractors are inexperienced. Other challenges identified bother on knowledge and skills issues. These include low training of the contractors in relevant fields. Being extremely knowledge dependent, the ability of the construction industry to deliver on services largely depends on its knowledge and skills base.

Further, slowness of the decision-making process (by clients and their agents), rework due to errors, delays in approving changes, delays in approving significant changes in the scope of work, shortages of skilled equipment operators among other challenges were identified as the major causes of project schedule overruns in the industry. These findings were drawn from a questionnaire survey of architects, construction managers, and project managers in the Gauteng province by Mukuka *et al.* (2015). Other pertinent challenges beleaguering the SACI include widespread corruption and related ethical issues (Bowen *et al.* 2012b, 2015, 2012a), less than optimal risk management practices by construction industry organisations (Chihuri and Pretorius 2010). So also are the pervading non-value adding activities in construction (Emuze and Smallwood 2011), and contractors' lack of structure in motivating workers to be waste conscious (Emuze and Ungerer 2014) among others.

In more performance focused literature, while alluding to reports of poor performance and its link to marginal infrastructure development, particularly in

Africa, Emuze and Smallwood (2012) studied related barriers and interventions for infrastructural projects in South Africa using a quantitative survey conducted among consulting engineering firms, contractors, and selected public sector client organisations in the Eastern Cape province. They found that among other challenges impeding the performance of projects; lack of infrastructure delivery management skills, inappropriate organisational culture among project stakeholders, fragmented health and safety practices, lack of essential management skills, among others, are prominent. Other impediments include inconsistent and inadequate risk allocation and time lags between tender submission and contract award by the client. Interestingly, Pretorius *et al.*'s (2012) questionnaire survey cutting across the South African construction industry reported that only 46 percent of projects were considered successful. Nevertheless, of particular interest to this study are challenges relating to the difficulty in aggregating information within multidisciplinary project teams. These challenges include poor definition and coordination of process and product quality, inadequate documentation, inadequate knowledge transfer, and the poor interface between multidisciplinary design teams.

In a study that sought to assess the level of collaborative working among project team members in the South African construction industry from the perception of general contractors, Emuze and Smallwood (2014) found that a focus on short-term objectives and price-oriented approaches in procuring projects is prevalent. The findings also show that current challenges include poor problem-solving mechanisms among project teams, rigid adherence to agreed contract data, and most importantly, there is a shortage of project participants with appropriate collaborative skills in the industry. However, the authors, perhaps due to the study's design and scope did not adequately unpack the later finding. As such, it isn't particularly evident which specific skills are lacking. Their choice of participants (general contractors) doesn't also instil confidence in the results.

Emuze and Smallwood (2011) had in the same vein reported on a quantitative study that aimed at identifying contributors to poor performance in the South African construction industry alluding to the common theme of the lack-lustre performance of South African projects regarding cost, time, quality, environment, health and safety in published literature. The findings depict some issues linked to inadequate capture, transfer and management of knowledge. These include poor information management, lack of detailed databases of past projects, lack of post-project reviews, ineffective problem-solving capabilities of project participants, inability to innovate and respond to client demands and loss of contractor records. All of these also contribute to poor multi-disciplinary collaboration between project participants in the South African construction industry.

In the reviewed literature, several recommendations for improvement of the industry were made. These include the need for better communication between the procurement team and the client (Bowen *et al.* 1997), application of appropriate technology (Bowen *et al.* 2012b), and instituting experiential training for construction professionals (Chileshe and Haupt 2007). Others include early involvement of key project team members and embracing collaborative practices and contracts by project participants (Emuze and Smallwood 2014).

2.2.3 Summary

Heavy capital investment is one of the principal avenues through which the country aims to achieve its socio-economic objectives. In the face of scarce resources and dire needs, achieving the highest levels of efficiency in managing the resources put into infrastructure development by both public and private entities is of utmost importance. It is evident from the literature cited that the South African construction industry also contends with perennial global challenges of the industry. It is also clear, as advocated in the works of Latham (1994) and Egan (1998), that providing robust solutions to these challenges require changing construction industry practices, particularly within organisations and teams, and using the right kind of technology. However, implementing information technologies within work systems have been known to bring about new issues that require management to achieve its potentials. These ideas are from Information Systems (IS) literature. They are therefore discussed further in the next section regarding their potentials, challenges and success factors to provide further context for this study.

2.3 Overview of Information Systems implementation issues

2.3.1 Benefits of implementing Information Systems

Technological advancements in computing and data processing power over the decades offer new opportunities for employing IT for better management of organisations', teams' and institutions' work processes; thus Information Systems have been employed over the years in virtually all aspects of human endeavour (Agrawal et al. 2010). These include those in healthcare, primary and tertiary education, aerospace, agricultural, energy and the construction industry among others; though the construction industry has lagged significantly behind other critical industries in applying technology despite its several challenges (Crotty 2012). The potentials of IS in addressing challenges in these industries are significant as Information Systems are capable of facilitating innovations by individuals, organisations within the works systems and the broader socio-economic contexts within which they function (Avgerou 2008).

Recognizing its socio-technical nature, Alter (2008) describes a work system as comprising human and inanimate actors using information technology and other resources to produce outcomes. Thus, an information system is that in which work is performed by human and inanimate actors using information technology and other necessary resources to produce outcomes intended for use internally within an organisation or externally. The multidisciplinary and socio-technical nature of IS implementation has therefore predetermined its research as inclusive of both behavioural and design science perspectives (Agrawal et al. 2010).

In this sense, Management Information Systems has also developed as a subject within the IS discipline over decades along with the emergence of computers as enablers of the digital capture and management of business transaction data and process automation (Agarwal and Dhar 2014). Enterprise resource planning systems, for instance, are such that integrate organisations' tools and processes to meet their needs and proffer solutions to their various challenges (Kumar et al. 2003).

As is typical of many information technology-based systems, benefits accruable from implementing Information Systems drive its adoption and use. These benefits are well documented in the literature. They include competitive advantage, internal efficiency for organisations, inter-organisational efficiency, the creation of unique product features, enlarged scope/reach of products, cost reductions, the less quantifiable reduction in overhead and increased product differentiation (Johnston and Vitale 1988). Furthermore, Information Systems like ERPs are also known to be capable of enabling integration of processes, improving communication within internal and external organisational networks, and enhancing decision-making processes, improving performance (Al-Mashari and Al-Mudimigh 2003) and even serving as the foundation for organisational business intelligence.

While Johnston and Vitale (1988) had argued importantly that these benefits are achievable only through inter-organisational Information Systems rather than the discrete implementation of Information Systems, Alter (2008) affirmed that competitive impacts of information technology could only be achieved when investment in IT are incorporated into the information and work systems they support. These are arguments for implementing technology not merely as technical implementations within organisations but rather as integral parts of the existing information and work systems they enable.

Therefore, while their potentials in enhancing organisational performance inter alia are not in doubt, the foregoing indicates the need to manage associated risks to unlock its potentials adequately. Therefore, Information Systems implementation risks and success factors are the subjects of the next two sections.

2.3.2 Information Systems implementation risks

Huang et al. (2004) identified top risk factors in implementing Information Systems as inclusive of lack of commitment from senior management, insufficient training, lack of user support, and lack of adequate project management methodology. Others include attempting to link Information Systems to legacy applications, conflicts between user departments, failure to redesign organisational business processes and a misunderstanding of changing requirements. Motwani et al. (2005) also affirmed that Information Systems like ERP implementations are known to cost a lot of money while failing to provide the expected results. Sometimes, these challenges are severe enough to cause failure. Importantly, integrating such information technologies into organisational practices pose substantial socio-technical challenges (Davidson and Chiasson 2005). Though, the cost of Information Systems failure has remained very high (Ashurst et al. 2008).

Implementing Information Systems is typically characterised by high implementation costs and difficulty in quantifying benefits (Johnston and Vitale 1988; Motwani et al. 2005). Although there are often reports about experiences of benefits from implementing various types of Information Systems, there are also reports of severe difficulties. According to research done in the healthcare sector by Berg (2001), determining whether Information Systems implementations have failed or not is not only a technical judgement. The emphasis should instead be on social aspects of the implementation as technical challenges are often the result of poorly managed development processes within organisations. Al-Mashari and Al-Mudimigh (2003) for instance identified the tendency to isolate information technology from business affairs; this is connected to the employment of a purely technical approach to implementing Information Systems, lack of performance measurement, and lack of change management.

In summary, process change relating to technology change, change in the size of projects, change in requirements and personnel change (turnover) among other things are fundamental challenges to successfully implementing Information Systems. Heeks (2002) found that several Information Systems implementations, particularly in developing countries can be classified as either partially or failed. Furthermore, Dwivedi et al. (2015) found that in spite of efforts to understand the underlying factors for failure of Information Systems, their rate of failure has remained high while affirming that identifying success factors for Information Systems has dominated the literature. Therefore in the next section, the literature on Information Systems success which may also assist the understanding the factors that may influence the success of BIM implementations are discussed.

2.3.3 IS implementation success factors

Notably, DeLone and McLean (1992) had identified in broad terms that systems and information quality, Information Systems use and user satisfaction, individual and organisational impact are interrelated and interdependent components of the success model. Furthermore, Berg (2001), acknowledged the impracticability of identifying a definite set of Information Systems failure or success factors. This is presumably because of the importance of contextual peculiarities of Information Systems implementations and type. The author identified as crucial, management and user support, top-down vision and a comprehensive implementation framework. Berg (2001) also emphasised balancing the initiation of organisational change and the employment of Information Systems as a change facilitator. This is related to Motwani et al.'s (2002) affirmation that achieving success at such implementations is linked to careful change management and cultural readiness.

Johnston and Vitale (1988) had identified inter-organisational Information Systems success factors as inclusive of incentivising use for all participants (because inter-organisational Information Systems cannot be implemented by fiat). Furthermore, they identified provision for reliability, data security, user privacy, and systems integrity as pertinent factors. They argued further that beyond mere improvement of overall efficiency of processes, inter-organisational Information Systems must provide a positive return on investment. Further, according to Johnston and Vitale (1988), in implementing inter-organisational Information Systems, it is vital to create awareness and understanding of its impacts on strategy and tactics at the functional level.

Similarly, Zhang et al. (2005) put forward an ERP success framework that includes top management support, company-wide systems support, effective project management, organisational culture, education and training, user involvement and user characteristics. Others identified are software usability, information quality, system quality and vendor quality. Furthermore, in a study that examined the critical success factors for adopting ERPs, Ngui et al. (2008) also identified appropriate business and IT legacy systems, business process re-engineering, change management, effective communication, monitoring and evaluation as critical. Other factors identified by the authors are the need for a project champion, top management support and fit between the implementation and organisations' business processes.

In more recent literature, Petter et al. (2013) identified fifteen similar factors for the success of Information Systems implementation. The factors include the management process, management support, organisational competence, domain expert knowledge, and relationship with Information Systems developers. Others identified include user involvement, organisational role, attitudes towards technology, task compatibility, task difficulty, IT infrastructure, extrinsic motivation, user expectation, trust and enjoyment. Importantly, Dwviedi et al. (2015) assert that explanations of Information Systems failure or success are multifactorial. One of the most important factors remains the focus on socio-technical organisational contexts rather than on 'narrow considerations' of the IT artefact in the implementation. Specifically, Dwviedi et al. (2015) identified as critical; foremost, top management support and second, the necessity of having a project champion within such an organisation. Others are, obtaining user buy-in to tailor solutions to problems, developing an understanding of user requirements and lastly seeking advice from experts/consultants.

Dwviedi et al. (2015) further emphasised the importance of ensuring the systems development approach guarantees seamless collaboration, continuous change management (crucial to managing the emergent nature of Information Systems), and understanding the cost of collaboration. This is the common thread that runs through the literature on Information Systems. That is, success is dependent on a holistic approach to managing Information Systems implementation which emphasises the importance of employing a human-centred approach to its implementation and development with emphasis on the importance of human actors within organisational and multi-organisational work teams. Over the last three decades, therefore, Information Systems research and practice have continued to develop a human/social-centric approach to the management of associated change. These ideas are discussed in the next section.

2.3.4 Information Systems induced change

Martinsons and Cheung (2001) as with Rintala and Suolanen (2005) raised important questions about how Information Systems induce changes in work practices. In their work, Rintala and Suolanen (2005) acknowledged that technology is known to have significant impacts on job roles. They found that changes in job descriptions can occur in three different ways; transferring tasks from one job description to another, fusing two or more job descriptions or by adding new tasks to the job descriptions. These are similar to the theoretical explanations of work role transitions given in the work of Nicholson (1984).

Davidson and Chiasson (2005) also raised some of the key questions previously posed by Johnston and Vitale (1988). These are questions about Information Systems' impact on organisational structure and strategy, and inter-organisational Information Systems' potential impact on industry structure. In their work, Johnston and Vitale (1988) had emphasised the need to recognise that the electronic link between several organisations accounts for much of the changes in their relationship.

Furthermore, Vaast and Watsham (2005) examined how practices impacted by Information Systems change at the micro/individual relationship level. They approached the understanding of Information Systems induced change, in the context of consonance and dissonance. Vaast and Watsham (2005) argue that IS-/IT-induced change may be explained by the dynamics through which agents modify their actions and representations to re-establish consonance when they perceive a dissonance. They defined representations as the way in which actors act in different work contexts. Furthermore, they suggested the need to examine representations that shape agents' understanding of their work and technology, and the consonance or dissonance they may experience, to fully understand how IS/IT may trigger changes in work practices. Vaast and Watsham (2005) further assert that new actions that result in changed practices must be recurrent, socially shared, and one may argue further, socially acceptable.

In their work, Lyytinen and Newman (2008) support the idea that Information Systems change has to do with deliberately changing an organisation's subsystems that deal with information (Swanson 1994). Furthermore, that the dynamics of such change has remained challenging and disputed. Nevertheless, they affirm that such change entails implementation of new work elements within an organisation's social and technical systems that aid the management of information.

Furthermore, Yeh and Ouyang (2010) found, in a study on how organisations change when ERPs are implemented, that power related issues are of significant concern and crucial to the success of such implementations. In essence, they affirm the need for understanding the values of individual groups within the organisation and the management of the dynamics of power within them. They found that personnel like functional managers were concerned about losing power in decision-making processes and therefore sought to sabotage the Information Systems project. Power and the retention of legitimacy are therefore essential considerations especially when Information Systems are implemented in highly knowledge dependent fields, practices or organisations. This gives credence Symons' (1991) advocacy for an interactionist approach to managing Information Systems that would focus on historical contexts, social contexts, and formal/informal information flows. It was also reaffirmed in the latter work of Rizzuto et al. (2014) by their advocacy for change management practices that account for multilevel interfaces evident in individual-, organisational- and team-level interactions.

Skoumpopolou and Nguyen-Newby (2015) in a study of organisational impacts of implementing Information Systems also found that one of the key impacts is the growth of alternative power bases within the organisation (a university). Furthermore, the emergence of new roles, responsibilities and different working environments have enabled a shift of significant power to 'an elite group' of administrative staff who have control of data (and the information system), at the expense of academics who perform the core functions of teaching and research within the university. This is also similar to the role of Champion and its impacts on existing power dynamics within organisations and multi-organisational teams. The role of Champion is therefore not new in the field of Information Systems. For instance, Champions acting as opinion leaders, change agents, and top management surrogates have long since been identified as key to Information Systems implementation success (Curley and Gremillion 1983).

While much of Information Systems literature has dealt substantially with the subject matter, current literature still asserts the dearth of knowledge that informs managers about how best to facilitate the continuous post-implementation adaptation of Information Systems. Regarding this, Aanestad and Jensen (2016) cited an instance of Information Systems implementation that was initially planned to be a minor project but ended up leading to a thorough redesign of work practices and routines within the organisation (Aanestad and Jensen 2016). Aanestad and Jensen (2016) further emphasised that when Information Systems are implemented, the organisation works to adapt the acquired Information Systems and the work processes to ensure the realisation of expected benefits.

2.3.5 Summary

Information Systems are crucial to the improvement of organisations' business processes and outcomes. However, achieving success at implementing them can be challenging. This section has provided a context for understanding the issues surrounding the implementation Information Systems, since it is the normative literature in which BIM literature is embedded. In the construction industry, BIM is a promising innovative approach to creating and managing construction information throughout the building lifecycle. It is the process of digitally representing the physical and functional characteristics of a facility in a way that provides a shared knowledge resource for information about the facility and enables its management by organisations and project teams involved throughout the facility's lifecycle (NIBS 2007). Therefore, as with Information Systems implementation within organisational and project team work systems, it poses several costs and risks despite its potentials. These are discussed in the next section along with its impact on existing ways of working.

2.4 BIM implementation benefits, costs and risks

2.4.1 BIM implementation initiatives in different countries

BIM implementation has been argued as a way of improving the outcomes of construction projects and has gained prominence across the world. More so in the United States, United Kingdom, Australia and Scandinavia (Shou *et al.* 2015; Smith 2014; Wong *et al.* 2010). Nonetheless, BIM has been in use in several more countries than are commonly referenced in literature. The important distinctions are to what extent is BIM being implemented on specific projects, how many projects are executed on the BIM platform, how standardised are BIM project practices and the presence or otherwise of a clear and deliberate push or mandate driving BIM adoption and implementation. Also pertinent is the extent to which the push is supported by the government, professional institutions, construction-related private sector organisations, and educational institutions to provide the necessary policies, legislation, incentives along with required guidelines for the standardisation of BIM practice.

Government involvement is particularly important for several reasons. First, governments are often the biggest investor of resources in the construction industry. Therefore, they hold a significant stake in the success of the industry and every effort to innovate, such as with BIM, benefits from their support. The second reason is linked to the heavy dependence of BIM-enabled project success on the standardisation of shared project information, guidelines and processes (Gu and London 2010; Porwal and Hewage 2013; Singh *et al.* 2011). Support from government bodies for BIM adoption and implementation has also been identified as necessary for providing necessary mandates, incentivising legislation and policies. These go a long way in driving in part, support from construction professional institutions while also helping to drive public and private client buy-in and demand for BIM. These are essential for a complete project team buy-in into BIM implementation on projects. A good example is the UK construction industry's approach to BIM adoption and implementation, which is the most structured among countries leading in BIM. Nevertheless, in countries like South Africa where BIM model-authoring software have been in use for at least a decade, despite a lack of country-specific BIM standards and guidelines, progress is yet being made.

The uptake of BIM in the South African construction industry as with other African countries has however been slower than has been witnessed in Europe and America (Froise and Shakantu 2014; Harris 2016). The South African BIM Institute surveyed owners, architects, engineers and construction organisations to understand the alignment of their perceptions on BIM related issues. Responses from the survey revealed the "industry's inherent traditionalism towards Building Information Modelling technologies, with many survey respondents preferring to follow trends rather than to take the lead. Many who have adopted a BIM technology strategy have done so in a silo approach" (Harris 2016 p. 2). To this end, the report concludes that the local industry is a laggard regarding technology adoption and implementation.

These assertions are evident in the smallness of their sample considering that they attempted to cover all South African provinces, and the BIM institute is perhaps the only organisation with a register of BIM implementers in the country. The respondents were made up of 4 contractors, 17 quantity surveyors, 4 planners, 4 contracts managers, 22 BIM managers, 22 architects, nine draughtsman, 15 technical experts, 11 engineers, 11 project managers, 10 government employees, 1 assistant manager, and 4 IT services professionals. These were drawn mainly from Gauteng (45%), Western Cape (31%) and Kwa-Zulu Natal (8%) provinces (out of 9 provinces). These are indicative of the local industry's lag in BIM uptake. It is also similar to reports from Cameroon (Abanda et al. 2014) and Nigeria (Abubakar et al. 2014) of lag and lack of local standards and guidelines.

2.4.2 BIM standards and guidelines in use in different countries

The principal aim of the many BIM standards and guidelines from countries like the United States and the United Kingdom is to institutionalise a preferred pattern of collaborative practices in the delivery of projects through BIM (Atkinson *et al.* 2014; Shou *et al.* 2015; Smith 2014). Wong *et al.* (2010), Smith (2014) and Shou *et al.* (2015) provide valuable insight into these. Their analyses exhibit two patterns; a structured and controlled approach to implementing BIM countrywide through central standards and guidelines, and implementation of BIM without clear standards and guidelines.

Shou *et al.* (2015) in a similar approach to Wong *et al.* (2010) outlined a non-exhaustive list of about 40 different BIM related standards and guidelines originating from 10 different countries. These are to define information creation, usage, sharing, storage, and re-use standards/specifications as well as collaborative relationships based on BIM within the construction supply chain. They are the products of initiatives by government bodies, educational institutions and private sector entities, sometimes solely and at other times in collaboration. Some of the standards and guidelines are duplications. However, a proliferation of implementation methodologies is not necessarily advantageous. The UK approach to implementing BIM as a government-supported initiative has been the most deliberate and structured (Smith 2014). Theirs is a central, government-backed initiative to institutionalise BIM practice through the UK government's construction strategy. The strategy sought to ensure compliance with a mandate to have all public projects executed on the BIM platform by 2016. The intention was to attain a cost reduction of up to 20 percent in construction procurement costs (Cabinet Office 2016).

To this end, appropriate standards documents have and are being developed for BIM implementation to guide information creation, sharing, storage, use, re-use as well as collaborative relationships based on BIM within the construction supply chain. These include, but not limited to:

- **PAS 1192-2:2013** – Specification for information management for the capital/delivery phase of construction projects using building information modelling
- **PAS 1192-3:2014** – Specification for information management for the operational phase of assets using building information modelling

- **BS 1192-4:2014** – Specification for collaborative production of information and fulfilling employer's information exchange requirements using COBie
- **PAS 1192-5:2015** – Specification for security-minded building information modelling, digital built environments and smart asset management
- **COBie** (Construction-Operations Building Information Exchange) – a data format for the publication of a subset of building model information focused on delivering building information rather than geometric modelling.

These efforts are claimed to have delivered efficiency savings of about GBP 3 billion over 5 years (2011 – 2015) enabled in part by the BIM maturity level 2 mandate (Cabinet Office 2016). New targets have been set for the next five years after 2016 during which a higher level of BIM implementation maturity is desired. During this period, also, a 33 percent reduction in costs, 50 percent lower in emissions and 50 percent faster delivery are targeted (Cabinet Office 2016). This is in recognition of the evident and potential benefits of implementing BIM.

Essentially, one of the significant challenges in implementing BIM is the variation in its level of adoption and implementation across disciplines and organisations constituting project teams (Gu and London 2010; Porwal and Hewage 2013; Singh *et al.* 2011). A precise method for categorising and clarifying different levels of collaborative working on projects is therefore necessary for selecting a specific level against which change may be assessed. This is important as different levels of collaborative working with BIM will demand different types of changes. Some of these models are therefore reviewed in the next section.

2.4.3 BIM implementation maturity levels

There have been a number of attempts at defining models for categorising different levels of collaborative working with BIM (BSI 2013; Succar *et al.* 2012; Taylor and Bernstein 2009), however the most prominent and referenced model has been that of the BIM Industry Working Group in the United Kingdom, first in a strategy report published in 2011, and in a published UK BIM standard, the PAS 1192-2:2013 (BSI 2013). The document describes a four-level categorisation of BIM implementation maturity from levels 0 to 3. *Figure 2.1* compares three maturity models (BSI 2013; Succar 2009; Succar *et al.* 2012; Taylor and Bernstein 2009).

Notably, Taylor and Bernstein's (2009) four-level classification of BIM maturity did not, include enough detailed descriptions of the distinguishing characteristics between the levels. This makes it difficult to apply in other settings or replicate through research.

BSI (2013)	**TAYLOR AND BERNSTEIN (2009)**	**SUCCAR (2010)**
BML-0 Unmanaged CAD with the use of 2 dimensional (2D) or paper as the information exchange mechanisms		*INITIAL* Undeveloped BIM processes, technology, and policy.
BML-1 Requires a collaboration tool to provide a common data environment. Established standard data status and formats. Cost data to be managed by standalone packages with no integration.	*VISUALISATION* *COORDINATION*	*DEFINED* Some level of definition of protocols, technology requirements and organisational/inter-organisational relationships and policies
BML-2 Collaborative environment to be of 3-dimensional form, held in separate discipline BIM authoring tools with attached data managed by Enterprise Resource Planning (ERP) Approach may also utilise 4D and 5D capabilities.	*ANALYSIS PARADIGM*	*MANAGED* Standardised and controlled BIM processes and policies
BML-3 Fully open processes and data integration enabled by web-services. Compliance with relevant data exchange standard (IFC's etc.) all managed by a collaborative model server.	*SUPPLY CHAIN INTEGRATION PARADIGM*	*INTEGRATED* BIM technologies, processes and policies are integrated into organisational strategies and aligned with business objectives
		OPTIMISED Continuous improvement of established BIM technologies, processes and policies

Figure 2.1: Comparison between BIM maturity levels as defined by different authors

While several benefits are accruable from implementing BIM at a relatively high maturity, organisations or project teams' inability to implementing at reasonably high maturity levels may also be linked to several challenges. In the next section, these issues, relating to BIM benefits, costs and risks are reviewed.

2.4.4 BIM implementation benefits

The importance of BIM in the engineering, design and construction stems from the need to address two key challenges; the poor quality of information being generated and used on construction projects and the challenges relating to communication and collaboration among project team members (Crotty 2012). The potentials of BIM, therefore, are well evidenced in research. Benefits that are associated with implementing BIM include time and cost savings (Fan 2014; Suermann and Issa 2009), reduction of waste, reduction of rework, increase in productivity (Love *et al.* 2011b), enabling lean construction (Sacks *et al.* 2010) and an enabler of sustainability (Bynum *et al.* 2013). These are acknowledged as the primary drivers for BIM's adoption and implementation by construction industry professionals.

Many innovative and practical applications of BIM have also been researched. For instance, Garzia and Lombardi (2017) highlighted the use of BIM in managing safety and security employing what was termed an integrated multidisciplinary model for safety and security management. This is intended to be supported by applications in the form of the internet of things (IoT). GhaffarianHoseini et al. (2017) also attempted to enhance the practicality of using BIM for delivering Green Star certification in New Zealand. They used an extensive literature review to develop a conceptual framework that focusses on the relationship between BIM benefits and challenges. Further, they found that BIM supports professionals in achieving 75 percent of the Green star rating criteria.

An interesting addition to the BIM literature is its use in providing conducive environments in terms of building structures for housing vertical farming practices (Khan and Ahmed 2017); this was intended as a futuristic application of green building construction. Khan and Ahmed (2017) developed a conceptual framework that integrated plant growth and building data with BIM models to produce 3D visualisations, energy analysis and plant growth schedule. Their study demonstrated the capability of employing BIM to integrate building and farming data for managing farming processes.

However, beyond the identification of mere benefits, holistic appraisal of BIM's value has become important. Using case studies of public and private sector building project development in Australia and Hong Kong, Aranda-Mena et al. (2009) investigated value propositions for the adoption of BIM. These were grouped into benefits of technical outcomes, operational capability and business capability. In detail, they affirmed that BIM has the capability to improve information management and sharing, evaluation of design scenarios, efficiency, confidence in design outcomes, coordination between project team members, buildability, alignment of stakeholders' expectations, and provides a foundation for facilities management.

Furthermore, the implementation of BIM has been characterised by uncertainties about its real value to asset owners, project consultants and contractors. Therefore benefits realisation assessments and management are gaining in importance (Love et al. 2014). Real-life case studies of BIM use have also yielded varying levels of return on investment. Barlish and Sullivan (2012), in their study, aimed at developing a methodology for analysing BIM benefits and ultimately produce a holistic framework of BIM and its impact on efficiency. Through literature review, they developed a framework calculation model to determine that could aid the determination of the value of implementing BIM. This is an important addition to this stream of the literature.

In the same vein, Love et al. (2014) argued that only a business change program that can impact on asset owners' value proposition rather than the discrete implementation of information technology projects can deliver on expected outcomes. According to Love et al. (2014), many asset owners are still doubtful of about the value of adopting and integrating BIM into their existing organisational infrastructure and work practices. They further argued that BIM implementation benefits can only be realised when project information (graphic and non-graphic data developed by the project team) are transferred to asset owners upon completion of the project.

Furthermore, Love et al. (2014) identified five principles, adapted from Information Systems research, that underpin the realisation of the business value of BIM. These include first that BIM technology has no inherent value in and of itself except when applied in the right way. Second, that BIM benefits only materialise when people and organisations are enabled to practice in new ways. Third, only through change and innovation in the work practices of business managers can the benefits of BIM be realised for organisations. Fourth, not all BIM-enabled projects' outcomes are beneficial, and fifth, obtaining BIM benefits requires active management. They concluded that the BIM benefits realisation process should be viewed as one that helps owners to learn as they question and measure said benefits.

In a related study, Won and Lee (2016) developed and tested the applicability of a success level assessment model for BIM using case studies. They developed this based on the idea that a project's success cannot be evaluated without first identifying its goals; thus, key performance indicators (KPIs) can vary according to the project goal. The model consists of five key steps including the determination of BIM goals, determination of BIM uses, identifying the BIM KPIs, developing the unit of measurement, and development of the data collection forms.

Clearly, optimism about BIM implementation, informed mainly by its potential and demonstrable benefits abound. Yet, there are several challenges to the success of its implementation. The costs of achieving these benefits are discussed in the next section.

2.4.5 BIM implementation costs

Ku and Taiebat (2011) carried out a baseline study to establish the level of BIM implementation, capabilities of construction organisations and their expectations for new staff hires in terms of BIM knowledge. Their study employed an online survey of 31 construction companies. Despite the small sample size and response rate which is typical in BIM research, the results confirm existing evidence in the literature. The challenges identified include importantly, a lack of skilled staff and a steep learning curve. Others are the high cost of investment in BIM tools, lack of collaborative work processes and modelling standards, non-interoperability, and lack of legal or contractual agreements for implementing BIM.

Sebastian (2011) also carried out two case studies of large medical facilities in the Netherlands. Firstly, Sebastian (2011) found that despite efforts by the design team to agree beforehand on the BIM authoring software to use, not all of the project participants were capable of using the selected tool, therefore, necessitating the conversion of BIM models to formats that are readable and usable to non-BIM users. This is a big challenge that is capable of bringing about non-interoperability and an eventual breakdown of communication between project team members. In the extreme, it could render the information modelling process useless. The study showed that the lack of knowledge about the ICT capabilities, systems and applications of contractors before they tender is a challenge as is the uncertainty about returns on investing resources in the BIM-enabled project process. Similarly, in a case study of specialist sub-contractors included in the design and construction of engineered façade, Brewer and Gajendran (2012) while claiming a phenomenological perspective as well as ethnographic data collection techniques also found that the high initial cost of investment in high-end technological infrastructure required for implementing BIM is a significant challenge.

In Eadie *et al.*'s (2013) study of BIM implementation in UK construction projects' lifecycle, participants were drawn randomly from a BIM expert group on LinkedIn for a questionnaire survey. This was preceded by three semi-structured interviews. Interestingly, about 83 percent of their respondents believed the implementing BIM on projects where it wasn't, would have been advantageous while 17 percent thought otherwise. However, this was not an objective assessment. Further, they found that the top two reasons why BIM is not implemented on projects are first, the lack of knowledge on the part of the project team and the lack of knowledge and expertise within organisations. These two are clearly linked as organisational level BIM expertise would influence team level BIM expertise. Virtually all of the BIM literature is in agreement that lack of knowledge and expertise are significant challenges, perhaps the most important. There are questions in the literature and in practice about how best to provide the knowledge required by professionals to participate and collaborate in BIM-enabled projects successfully. There are also pedagogical questions on the depth of knowledge that can, or should be provided at the tertiary level as well as how best to teach BIM related concepts.

A significant portion of the BIM literature has been dedicated to providing a general perspective of issues without unpacking how the results of can be partitioned to show discipline specific peculiarities or nuances. Yet, most of those that provide a more nuanced perspective do not always provide an informed idea of the differences in, for instance, adoption patterns, attitudes, procedures, processes, challenges among other issues. Aibinu and Venkatesh (2014) nevertheless investigated the experience of quantity surveyors in implementing BIM. This was to examine its impacts on the firms, and also the benefits, barriers, and drivers of BIM use among quantity surveying professionals. The study does corroborate findings from similar non-discipline-specific studies using a web survey of quantity surveying firms in Australia including two follow-up interviews. Further, it reports of scarcity of skills among quantity surveyors, although employee turnover was not rated as a highly significant challenge. The study highlights interoperability challenges, high costs of procuring relevant software and model inaccuracy. In the main, there are concerns that regardless of the effort put into modelling accuracy, the responsibility for the integrity of cost estimates still rests with the quantity surveyor. Some of the respondents also highlighted the need for learning new ways of working, the need to change procurement culture and lack of demand by clients as barriers.

Manderson *et al.* (2015) reported on a study which alluded to the inability of the industry to achieve integration through BIM despite its benefits as motivation. The qualitative study reported challenges to implementing BIM as including high costs of procuring software, hardware upgrades and staff training. One interesting finding is the difficulty in getting project participants to collaborate in the real sense when they could become competitors for future projects. The reasoning behind this is perhaps that organisations that compete for construction work essentially need to demonstrate an edge over each other to win bids. In a fully collaborative team, however, knowledge sharing and transfer are inevitable. This may, therefore, hinder the willingness to collaborate fully with others on BIM-enabled projects.

To provide perspectives from the Malaysian consulting engineering organisations on the adoption of BIM, Rogers *et al.* (2015) conducted a questionnaire survey. The results of the study show that the challenges to adoption and implementation include inconsistencies (in models and modelling methodology), lack of common platforms for standardising information, cumbersomeness of the software, deficiencies in graduate training and a shortage of skilled personnel in BIM. Importantly, the study found that one of the key challenges to implementing BIM is a lack of understanding of how the design and construction processes are, and could be impacted when BIM is implemented.

Using a mixed method research design (questionnaire, focus group), Abandah et al. (2015) found that 34% to 50% of their survey respondents indicated that the current proliferation of BIM-related software is a significant barrier to the uptake of BIM. However, it can be argued that the proliferation of authoring software and associated tools impacts more on technological interoperability rather than being a direct impediment to the uptake of BIM. The authors also found that half of their survey respondents indicated the lack of BIM knowledge as a significant challenge. Further, in a study that aimed at analysing the impact of implementing BIM on bridge construction projects (although it is non-specific about which aspects), Fanning *et al.* (2015) conducted a case study research involving two similar roadway bridge construction projects. The study found, *inter alia*, that a key impediment to implementing BIM remains a lack of standards that facilitate tool and business process interoperability among project stakeholders.

Gledson (2016) conducted a study aimed at gaining novel insights into organisational perspectives on BIM adoption in the innovation-decision process using case studies of early BIM adopters (employing mainly semi-structured interviews). The findings portray, although anecdotally, that implementing BIM requires changes in culture and the processes delivery process for projects. Another important finding emanating from the study is the difference in technological capabilities between relatively younger organisation staff compared to the older ones. This finding supports that of Hachmann (2004) in a study that provided a German perspective on socio-technical aspects of concurrent engineering in construction. This is a classic implication of new technology adoption within organisations. The solutions to these kinds of problems lie mainly in encouragement, incentivising and continuous training. According to Gledson (2016), this situation called for a two-way transference of knowledge between younger and older staff. The senior staff transfer in-depth experience of building knowledge while the younger exchange that with knowledge acquired through their superior ability for grasping new ideas and concepts. Other challenges identified in the study include high investment costs, particularly for smaller contracting firms, and large file sizes that place heavy demands on projects' IT infrastructure.

Sun et al. (2017) conducted a literature review to identify and classify negative factors limiting the application of BIM in the construction industry. They classified 22 limiting factors including, for example, lack of data interoperability, cost of training, changes in workflows and inappropriate business models, need to educate professionals, ownership of BIM data and intellectual property rights into five areas. These were technology, cost, management, personnel and legal limiting factors respectively. Furthermore, they found that the top cited limiting factors in the literature are management, technology, personnel, legal and cost factors in that order.

2.4.6 Building information modelling risks

An important and well-cited addition to BIM literature is the work of Gu and London (2010). It was carried out to understand and facilitate BIM adoption in the architecture engineering and construction industry. Using a qualitative approach, Gu and London (2010) found that there are varying levels of BIM adoption in the industry. This finding is linked to challenges like lack of standardised processes and non-interoperability of business processes and tools. Their study also found that in the Australian industry, there are also varying levels of experiential knowledge of BIM along with the varying levels of adoption. Furthermore, while the authors acknowledge that implementing BIM faces both technical and non-technical challenges, they advocate addressing these through research frameworks that integrate both.

Similarly, Sebastian (2011) found that implementing BIM with traditional methods of procurement brings about several technological and non-technological interoperability issues. Lack of awareness, scepticism about adopting new technology, interoperability of technology and business processes, changes in firm culture and changes in workflows have also been identified as significant risk factors (Deutsch 2011). However, it can be argued that the most critical challenges to address are non-technological in nature as has been argued extensively in the Information Systems literature. Therefore non-technological challenges of BIM implementation are central to this study.

Grilo and Joardim-Goncalves (2010) alluded to the goal of full interoperability in the construction industry as being far from achieved, a position that was subsequently re-affirmed (in later work (Grilo and Jardim-Goncalves 2013)). This can be attributed to the structure of the industry which creates a dispersion of multidisciplinary collaborating organisations across different electronic platforms. In a sequential mixed method study covering ten semi-structured interviews with construction professionals and subsequent questionnaire survey in China, Xu *et al.* (2014) also found that attitude, in terms of interest and willingness to adopt and implement still constitutes a significant barrier to implementing BIM. This is alongside a lack of BIM standards and guides for facilitating uniform implementation on construction projects.

According to Barlish and Sullivan (2012), regardless of claims about many potential benefits, BIM has not been sufficiently empirically demonstrated to be the solution for the diverse perennial challenges of the construction industry. Further, Bercerik-Gerber *et al.* (2012) on the basis of questionnaire survey sought an understanding of the construction industry's needs for BIM and how its potentials can be explored and applied to facilities management. The two-stage research yielded several important but not distinct findings. The authors reported that barriers to implementing BIM include unclear roles and responsibilities for data modelling and model maintenance, non-interoperability (which is linked to a proliferation of tools) and organisational resistance. Others are inadequate legal frameworks, undefined fee structures for additional work scope, and uncertainty about levels of return on investment on human and technological resources. These findings are clearly of significant importance.

Arensman and Ozbek (2012) provided a legal perspective to understanding the challenges associated with implementing BIM in the construction industry. Semi-structured interviews were conducted with participants selected from small to large sized architectural, contracting and client organisations that were described by the authors, arguably, as the primary entities affected by potential legal challenges. This may not always be true because different procurement paths and contractual arrangements would bring about distinct legal project dynamics and challenges for project participants. However, they found that implementing BIM brings about a shifting of risks among project participants and this shift is not always apparent. While affirming the need for an increment in the standard of care on projects, the study also established model ownership issues and the extent to which shared information may be relied on by users of such information as key challenges. These issues are clearly connected to model authorship and liability considerations. While all projects regardless of BIM are collaborative in some way, the BIM-enabled project process is one that requires a higher level of integration. Nevertheless, project team members cannot just be viewed as collaborating individuals. Instead, they should be viewed as collaborating organisations with different goals and objectives per project.

Jenson and Johannesson (2013) carried out a study covering both Iceland and Denmark. A questionnaire survey of 60 architectural, engineering, contracting, and manufacturing firms was conducted in Iceland. This was complemented with semi-structured interviewing of clients, architects, engineers and contractors in Denmark. Their study found, among other things, that there is a proliferation of diverse digital working methods. Second, many construction industry professionals are still working based on 2D methodologies. It was established that non-interoperability remained a significant technical challenge to implementing BIM collaboratively. Perhaps, most importantly, the authors surmise that BIM benefits will not appear immediately and that organisations would have to contend with an initial decrease in productivity during the transition period from conventional methods to BIM methods. This is a significant finding.

In an attempt to examine the level of information management during the operations phase of buildings from the client's perspective, Bosch *et al.* (2015) carried out a study based on literature review and 21 semi-structured exploratory interviews with public real estate and infrastructure owners/operators, software companies, service providers and contractors. While claiming to provide empirical insight into the sources of inefficiency and ineffectiveness in the activities of Dutch semi-public and public clients, the study affirms through findings that the added value of BIM at the operations stage is marginal. This was attributed to the misalignment between the supply and demand of, and for information. It shouldn't be interpreted as a failure of BIM but that of the peculiarities of the referenced cases. Nevertheless, the finding is significant since ideally, the most profound of BIM benefits are arguably accrued at the operations stage, that is, a direct benefit to the client. It is a huge waste if project information created in a BIM-enabled project is either not useable or is not turned over in useable form to building operators and maintainers.

Gheisari and Irizamy (2016) conducted online surveys to investigate human and technological requirements for successful implementation of a BIM-based augmented reality application for facilities management. The authors found among other things that out of 12 issues rated on Likert scales using the survey, high administrative costs, and lack of BIM models of facilities were rated as the most important challenges to implementing BIM in the facilities management practice. This is a pointer to the need to bridge the gap between project delivery and operations & maintenance. Furthermore, there is a need for more research into post-construction handover applications of BIM which arguably hold the most important and significant potentials of implementing it.

*Table 2.2 s*hows a summary of key BIM implementation challenges identified literature by several authors. These, along with the foregoing, show that BIM implementation challenges cover a range of areas. That is the process, socio-cultural and technical areas. However, when innovation such as BIM, as in any Information Systems application, is implemented, it inevitably induces changes either deliberately or inadvertently. These are of specific interest in this study and have been reviewed in the next section to provide a foundation for the rest of the study.

Table 2.2: BIM challenges identified in literature

Current challenges militating against successful BIM implementation	**Singh et al.** (2011)	**Trebbe eta al.** (2015)	**Lawrence *et al.*** (2012)	**Miettinen and Paavola** (2014)	**Porwal and Hewage** (2013)	**Dossick and Neff** (2010)	**Elmualim and Gilder** (2014)	**Rowlinson et al.** (2010)	**Jensen and Jóhannesson** (2013)	**Khosrowshahi and Arayici** (2012)	**Steel et al.** (2012)	**Ham and Golparvar-Fard** (2014)	**Nepal et al.** (2013)	**Owen *et al.*** (2010)	**Rekola *et al.*** (2010)	**Bryde et al.** (2013)	**Gu and London** (2010)	**Becerik-Gerber and Kensek** (2010)
Construction industry fragmentation	x					x										x	x	
Inability of BIM tools to accommodate certain preferences of implementers		x	x															
Varied readiness to implement BIM across stakeholders	x				x												x	
Industry's reluctance to change existing work practices/workflows	x				x		x		x	x							x	
Lack of clarity of stakeholder roles and responsibilities on BIM projects	x		x				x								x		x	
Information gap from the design stage to the O&M stage/ data fragmentation	x			x														
Lack of understanding of BIM capabilities, challenges and expected benefits/value			x															
Dearth of real-world cases with proof of positive ROI			x															
Need for changing or adapting intra- and inter-organisational workflows/work practices					x	x	x							x	x		x	
Need to train staff on new technology							x			x								x
Need to establish new process or workflows for delivery of projects							x							x	x		x	
The requirement for complete models prior to start of construction (can be ambivalent in implication)								X										
Need to manage changes in information release schedules and shift in workload to start of project								X										

Current challenges militating against successful BIM implementation	**Singh et al.** (2011)	**Trebbe eta al.** (2015)	**Lawrence *et al.*** (2012)	**Miettinen and Paavola** (2014)	**Porwal and Hewage** (2013)	**Dossick and Neff** (2010)	**Elmualim and Gilder** (2014)	**Rowlinson et al.** (2010)	**Jensen and Jóhannesson** (2013)	**Khosrowshahi and Arayici** (2012)	**Steel et al.** (2012)	**Ham and Golparvar-Fard** (2014)	**Nepal et al.** (2013)	**Owen *et al.*** (2010)	**Rekola *et al.*** (2010)	**Bryde et al.** (2013)	**Gu and London** (2010)	**Becerik-Gerber and Kensek** (2010)
Need for change in procurement culture								X										
Reluctance towards adoption due to time required to produce and maintain complete models										x								
Maintaining completeness, quality and consistency of models											x	x						
Receiving construction specific information from BIM authoring tools													x					
Need to examine all impacted processes and roles in BIM implementation														x				
Lack of skills among project team members										x					x			
Lack of understanding of other team member aims and work processes on BIM projects															x			
Quantity take-off problems															x			
Sharing and use of incomplete models by project team members															x			
Challenges to project management when BIM is implemented due to time required for interfaces between new BIM tasks															x			
Unclear distribution of benefits from adopting the BIM approach to project delivery	x																	
Lack of adequate collaboration among project team members for modelling and model utilisation																		x
Cultural barriers towards adopting new technology/cultural division within teams						x												x

Current challenges militating against successful BIM implementation	**Singh et al.** (2011)	**Trebbe eta al.** (2015)	**Lawrence *et al.*** (2012)	**Miettinen and Paavola** (2014)	**Porwal and Hewage** (2013)	**Dossick and Neff** (2010)	**Elmualim and Gilder** (2014)	**Rowlinson et al.** (2010)	**Jensen and Jóhannesson** (2013)	**Khosrowshahi and Arayici** (2012)	**Steel et al.** (2012)	**Ham and Golparvar-Fard** (2014)	**Nepal et al.** (2013)	**Owen *et al.*** (2010)	**Rekola *et al.*** (2010)	**Bryde et al.** (2013)	**Gu and London** (2010)	**Becerik-Gerber and Kensek** (2010)
Organisational resistance																		**x**
Need for investment in new IT infrastructure																		**x**
Undefined fee structures								**X**										**x**
Insufficient legal framework																		**x**
Difficulty in measuring costs/benefits of BIM implementation					**x**													
Varying degrees of experiential knowledge and understanding within project teams																	**x**	
Software interoperability issues															**x**			**x**
Competition and lack of common interests among authoring tool vendors																		**x**
Large file sizes												**x**						
File exchange standards challenges															**x**			
Logistics of delivering 3D information to work teams on site																		

2.4.7 Impacts of implementing BIM on work practices

Taylor and Bernstein (2009) found, using a grounded theory research approach with elements of an action-oriented research methodology, that just dealing with technological interoperability issues is not sufficient to unleash the benefits of BIM; inter-organisational business practices must also evolve and adapt to these changes. Furthermore, Gu and London (2010) found that factors affecting BIM implementation include the fragmented nature of the AEC industry, the industry's reluctance to change existing work practice. Other factors include the lack of clarity on the roles, responsibilities and distribution of benefits in BIM implementations. In essence, the authors affirm that implementing BIM introduces new risks, and relationships in the project delivery process (Gu and London 2010).

Their views are not different from that of Sebastian (2011) who studied practical implications of BIM implementation, based on a review of literature and case studies. Citing perennial issues of the uncertainty of budget, delay, poor quality, low user satisfaction, and energy inefficiency, as motivations for BIM implementation, Sebastian (2011) asserts that effective multidisciplinary collaboration through BIM requires changing the roles for all project stakeholders, new contractual relationships, re-organised collaborative processes and a shift in the mindset of parties on both the demand and supply sides of the construction business process. The author went on to highlight the gap in practical knowledge in how to manage the stakeholders, in order to efficiently collaborate with their changing roles. As changing construction work practices relate to changes in contractual relationships, it is noteworthy that the existing standard forms of contractual engagement may fall short of providing support for collaboration through BIM. Some of these claims are highlighted in *Table 2.3*.

Table 2.3: Summary of claims to BIM impacts on how work is done in the construction industry

AUTHOR	CLAIMS/ASSERTIONS
Xu *et al.* (2014)	▪ BIM brings about a changed way of thinking ▪ It represents an innovation of business processes and modern technologies

AUTHOR	CLAIMS/ASSERTIONS
Bryde *et al.* (2013)	▪ BIM enables improved workflows
Aranda-Mena *et al.* (2009)	▪ BIM requires change management which can be challenging
Arensman and Ozbek (2012)	▪ Need for efficient change management procedures ▪ Many design changes happen much earlier in the BIM workflow
Sebastian (2011)	▪ BIM implementation induces / requires changing roles of construction professionals
Gu and London (2010)	▪ Implementing BIM drives a different approach to model development that allows for collaborative development of a single shared model ▪ Requires standardization of process and protocols to assign responsibilities *inter alia* ▪ Implementing BIM requires development of dedicated roles for large-scale projects
Gheisari and Irizarry (2016)	▪ BIM workflows require adaptation to fit within existing project delivery workflows
Rogers *et al.* (2015)	▪ New workflows, practices and procedural changes are necessary for BIM implementation ▪ Current workflows, practices and procedural changes are problematic
Manderson *et al*. (2015)	▪ BIM implementation requires typologies for describing technical implementation and associated procedural/workflow implementation
Aibinu and Venkatesh (2014)	▪ Implementing BIM requires a new digital workflow
Kaner *et al.* (2008)	▪ 2D CAD informed practice needs to be replaced with BIM informed practices. This transition can be challenging
Ambrose (2012)	▪ The way projects are being delivered is changing ▪ Old architectural methods are being transformed by digital tools and applications
Zhang *et al.* (2013)	▪ BIM is changing the way construction projects are being delivered
Chi *et al.* (2015)	▪ BIM is changing the conventional structural design process
Wu and Issa (2014)	▪ A new role of BIM manager is created and charged with managing the integration of BIM models across multidisciplinary project team members
Arayici *et al.* (2013)	▪ Implementing BIM requires significant changes in virtually in all aspects of the construction business

AUTHOR	CLAIMS/ASSERTIONS
Steel *et al.* (2012)	▪ With BIM, changes are expected in the long term with respect to organisational work practices. These changes are difficult to predict at the moment
Demian and Walters (2014)	▪ To achieve its full potentials, changes must be made gradually with consideration for project specific dynamics and requirements
Poirier *et al.* (2013)	▪ With BIM workflows are changing and new roles are emerging
Burt and Purver (2014)	▪ Changes to team organisation, procurement and contracts, programming and deliverables *inter alia*
Cavka *et al.* (2015)	▪ Implementing BIM in large client firms requires significant changes in organisation structure and information exchange mechanisms ▪ These changes are both inter-organisational and intra-organisational
Cao *et al.* (2015)	▪ Their results suggest that responsibility reallocation did not significantly 'change the project' despite the creation of a new department to 'build BIM models' ▪ The limited organisational change was propositioned to be attributable not only to lack of knowledge but also resistance to change

Against the backdrop of the problematic nature of using BIM tools to support the activities of construction management organizations in practice, Hartmann *et al.* (2012) provided very interesting perspectives on the BIM impact debate. They analysed BIM implementation from two perspectives, a 'technology pull' perspective and a 'technology push' perspective. Hartman *et al.* (2012) argued that within practical BIM implementation, the top-down approach is limited in the rareness of its ability to significantly change existing work processes to enable the implementation of new technologies. This is based on the premise that construction project work practices are well structured, generally accepted and are thus difficult to change. They, therefore, propounded a 'technology pull' strategy whereby technology is modified to fit into existing work processes rather than changing existing work processes. It may, however, be more beneficial to explore a mix of push and pull strategies because BIM implementation inevitably causes changes in the norm, while it may also be easier to implementers to find ways of adapting the technology to achieve some aspects of their work objectives. The research was thus focused on a different perspective compared to what is commonly espoused in existing literature. For instance, in their study, Arayici *et al.* (2012) recognised that in order to achieve the full benefits often associated with BIM; the stakeholders need to go through a comprehensive change management process, which is likely to require external assistance.

Furthermore, according to Hartmann *et al.* (2012), little is known about the possibilities of adapting BIM technologies to aid existing organizational work processes, a gap they sought to fill through an empirical study based on two case studies of practical BIM implementation on construction projects. They found that while implementers of BIM hold initial beliefs that the implementation would require a change in the work process for estimating, this perception changed as they became more aware of the possibility of adapting the technology to their work processes. Nevertheless, Hartmann *et al.* (2012) acknowledge also that despite the evidence supporting their view, the specific dynamics in organisational settings might necessitate a radical change in existing and established work processes, to successfully implement BIM. In conclusion, they suggested that future research should investigate the emergence of organisational change around BIM-based tools, at different levels within an organisation by applying multi-level organisational research methods. However, their summation, based on case studies of only two construction organisations, cannot be generalised from.

Holzer (2015), similar to the earlier work of Sebastian (2011) affirmed new roles are emerging to maximise efficiency within BIM workflows such as BIM content creators, BIM model manager (project level), BIM manager (office/organisation level) BIM coordinators (multidisciplinary projects). However, it is uncertain how their emergence might impact the dynamics of power and how legitimacy is gained within the existing framework of practice, within organisations and on multidisciplinary project teams. These studies indicate a need for changing work practices to implement BIM successfully. Therefore some of the key questions this study sought to answer are how precisely the delivery processes are altered? How does one understand the impact of BIM implementation of existing delivery work practices? And how can the activities and people involved in the delivery of projects be aligned to the requirements for implementing BIM in South Africa? More so, since a new stream of research in BIM has begun to examine claims about BIM implementation impacts and potentials critically. As Ahbabi and Alshawi (2015) asserted, there is a need to understand the implementation mechanisms clearly, determine how much change is required within organisations, and evaluate how best to make the change.

The work of Olatunji (2011), also similar to Sebastian (2011), supports the idea that BIM implementation does not generate guaranteed results. Furthermore, Olatunji (2011) highlighted the need for industry organisations to understand the nature of BIM induced change and develop effective ways of coping with it. Similarly, Foster (2011)'s work on BIM makes a sound contribution to the debate BIM's impact on industry business processes. As with several other authors, Foster (2011) acknowledges the blurring divides between design and construction in integrated practice with BIM. Moreover, BIM brings on the possibility of fundamental changes in the project delivering process. Importantly, Foster (2011) noted that new business models have not been developed to suit the use of BIM and that its implementation requires a change in risk allocation among project stakeholders. New contractual arrangements will ultimately dictate which project stakeholder bears which risks.

In furtherance of this perspective, Olatunji (2011) puts forward the notion that the gap between the legal frameworks for traditional delivery systems and those advocated for use in integrated project delivery with BIM is quite large. In fact, it represents a considerable departure from the norm. There is a need, therefore, for a reformulation of legal frameworks supporting the delivering of projects to cater to the new demands. BIM legal impediments are further discussed under the headings of model authorship, model ownership, obligations, considerations, jurisdiction and security of electronic information. Further, in an earlier related study, Olatunji (2010) opined that quantity surveying might be one of the industry professions to be significantly impacted by BIM. This view is conceivable considering the erroneous perception of quantity surveyors as mere measurers in the industry.

New studies have started to stimulate new research questions about the 'technocratic optimism' that often dominates the current debates around BIM as a tool and its implementation (Dainty et al. 2017). For instance, Dainty et al. (2017) scrutinised the enthusiasm around BIM and assertions about BIM's revolutionary impact on construction industry practices (as in *Table 2.3*). They argued that it is yet important to complement institutional explanations of BIM adoption with a focus on 'the firm and its people'.

Cidik et al. (2017), in a similar approach to Dainty et al. (2017) argued the importance of nuanced and critical understandings of the changing logic of work practices. In this study, while the potential of BIM to impact significantly or transform construction industry work practices is acknowledged, as for example by Dainty et al. (2017), this study is situated in the current discourse that seeks to provide nuanced explanations or understandings of BIM-induced change in organisations' work practices.

Particularly, Dainty et al. (2017) made a number of assertions that raise important questions in this regard. They asserted that:

- The discourse on BIM technology and supporting policies have been mostly uncritical;
- The current enthusiasm for BIM can be associated with typical new technology hype cycles;
- There appears to be an endless hyperbolic rhetoric around the claims of BIM's potential to revolutionise construction practices;
- Surveys on BIM typically indicate that it requires changes in work practices but do not show whether such changes are actually happening;
- The actual impact of BIM is still uncertain, although its role in realizing cultural and structural reforms in the construction industry is no longer in doubt; and

- There is a serious need to examine BIM implementation from the viewpoints of the organisations that put it into practice.

These are reasonable arguments. It is clear that when BIM is implemented, the intention is typically not to effect change in professional work practices, but rather to realise benefits that it is potentially capable of providing. However, along with its implementation within organisations and teams come constraints and enablement which inadvertently induce changes in work practices. Though some of the claims made in the literature about BIM's capability to revolutionise construction industry practices are not unfounded, it is important to develop nuanced practical and theoretical understandings of experienced changes in work practices and how such changes came to be. Objective assessments in the literature of these kinds of changes in workflows are reviewed in the next section.

2.5 Review of BIM process modelling/remodelling efforts in the literature

There have been attempts to objectively evaluate the impact of implementing BIM on the organisation and inter-organisational work practices and workflows in the literature. However, many of these have been private organisation-led initiatives while others have been developed by teams of academics in universities. Examples of BIM use-case workflow modelling in referred journal articles are in the works of Aram et al. (2013) who developed a process model for the reinforcement information creation and exchange for the whole project lifecycle; Lu and Olofsson (2014) modelled the process for extracting quantities from BIM for estimating purposes; Love et al. (2014) modelled the COBie process showing the required data drops and responsibility for doing these as in *Figure 2.2*; and Papadonikolaki et al. (2015) produced graph-based models of supply chain integration with BIM. They combined BIM as a product with the organisational process model to integrated information flows within the supply chain.

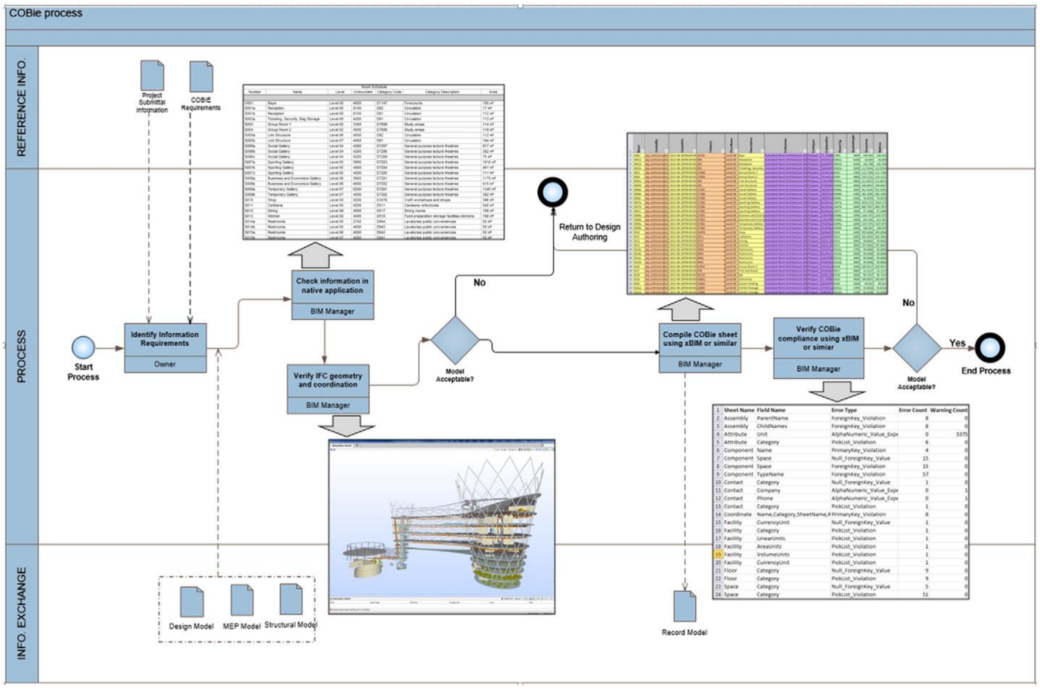


Figure 2.2: COBie process at each defined data drop

Source: Love et al. (2011)

Other process modelling efforts relating to BIM and that are of vital importance to this study include:

- The Process Protocol (Aouad et al. 1998; Kagioglou et al. 2000);
- The work of Eastman et al. (2011) on the guide to building information modelling for owners, managers, designers, engineers and contractors;
- The work by the team of academics at the Pennsylvania State University United States to produce the guide for BIM execution and mapping related workflows (CICRP 2010); and
- Five business process remodelling efforts in the BIM literature.

There were reviewed in the next section, in detail.

2.5.1 The Process Protocol

Aoud et al. (1998) in their work proposed an IT map for a generic construction process protocol. The authors asserted that the potential benefits of improved processes are only achievable with significant IT support and also that profound change in business processes can only be achieved through IT if its use is linked to changes in the whole project lifecycle. Their IT map essentially proposed the application of IT in the broad areas of economic appraisal and risk analysis, scenario-based analysis and simulation, artificial intelligence, cost planning, virtual reality, constructability, visualisation planning, cost control, robotics, resource management among others.

In work done later involving some of the same authors, Kagioglou et al. (2000), leaning on the findings of Latham (1994) and Egan (1998) on the need for integrated processes and teams, developed a generic design and construction process protocol. Their study was based on three case studies including one manufacturing organisation and two construction projects. The principal objectives were to:

- Analyse current practices in the construction industry and develop an improved design and construction Process Protocol; and
- Identify the information technology requirements needed to support the Process Protocol.

Conceptually, the Process Protocol was based on deficiencies in the then current practices in the construction industry. Therefore the aim was to identify areas for improvement in them and develop a process map that addresses them. This work is similar to the thrust of this study although the aim here is not process improvement in the strict sense but alignment or a process to specific requirements.

2.5.2 Computer Integrated Construction Research Program BIM execution planning guide

The Computer Integrated Construction Research Program version (CICRP) 2.0 (2010) authored a planning guide through a team of academics at the

Pennsylvania State University. This was sponsored by the Charles Pankow Foundation, the Construction Industry Institute, the Penn State Office of Physical Plant and the Partnership for Achieving Construction Excellence in the United States. Its purpose was to provide guidance for planning BIM execution to include the following aspects:

- Methods for identifying BIM use for projects;
- Procedure for designing the BIM process for projects;
- Methods for defining information exchange requirements for projects;
- Methods for defining infrastructure support for the BIM process;
- A structured method for team implementation of the procedure; and
- A structured method for organisational development of typical methods for BIM implementation.

To create a detailed process map, the CICRP (2010) recommended:

- Hierarchical decomposition of the BIM use into a set of processes;
- Defining the dependencies between the processes;
- Developing the detailed process map to include reference information, information exchanges and parties responsible for different tasks;
- Adding goal verification gateways at important decision points; and
- Documenting, reviewing and refining the process for further use.

In essence, the CICRP (2010) presented a generic BIM process maps at two levels of abstraction. The Level 1 process map shows the whole building lifecycle at a medium level of abstraction while the Level 2 process maps depicted details of applying BIM for the identified BIM uses. These include, inter alia, existing conditions modelling; cost estimation; 4D modelling; site analysis; programming; design authoring; design review; energy analysis; structural analysis; lighting analysis; design coordination; site utilisation planning; 3D control and planning; record modelling; and maintenance scheduling.

2.5.3 Eastman et al.’s (2011) guide to BIM for owners, managers, designers, engineers and contractors

In Eastman et al.’s (2011) guide to building information modelling for owners, managers, designers, engineers and contractors, they presented ten real-life cases of BIM implementation for various types of projects including medical, commercial, residential and sports facilities. Eastman et al. (2011) however acknowledged that none of the cases cited represented a complete BIM implementation case through the whole building lifecycle since the project cases were mostly of on-going construction projects. Taken together, however, the ten cases cover the aspects/phases of feasibility, concept development, design development, design documentation, pre-construction, construction and operation stages (Eastman et al. 2011). The authors provided depictions of workflows for instance of the conceptual estimating process, general design workflows, decision process workflows (modelled on-site in real time), information exchange workflows and workflows for assessment of buildings’ existing conditions. Some of these compared old and new workflows albeit at low levels of abstraction and for small portions of the delivery process.

As mentioned before, in this study, the intention is not to ‘improve’ an existing process but to align existing pre-BIM workflows to the requirements of implementing BIM at the pre-construction stage and at a medium level of abstraction.

2.5.4 Other business process remodelling efforts in the BIM literature

Five closely related published research studies that attempted to model both as-is and to-be project workflows depicting pre-BIM and BIM-enables project process covering the whole project lifecycle. Their foci and methods are critiqued in this section as a prelude to the second stage of empirical work in this thesis.

Title: Case studies of BIM adoption for pre-cast concrete design by mid-sized structural engineering firms authored by Kaner et al. (2008)

Method: Case studies drawn from two medium sized structural engineering firms. They are case studies of four buildings, two designed with BIM tools and the other two described as reasonably standard projects. The authors depict a comparison between CAD and BIM workflows as shown in *Figure 2.3*.

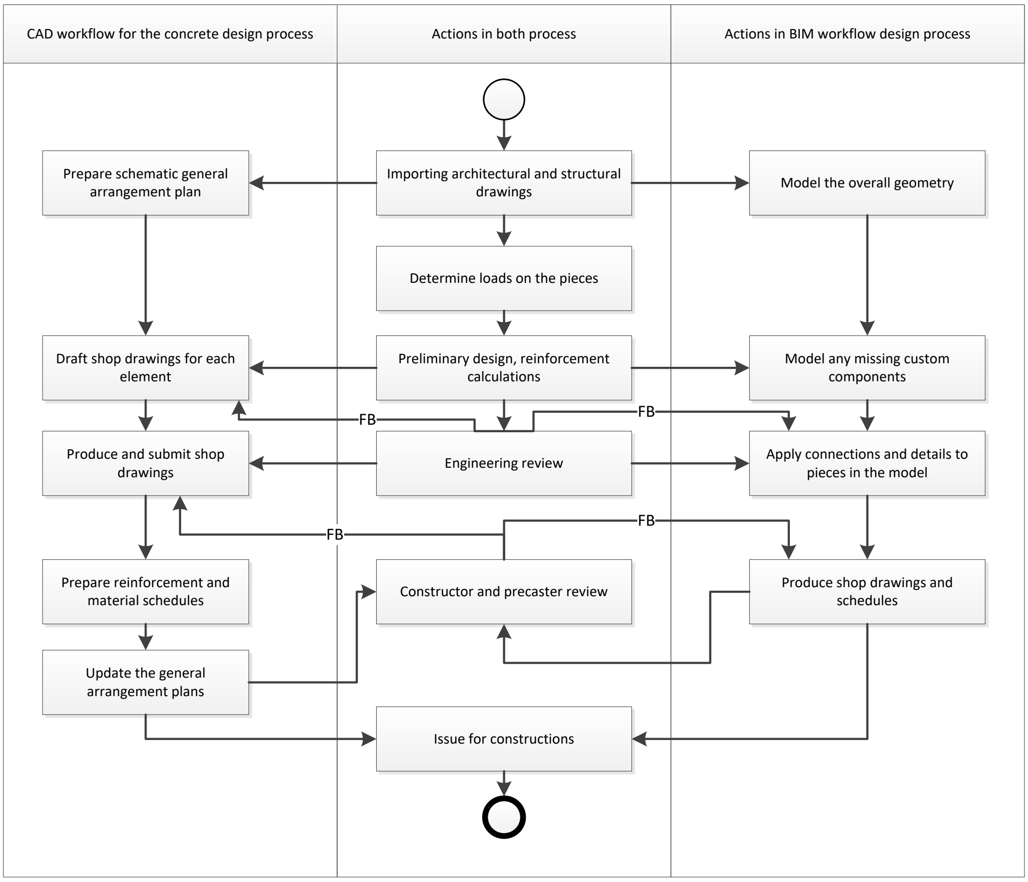


Figure 2.3: Comparison of CAD and BIM workflows
Source: Kaner et al. (2008)

Critique: The work provides some insight, albeit limited, into the implications of implementing BIM on design workflows. The comparison made between CAD and BIM workflows is somewhat limited in scope as it does not cover the whole building delivery process. It shows only a BIM modelling workflow for concrete structures and without taking into account the multidisciplinary nature of design development. It must also be noted that the kind of comparisons drawn in the study between CAD and BIM design workflow may have a limitation in that no two projects are the same even though they are executed by the same organisation.

Title: Towards integrated design and delivery solutions: Pinpointed challenges of process change authored by Rekola et al. (2010)

Method: The study employed a considerably elaborate research methodology. The objectives of the study included the identification of areas that need to be altered for the successful implementation of BIM within a multidisciplinary project workflow. As in similar studies, the research was qualitative in nature. It combined case project data (documents), interviews (22 participants – one on one and small group interviews), group discussions, and process simulations. The study was therefore based on a single case study of a project where BIM in complement with integrated design and delivery was implemented at an advanced level in Finland. The project team members recruited for the study included the client, user, contractor, designers, project manager, and cost estimator.

Process maps were developed, apparently from project documents and other relevant information. Thereafter interviews were conducted to obtain the opinions of the project team members on the initial process map. Next, this insight was used to modify the process map as necessary. Finally, the modified process map was simulated in a group discussion scenario with visual aids where all the participants got the opportunity to further reflect and comment on the process map.

Critique: The paper reports on one of the most elaborate research methodologies employed for process modelling around BIM implementation. It does, unlike others, account for the multidisciplinary nature of project workflows. However, going by the fact that the research objective was to identify changes that need to be made for successfully implementing BIM, a before-and-after modelling methodology that starts from a pre-BIM state would have been more effective. The modelling granularity or level of abstraction as the case may be could also benefit from better definition. Therefore, it features a mix of granular and very abstract elements in the workflow representation.

Title: Building information modelling (BIM) partnering framework for public construction projects authored by Porwal and Hewage (2013)

Method: No method was reported for the model/framework development as this was a conceptual paper. However, the aim was to propose a structured public procurement methodology for the Canadian construction industry and to this end develop a BIM partnering project procurement framework.

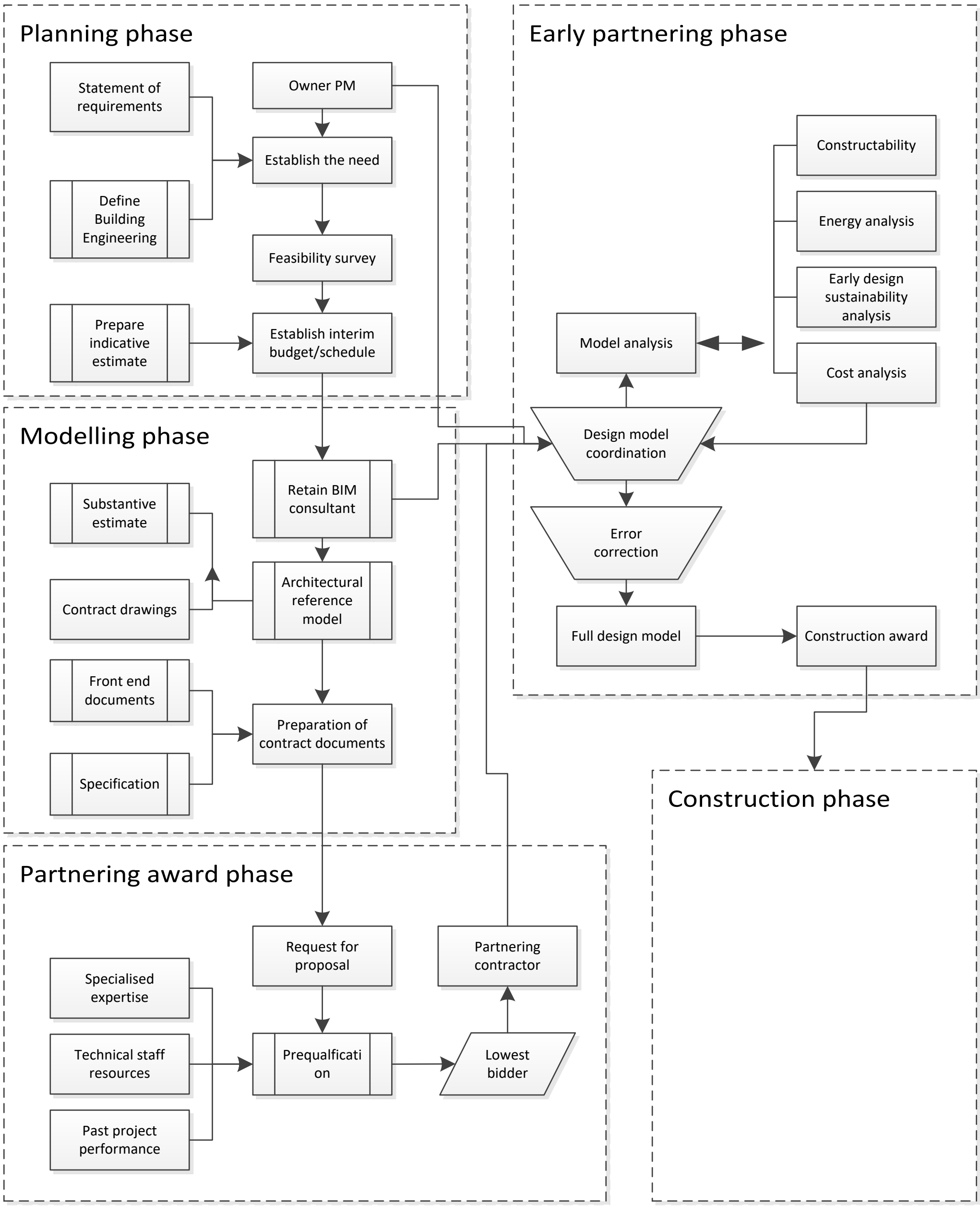


Figure 2.4: Early BIM partnering project delivery approach
Source: Porwal and Hewage (2013)

Critique: The proposed framework shows a mix of high and low abstraction project tasks/elements as in *Figure 2.4*. This is a common challenge with workflow modelling or framework development. The challenge is in the difficulty of determining suitable levels of abstraction and ensuring all elements are modelled on the same level as much as practicable. In terms of modelling methodology, it is clear that the framework is a mix of workflow elements designed both as planned action and as planned deliverables. This is not ideal as it makes frameworks such as this difficult to understand. Further, the framework does not account for the multidisciplinary nature of projects in that there is no separation of functions for actors involved in the process.

Title: Workflow re-engineering of design-build projects using a BIM tool authored by Tsai et al. (2014)

Method: The study based its rationale on the lack of studies in the area of re-engineering of organisational workflows to support the implementation of BIM tools. Though it was not clearly evident from the reporting of the results, the researchers claimed to have adopted a participant observation methodology (inclusive of interviews) to collect data about the existing (pre-BIM) workflow within a 'successful' consulting firm (design and build organisation). Further, a new workflow was proposed as that which supports the implementation of BIM. Thereafter, interviews were conducted with the organisation's employees to review the new workflow in terms of roles and responsibilities modelled. After this, the workflow was modified again. The focus of the study was on intra-organisational workflows rather than inter-organisational workflows.

Critique: While an attempt appears to have been made to employ a reasonably rigorous methodology, some of the tasks modelled could be better described. For example, the tasks 'contract' and 'schedule plan' may not communicate much information to the users of the workflows. The workflow suffers from the challenge in deciding and maintaining the level of abstraction at which a workflow may be appropriately modelled and also in deciding on whether to model the workflow as planned actions or as planned deliverables. Further, there isn't much difference between the pre-BIM workflow and the new BIM workflow. This is mainly because the workflow was modelled at a high level of abstraction. In summary, while it is useful for visual representation to produce concise versions of workflows that support the introduction of BIM into existing workflows (or indeed any intervention), it doesn't show the real impacts of such interventions in a way that makes them understandable.

Title: Embedded contexts of innovation: BIM adoption and implementation for a speciality contracting SME authored by Poirier et al. (2015)

Method: The study was designed as multi-method using a longitudinal case study approach. This was to investigate BIM adoption and implementation within a speciality contracting Small and Medium Enterprise (SME) organisation in the mechanical services field of practice. The multi-method approach included semi-structured interviews with the same staff over an 18-month period. Interviews were conducted with the company president, general manager/estimator, construction manager, three project managers, BIM manager and principal BIM coordinator. Aside from interviews, other information utilised for the analysis included observation of meetings, meeting minutes, field notes, and informal discussion with project managers.

Critique: Poirier, Staub-French and Forgues (2015) produced pre-BIM, and post-BIM workflows depicting information flows between the company's office and field personnel, the result of the study to a fair extent helps the understanding of BIM implementation impacts within the organisation, as modelled in the changed workflow (see *Figure 2.5* and *Figure 2.6*). Notably, the post-BIM workflow is modelled in such a way that it requires more interfaces between tasks contrary to what ordinary expectations might have been following the claims of BIM's ability to facilitate more efficient processes. The pre-BIM and post-BIM workflows only show intra-organisational workflows and yet with limited coverage of project delivery activities. Furthermore, it does not explicitly show split responsibility for project tasks between the different actors in the process.

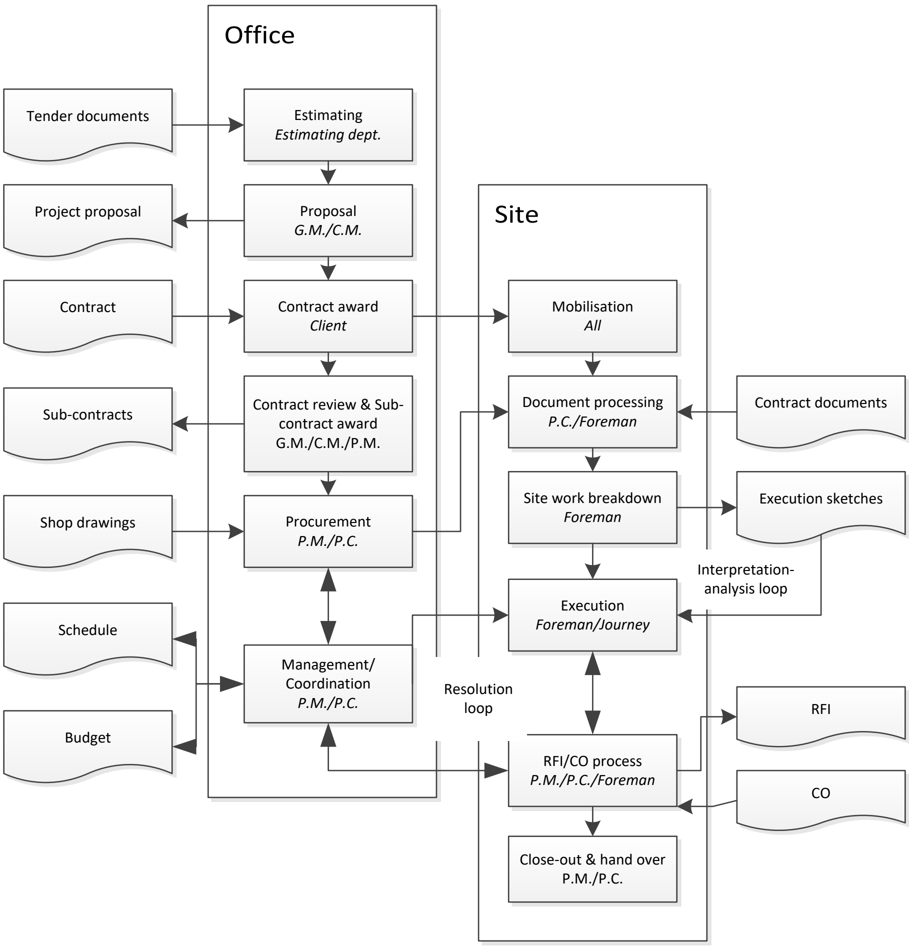


Figure 2.5: Pre-BIM intra-organisational workflows (design-bid-build)
Source: Poirier et al. (2015)

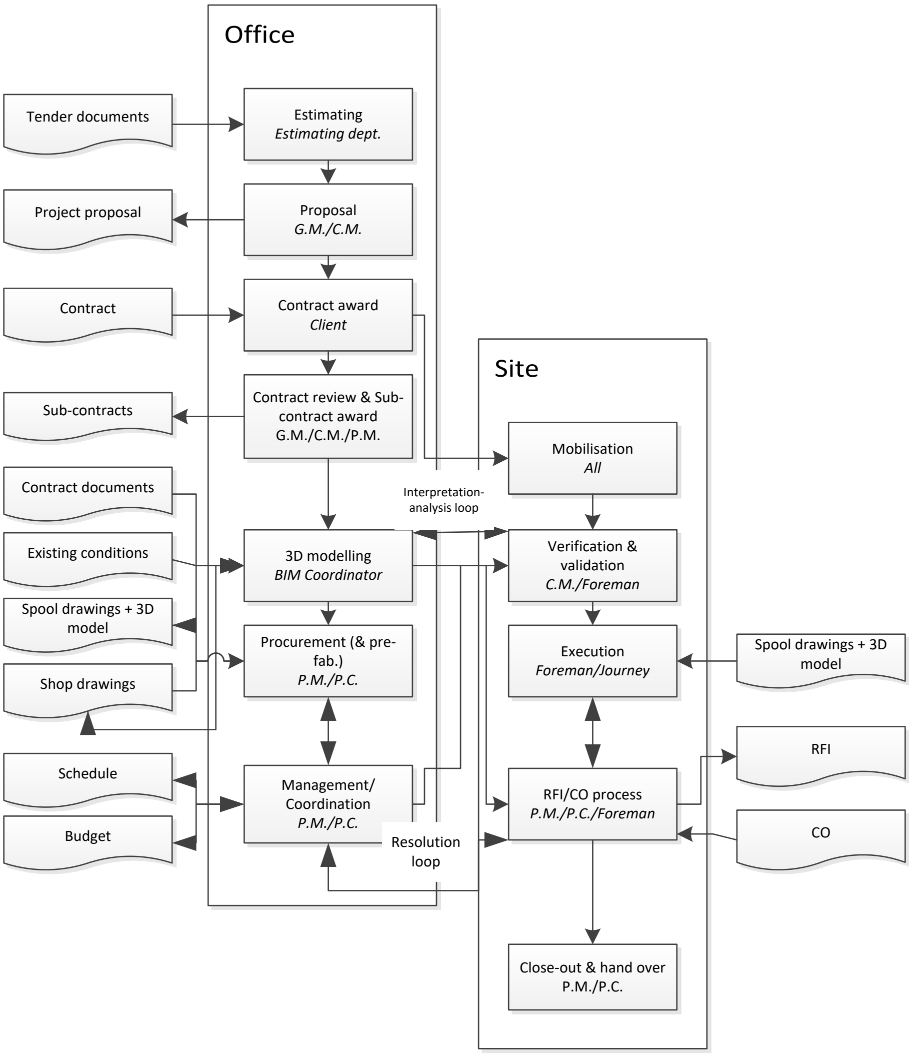


Figure 2.6: BIM intra-organisational workflows (design-bid-build)
Source: Poirier et al. (2015)

Having reviewed works on BIM workflow modelling in the literature, in the section that follows, a brief introduction and review of process modelling and its techniques are provided as a basis for making method choices for this study.

2.6 Process modelling

One of the objectives of this study is to assess the impact of introducing new technology on project team work practices. Therefore, taking a business process view of project delivery, achieving this requires drawing from modelling methodologies that can represent and aid the analysis of the complexities involved in the project delivery process. The methods selected and the rationale for the selection is presented in the following sections. Therein, business process modelling techniques and a structured method for modelling process complexities are discussed.

2.6.1 Business process modelling techniques

A process is a collection of identifiable steps or tasks performed at a particular point in time by a single or multiple collaborating actors (Noumeir 2006). Harmon (2014) elaborates by describing a process as a set of activities that receives and transforms one or more inputs to generate one or more outputs. A process could also be described as a collection of interrelated activities, initiated in response to a propelling event, which achieves a specific result for the 'customer' (client) and other stakeholders of the process (Sharp and McDermott 2009).

In research and practice, there are a set of methods with which a workflow or business process may be modelled. These include coloured Petri-nets, force field analysis, process flowcharting, among others (Aalst 2003; Jensen 1997; Kettinger et al. 1997; Liu et al. 2002; Valk 1998). Aguilar-Saven (2004) provided a useful taxonomy of available methods and their applicability as shown in *Table 2.4*. Going by the pros and cons of each modelling technique, the workflow (swimlane) modelling technique is preferred for its ease of modelling and understanding by its target audience and representational capabilities.

Table 2.4: **Process modelling techniques' considered**

			PROCESS MODELLING TECHNIQUES			
			Strengths and Weaknesses			
Technique	Description	Attributes	User perspective		Modeller perspective	
			Strength	Weakness	Strength	Weakness
Flow Chart	Graphic representation	Flow of actions	Communication ability	Can be too large	Flexible, quick, simple	
DFD	Descriptive diagrams for structured analysis	Flow of data	Easy to understand	Only flow of data is shown	Easy to verify and draw	-
RID	Matrix representation of processes for coordination of activities	Flows of activities and roles	Intuitive to understand	Important information is not included	Rigid notation Complex processes can be displayed	Difficult to edit an existing diagram. Hard to construct
Gantt Chart	Matrix representation	Flow of activities and duration	Easy overview representation and control of performance	Not aid for analysis or design	Simple	No clear representation of dependencies
IDEF0	Structural graphical representation, text and glossary	Flows of activities, inputs, outputs, control and mechanisms	Shows inputs, outputs, control and mechanisms overview and details	Tend to be interpreted only as a sequence of activities. Roles are not represented	Strict rules. Possible to build software. Quick mapping	
IDEF3	Behavioural aspects of a system	Precedence and causality relationships between activities	Easy to understand dynamic aspects in a static way	Many partial diagrams to describe a process	Strict rules and notation Possible to build a software	Need a lot of data. Time-consuming when modelling complex systems

			PROCESS MODELLING TECHNIQUES			
			Strengths and Weaknesses			
Technique	**Description**	**Attributes**	**User perspective**		**Modeller perspective**	
			Strength	**Weakness**	**Strength**	**Weakness**
Coloured Petri Nets	Graphical oriented language to design, specify, simulate and verify systems	Network of places, transitions and arcs	Easy to understand how individual processes interact with each other	Models are excessively large	Formal mathematical representation. Well defined syntax and semantics. Possible to build a software Data concepts	Time-consuming when modelling
Swimlane workflow ✓	Computerised facilitation or automation of a business process	Flow of information, tasks and procedural rules	Easy to analyse. Shorter learning time		Possible to build software. Enables data transfer. Easy to make changes	Lack of a particular notation. Many languages

Source: adapted from Aguilar-Saven (2004)

To redesign a process to suit objectives of interest, Sharp and McDermott (2009) proposed a method (*Figure 2.7*) that begins with a discovery, and understanding of an existing process (as-is process) from the ground up, decomposed to the constituent activities and/or tasks, the actors, roles and responsibilities within the system. Thereafter, a new version is modelled based on clearly set objectives and principles.

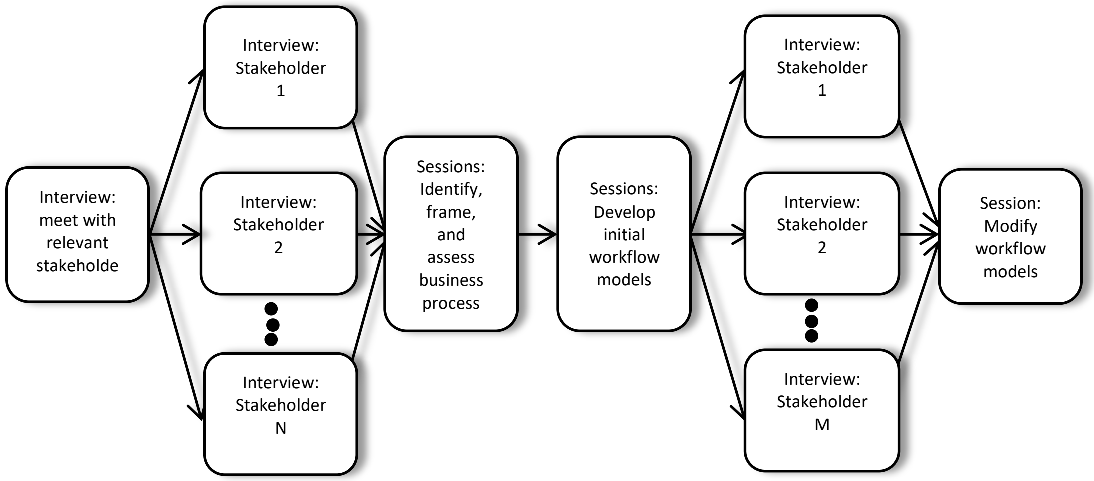


Figure 2.7: Determining the 'as – is' workflow
***Source: Sharp and McDermott* (2009)**

Similarly, Adamantia and George (2005) proposed a methodology for technology-induced business model change as depicted in *Figure 2.8*.

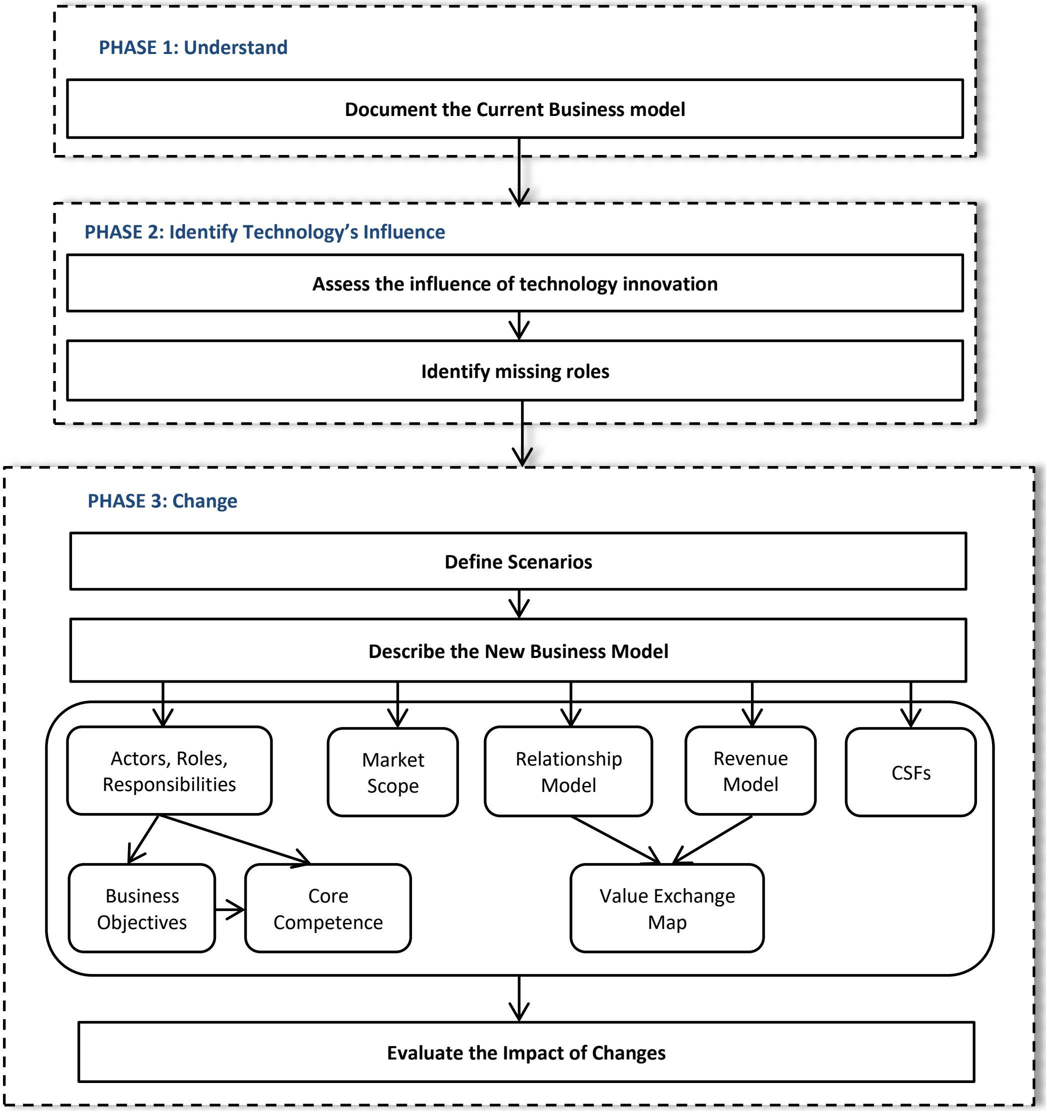


Figure 2.8: A scenario-based methodology for business model change
Source: Adamantia and George (2005)

While several other methods abound in literature, they typically suggest an approach that involves three basic steps. That is, establishing the status quo, assessing the problems, and making the change. The delivery process is made up of interconnected tasks of project team members that are executed in a specific, sequence, organisation, and structure. Consequently, this study will employ a workflow redesign methodological approach (second stage of the study). However, it is useful to employ other methods that can complement the capabilities of swimlane workflow models. One such method is the design structure matrix method which is capable of extensibility and could aid in-depth analysis of the structural characteristics of processes and discussed in the next section.

2.6.2 Design structure matrix method for modelling and analysis of complex systems

This study sought to provide an understanding of changes required in the existing project delivery workflow when BIM is implemented. Achieving this understanding, therefore, required unbundling the activities of all project stakeholders involved in the existing delivery process to a medium level of abstraction. Further, capturing such tacit knowledge requires decomposition of the delivery workflow into sub-systems about which more objective analytic decisions may be made (Browning 2001). Decomposition will enable appropriate determination of the interrelationships and interdependencies driving the behaviour of the system (Browning 2001; Venkatachalam and Varghese 2009). These expectations are achievable through design structure matrix (DSM) modelling techniques (Browning 2001; Eppinger and Browning 2012).

The design structure matrix (DSM) is a generic tool used to represent the constituent elements of a system and their interactions, in effect highlighting the system's structure or architecture (Eppinger and Browning 2012). Furthermore, according to Eppinger and Browning (2012), a system's architecture and interactions between its elements cause the development of the system. DSM's potentials are thus in the concise manner of arranging the structure of elements and interactions, visualisation of the relationship between elements showing attributes of interest, analytical capabilities (extensible to change propagation) and an opportunity for process optimisation (Eppinger and Browning 2012).

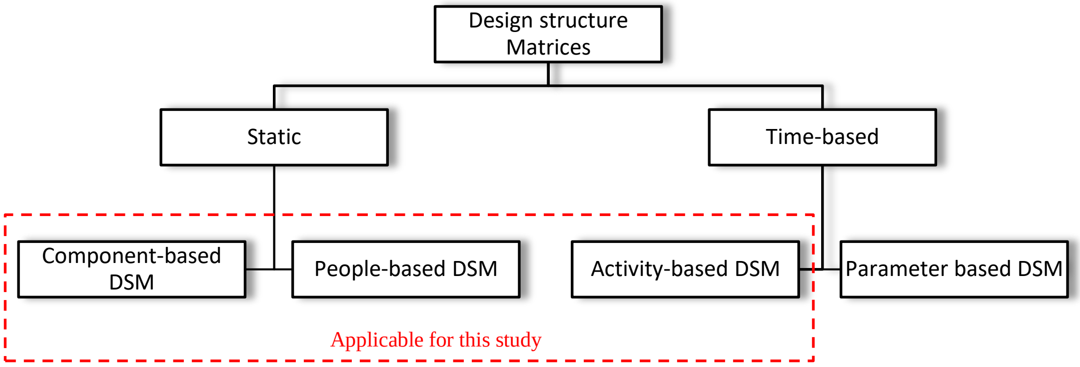


Figure 2.9*: DSM types*
Source: Browning (2001)

The DSM approach enables the decomposition of a system into its constituents at desired hierarchical levels, identification of the relationships among the elements, analysis to understand the system's behaviour, representation by modelling and lastly improvement (Eppinger and Browning 2012). The method has been applied in solving various problems in engineering and construction industry. It has also been used in research to optimise design information flows (Austin et al. 2001), expose the logic and knowledge behind dependencies, and interactions between modelled system elements (Tang *et al.* 2010), analyse iterations and rework in design (Tommelein 2009; Venkatachalam and Varghese 2009), change propagation (Lemmens 2007), visualise interdisciplinary change impact, identify the structure of organisational interactions, develop a collaboration plan, design information exchange processes (Eppinger and Browning 2012) and the management of risks within organisations and project teams (Steward 2015).

A generic example of a DSM developed from an Actitivty β and its constituent tasks A – G is shown in *Figure 2.10* and *Figure 2.11*.

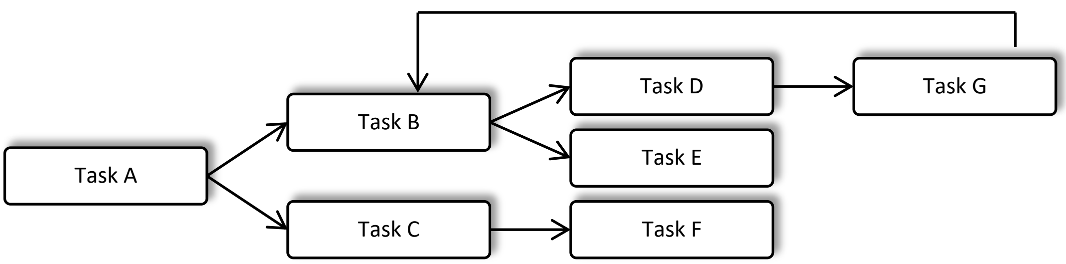


Figure 2.10: Structure of Activity β showing constituent tasks A-G and dependence for information modelled as a swimlane model

	Task A	Task B	Task C	Task D	Task E	Task F	Task G
Task A		x	x				
Task B				x	x		
Task C						X	
Task D							x
Task E							
Task F							
Task G		x					

Figure 2.11: Structure of Activity β modelled as a dependency matrix

As a baseline for this study, the project delivery framework for a design-bid-build method of procurement (CIDB 2010) is expressed first as a Swimlane workflow model and then a 19 x 19 square matrix model (see *Figure 2.12*) of the delivery workflow at a high level of abstraction. The 'x' marks indicate the interactions between tasks in the delivery process and the red coloured marks indicate rework and iteration in the process (these are common causes of inefficiencies on projects). This model can also be extended to show responsibility for each task by project stakeholder to create a DMM (domain mapping matrix). As might be obvious from the DSM model, the level of abstraction of the knowledge displayed is at a high level.

Consequently, it would be necessary to unbind these tasks so as to identify the interactions, sequence of steps taken, to whom they are assigned, and the flow of information between them. Otherwise, it becomes impossible to examine change within the delivery process properly. Taking task D in *Figure 2.11* as an example, it would be necessary to understand the type and possibly, the strength of interaction between it and tasks B and G, and indeed all other tasks in the activity. It also is necessary to determine its location in the sequence of tasks, who performs the task, and the documents/information produced from the task. Ultimately, the study sought to understand how all these interactions making up the workflow structure would change when BIM is implemented on projects. That is, what changes in this structure when BIM is implemented? What new tasks are created and which become redundant? Further, which roles are newly created or modified? This level of analysis, without doubt, requires the systematic capture of tacit knowledge about project team work practices. The appeal of the DSM modelling method for this purpose is to a large extent, its simplicity in representation and objective analytic functionalities.

	Prepare strategic brief	Investigate alternatives	Analyse options	Prepare concept report	Prepare implementation plans	Approval of PED	Professional services proc.	Approval of PSP award	Design work schedule	Architectural design dev.	MEP design dev.	Structural design dev.	Cost planning, estimation, and BOQ	Approval of design & cost	Production information	Preparation of procurement doc.	Request for tenders	Review tenders and rec.	Award of contract
Prepare strategic brief																			
Investigate alternatives	x		x																
Analyse options		x																	
Prepare concept report			x																
Prepare implementation plans				x		x													
Approval of PED					x														
Professional services proc.						x		x											
Approval of PSP award							x												
Design work schedule								x		x	x	x	x						
Architectural design dev.									x		x	x	x						
MEP design dev.										x		x	x						
Structural design dev.										x	x		x						
Cost planning, estimation, and BOQ										x	x	x							
Approval of design & cost										x	x	x	x						
Production information														x					
Preparation of procurement doc.															x				
Request for tenders																x			
Review tenders and rec.																	x		x
Award of contract																		x	

Figure 2.12: DSM model of the South African CIDB delivery workflow structure (Pre-contract) at a high level of abstraction

The DSM method allows modelling and analysis within a single domain of information. Extending its use to capture and analyse more complex relationships requires the use of Multi-Domain-Matrices (MDM). This allows modelling and analysis of complexities for example as applied by Chucholowski and Lindemann (2015) in the analysis of product development projects in multidisciplinary contexts; studying change dependency (Wickel and Lindemann 2015), and ranking risk of internal controls in critical infrastructure (Dister et al. 2015).

DSM/MDM (of people, activity and component-based methods) in complement with Swimlane process modelling is applicable for this purpose. Their use in this study is consistent with the views of Eppinger and Browning (2012), in that DSM/MDM modelling techniques, while not solutions to every problem, can be beneficial when used in complement to other modelling and analytical tools. Basically, the DSM method will provide a means for examining and analysing the dependencies and sequencing between the individual and team tasks that are impacted by BIM implementation at a medium level of abstraction. It is also capable of aiding the re-organisation of the existing project team workflow structure, to enable interoperability of processes, team roles and documents/information produced in delivering projects. This idea has been developed further in the concluding part of the next chapter.

2.6.3 Workflow/complexity management systems

Modelling and analysing complex information that has been decomposed can be cumbersome and nearly impossible to do manually. There are some software applications that can alleviate this challenge. Reichert et al. (2003), similar to Austin et al. (2001) and Austin et al. (2002) described the ADePT workflow management system as one that deals with enterprise-wide, adaptive workflow management, offering features such as temporal constraint management, ad-hock workflow changes, synchronisation of inter-workflow dependencies and scalability. This is similar to the capabilities of LOOMEO which is also a complexity management system. However, LOOMEO is a more advanced modelling and change management application that is capable of modelling and analysing dynamic relationships between elements of complex systems across multiple domains. It aids the acquisition, visualization and evaluation of complex systems regardless of size or complexity using Multi-Domain-Matrices (MDM). This makes LOOMEO a veritable decision-making tool in complex environments and systems across multiple domains. Its uses were explored in analysing DSM/MDM information for this study.

2.7 Summary

In this chapter, a review of closely related BIM literature, workflow re-modelling efforts and techniques have been presented. It is necessary to explore theoretical frameworks that are capable of providing a theoretical conceptualisation of the phenomenon of interest in this study. These would inform the choice of specific research methods and assist in making sense of research findings. In the next two chapters, the theoretical/conceptual framework and the research design are presented.

3 THEORETICAL PERSPECTIVES AND CONCEPTUAL FRAMEWORK

3.1 Introduction

Theories are basically statements of some type of relationship between two concepts or more. It is necessary therefore to seek theoretical understanding of the phenomena of interest in research endeavours. Conceptual frameworks ensue from theoretical perspectives and frameworks in such a way that it guides the research process from conception through to analysis; that is, up to analysing research findings. The more a theory is useful in conceptualising the research purpose, methodology and analysis of results the better its fit with the study. It is essential to also select theories with high explanatory power and preferably with a graphical form if they are to be useful beyond idea conception or just a mention by the writer as is common in contemporary research. These are elaborated below.

3.2 Theory use in BIM literature

In this section, theories that have been used in the BIM literature were identified analysed as a foundation for selecting a suitable theory or theories for this study. A total of 1040 journal articles and conference papers drawing from the years between and including 2005 and 2016 were selected. This was sifted through to identify those that have either employed the use of theory or claimed its influence on the conduct of their study. Of the 462 conference papers and 578 journal articles examined (with the help of computer-aided qualitative data analysis (CAQDAS), 64 were found to have either employed the use of theory or mentioned its influence on the research approach as in *Table 11.1* of *APPENDIX 1*.

It can be surmised from the table that BIM research has developed over the years without much use of psychosocial theory even though the key BIM implementation challenges have been of a socio-cultural nature. Further, upon closer examination of research where some element of theory was found, many authors have only sparingly explained their use of such theories and have applied them in making research design and analytical decisions.

The most common theories applied in BIM research are those relating to the diffusion of innovation and technology adoption (Davies and Harty 2013b; Enegbuma *et al.* 2015; Gledson 2016; Son *et al.* 2014; Wu *et al.* 2016; Xu *et al.* 2014). This is expected as a lot of the key BIM research issues have remained connected to *inter alia* awareness, user perceptions, benefits accruable from adoption and use. It is interesting to note however that there are a number of research efforts that are beginning to explore the strength of psycho-social theories. For instance, Doloi *et al.* (2015) employed social network theory to examine BIM project impediments. This was to identify the stakes of actors in multifunctional and organisational dynamics. Of specific interest to this research are studies that have employed theory in the area of computer supported collaborative work (CSCW) and human-computer interaction (HCI) research. For example, a known theorist Miettinen has co-authored a number of interesting applications of activity theory in BIM research. Miettinen and Paavola (2014) propounded an evolutionary approach to BIM implementation research that draws from cultural-historical activity theory (CHAT) and organisational studies. Similarly, Korpela *et al.* (2015) also applied cultural-historical activity theory in the study of challenges and potentials of utilising BIM in facilities management.

BIM education research has also benefitted from the use of like theories. Expectedly, learning theories have been used in some research of this nature. The ideas propounded by Vygotsky, a Russian psychologist, relating to learning and development (mainly in child psychology), particularly the zone of proximal development (ZPD) have been explored. The ZPD is the distance between a learner's independent learning and assisted learning or as applied by Ghosh (2012), the distance between independent BIM learning and collaborative learning. Chasey *et al.* (2012) also employed the same ideas to study the evolution of new types of classrooms. However, without appropriate use of theory, it is difficult to achieve conceptual clarity about what to study, within which boundaries, how to go about studying it, as well as how to make sense of findings from the research endeavour. Therefore, in the next section, theoretical choices made for this study and their justification are provided.

3.3 Activity theory as a lens for studying BIM induced change

Engestrom and Miettinen (1999) opine that a theoretical account of the constituent elements of complex systems, the class to which project delivery processes belong, is a necessary precursor to analysing their interactions. This makes activity theory relevant for analysing, and understanding object-oriented and motive-driven collective work. Further, in order to suitably conceptualise and clarify the nature of collaborative work of project teams with BIM in the delivery process, it is useful to employ the use of activity theory (Engestrom 1999, 2000). Activity theory has its origins in Russian psychology. It is a theory that aids the understanding of purposeful human interaction (Kaptelinin and Nardi 2006) and is considered appropriate for studies investigating interrelationships within human activity that employs information technology such as BIM as an enabler (Crawford and Hasan 2006; Kaptelinin and Nardi 2006). The theory enables the analysis of emerging patterns of human activity in terms of changing processes (Crawford and Hasan 2006). It has also been put forward as a means for making sense of the ways in which people act together, with the assistance of tools, and in complex dynamic environments (Crawford and Hasan 2006).

Activity theory is therefore expected to provide theoretical explanations to the dynamics within an activity system's elements (Crawford and Hasan 2006; Engestrom 1999; Kaptelinin and Nardi 2006). According to Engestrom (2000), a work activity system comprises; individual workers, tools they use to facilitate their work, rules that guide how they work, the purpose to which members of the workplace community direct their actions and the distribution of responsibilities between all the actors within the system. Holt and Morris (1993) also allude to Engestrom's (2000) description of an 'activity' as a system of collaborative human practice. Furthermore, activity theory posits that dysfunctions between components of an Activity system are the causes of change and development (Engestrom 1999). These dysfunctions, in turn, create need states, in which change, and development of the system can be accounted for (Engestrom 2000).

While the introduction of new tools (BIM as technology or as processes) into an activity system may proffer solutions to certain problems in human work, they introduce a new set of conflicts and contradictions (dysfunctions) that require studying and analysis within the socio-cultural context (Engestrom 2000). More importantly, when within an existing activity system a need cannot be met, a “need state” is created. The authors further pointed out that the theory is suited to engaging the system as it is emerging, its main purpose is to guide the system through various stages of dealing with the contradictions. As drivers for change, there are four types of contradictions; primary (within each component of the activity), secondary (between constituent components of the activity), tertiary (between the activity itself and a culturally more advanced form of the activity) and quaternary (between the central activity and its neighbouring activities) (Engestrom 1987).

To buttress this, Engestrom (2000), in the treatise that put the theory forward for analysing and redesigning work, further stressed the non-static nature of activity systems in that they are in perpetual evolution and internally contradictory. Contradictions in the system, manifested in disturbances, offer possibilities for developmental transformations in the creation of needs for change, to cater for missed targets, or expectations not being met (Engestrom 2000; Hassan and Banna 2010; Holt and Morris 1993; Kaptelinin and Nardi 2006). This assertion is essential to the cultural-historical analysis of project work practices, bringing to bear the ‘need states' created by contradictions within BIM implementation.

There is thus a strong case for exploring activity theory in analysing technologically induced change, as it is with BIM. This is supported in the work of Engeström and Escalante (1996), in which they showed that activity systems analysis could be used to describe collective activities involved in the development, and implementation of technological innovations, and also to analyse the effect of human interaction on the implementation (Yamagata-Lynch 2010). Closely related is Mwanza’s (2002) study in (Yamagata-Lynch 2010), designed to analyse work practices in relation to identifying design requirements for Computer Assisted Learning. This was an ethnographic study (conducted through observations, interviews and document analysis) that used the Engestrom (2000) activity systems model to map how existing work-related practices fit into each component of the model (Tool, Subject, Object, Rules, Community, Division of Labour and Outcome) as in *Table 3.1* and *Figure 3.1*.

Table 3.1: Mwanza's Eight-Step-Model for translating activity systems

TO IDENTIFY THE…		QUESTIONS TO ASK
Step 1	Activity	What sort of Activity is of interest?
Step 2	Object(ive)	Why is this activity taking place?
Step 3	Subject (s)	Who is involved in carrying out the activity?
Step 4	Tool (s)	By what means are the subjects carrying out this activity?
Step 5	Rules and regulations	Are there cultural norms, rules and regulations governing the performance of the activity?
Step 6	Division of Labour	Who is responsible for what when carrying out the activity?
Step 7	Community	What is the environment in which the activity is carried out?
Step 8	Outcome	What is the desired outcome of this activity?

Source: Mwanza (2002)

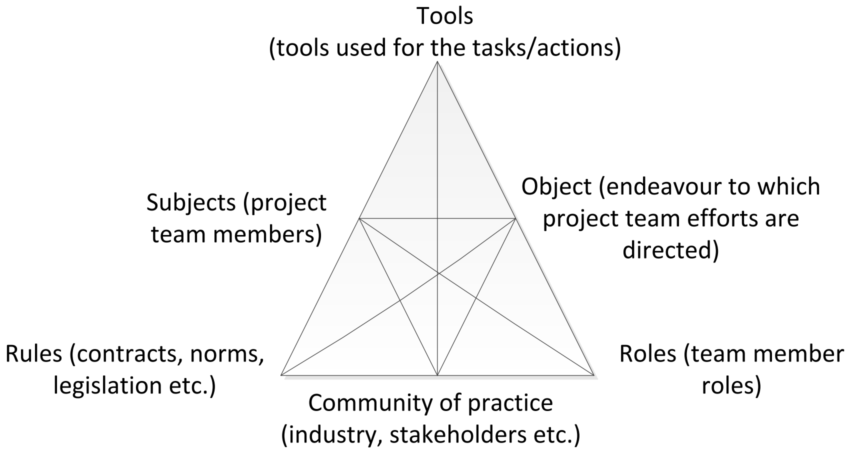


Figure 3.1: Engestrom's depiction of an activity system showing the relationship between elements
Source: Adapted from Engestrom (2000)

Furthermore, Engestrom (2000) demonstrated, through research in the healthcare sector, that problems created by lack of coordination and communication between participants or stakeholders in an activity system can be analysed through activity theory approaches. More so, the identification of contradictions in an activity system paves the way for stakeholders to focus their attention on the root causes of the problem(s). When these problems are analysed and modelled collaboratively, it enables the creation of a shared vision for the solution to the contradictions, by the stakeholders (Engestrom 2000). Activity theory thus provides a framework for guiding a system through the process of transformation while dealing with emergent contradictions and disturbances within and between components of the system, while also empowering actors in the system to innovatively adapt to new situations (Holt and Morris 1993; Kaptelinin and Nardi 2006). Since the focus of this study is to understand and analyse change in the patterns of professional work practices having been impacted by the use of new technology (BIM), an opportunity is presented to apply activity theory to elicit and contextualise the evolution of collaborative professional practices due to disturbances created by contradictions in the system. It also affords the potential of methodological developments in an area of research largely lacking the application of psychosocial theory.

A theory is only useful and practical as much as its key propositions and assumptions inform a study. To demonstrate this, several similarities have been drawn between the activity theory (AT) approaches, DSM method, and workflow re-design methods. All three are suited to addressing issues relating to human work activity, i.e. how work is done and the relationship between their constituent elements (Engestrom 2000; Eppinger and Browning 2012; Venkatachalam and Varghese 2009; Yamagata-Lynch 2010). Beyond these, there are other similarities in the strategies that have been used in literature for related studies as shown in *Table 3.2*. These further strengthen the argument for their complementary use. Therefore, one may construe the applicability of activity theory, DSM, and workflows re-design to be complementary in nature. While activity theory approaches aid the elicitation of knowledge during the data collection stage for this research, it was also useful in understanding and interpreting findings.

Table 3.2: Similarities between Activity theory, DSM and Workflow modelling

	DESIGN			STRATEGIES			RESEARCH METHODS						NATURE OF STUDIES				
	Qualitative	Quantitative	Mixed	Ethnography	Participatory action research	Case study	Interviews	Participant observations	Group interviews	Field studies	Brainstorming sessions	Document analysis	Study of specific work settings	Workplace studies	Work tool design	Change management	Human-computer interaction
AT	×			×	×	×	×	×	×	×	×	×	×	×	×	×	×
DSM	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	
WFM	×		×	×	×	×	×	×	×	×	×	×	×	×		×	

Furthermore, the method for DSM/workflow modelling and analysis fits suitably into the framework put forward by Engestrom (2000).

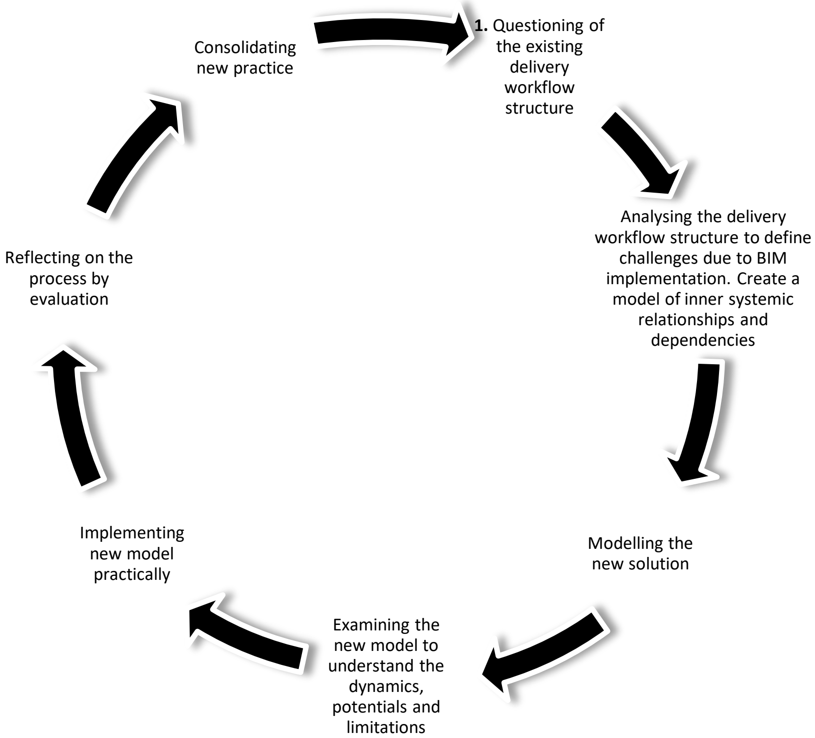


Figure 3.2: Cycle of Expansive transformation/Learning
Source: adapted from Engestrom (2000)

The framework describes a methodology for applying activity theory in practice as depicted in *Figure 3.2*. It provides for:

- Questioning: critic of aspects of interest in the current accepted practice
- Analysis: analysing the structure of the of the system to elicit causes of contradictions and constructing a model of inner systemic relationships (after BIM technology and associated processes are implemented)

- Modelling new solutions: emergence of new structure
- Examining the new model: to grasp the dynamics, potentials and limitations
- Implementing the new model: practical application
- Reflecting on the process: evaluation of the whole process
- Consolidating new practice: a new stable form of practice

3.3.1 Justification for choice of theory

As an argument for the theoretical choice made, activity theory is very specific in its focus. It is a theory for understanding the evolutionary dynamics of human endeavour. More so, it is clear in its explanation of key concepts, assumptions and propositions about transformations, or change within and between elements of an activity system. Further, there is a considerably large body of knowledge on the theory. For the purpose of this study, activity theory is therefore taken to be the base theory, upon which propositions and assumptions from other relevant theories and ideas may rest. Therefore systems thinking and role theory are explored in the next section to explicate areas of relevance or departure from the main theoretical choice. Perspectives from institutional theory (on legitimacy) were also drawn from at the data analysis stage. This theoretical framework afforded a holistic understanding of the phenomena of interest; changing patterns of professional work practices.

3.4 Other relevant theories

3.4.1 Systems thinking

DSM/MDM, workflows re-design and activity theory methodologies are centred on the understanding of the world and reality about it as complex. Therefore, the understanding and application of these ideas may remain incomplete without 'systems thinking'. Systems thinking approaches are not new to business process re-engineering efforts (Van Ackere *et al.* 1993). A system is composed of several elements in a hierarchical structure (*Ibid*). Particularly, the soft systems methodology (SSM) developed as a process with which problems are addressed by first providing a representational model of the behaviour of existing real-world systems (Checkland 1988; Forrester 1994). Further, systems thinking drives a methodological approach (*Figure 3.3*) that focuses on the present condition of a system, and the means through which improvement is achieved, instead of focusing on the ideal future form of the system (Forrester 1994).

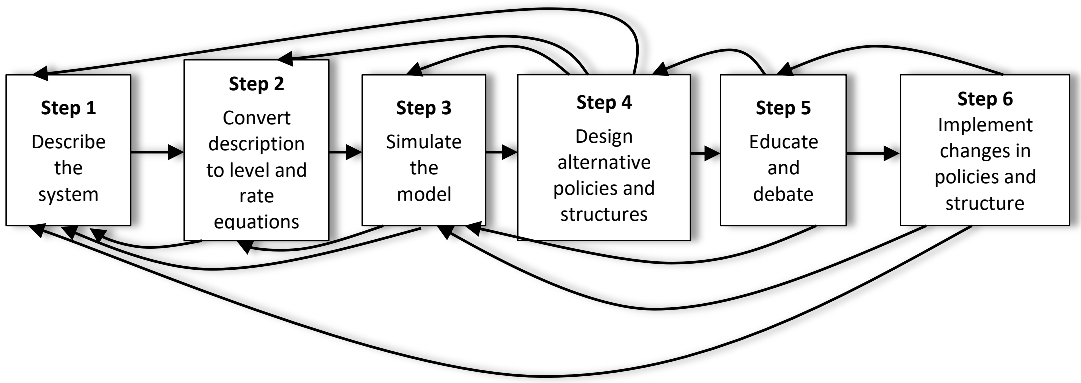


Figure 3.3: System dynamics steps from problem to symptoms to improvement
Source: Forrester (1994)

It is clear that the systems approach to problem-solving as depicted in *Figure 3.3* above is similar to business process re-design, DSM and activity theory methodologies that strongly favour a description of the existing system, identification of problem areas, and making desired changes. This is also consistent with contemporary change management methodologies as depicted in *Figure 3.4*.

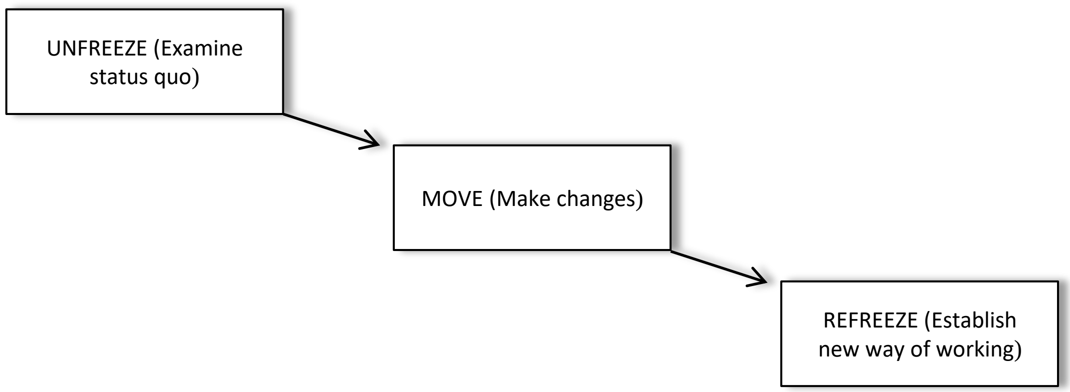


Figure 3.4: Lewin's 3-step change model
Source: Adapted from Cameron and Green (2012)

The underlying principle behind business process re-engineering (BPR) efforts and other such approaches is the existence of conflict in the system. Van Ackere *et al.*'s (1993) example of a problem involving the difficulties in matching product shipments and factory production to customer demand is a classic example of this. The problem can be interpreted using activity theory as a conflict between the object of the activity and stakeholder / community expectations and demands.

Interestingly, Ackere *et al.* (1993) claim a departure of the systems thinking approach from business process re-design from that of continuous development philosophy. That is, continuous process evolution. This position is however incongruent with the activity theoretical propositions on the evolutionary nature of human work practices. In seeming contrast, however, Checkland (1988) listed emergence, alongside hierarchy, communication, and control as the four main ideas in systems thinking. Checkland (1988) further described the two main ideas about systems as either natural or designed systems. An Activity system in this light can be described as a hybrid of the two, that is, it is both a product of conscious design effort and also naturally evolving over time. The systems thinking approach, therefore, helps to understand the idea of a system and its dynamics.

3.4.2 Role theory

In Biddle's (1986) review of developmental trends in role theory in research, the theory is described as a social theory that is suitable for understanding changes in protocols for social conduct. Conflicts in roles can be a result of a multiplicity of norms and conflicting norms. Yet, role expectations (norms, beliefs & preferences) influence the generation of new roles and behaviour. These and other assumptions put forward by Biddle (1986) were conceptualised as depicted in *Figure 3.5*. One may thus surmise from these that without doubt, role theory supports the notion that roles and rules are inextricably interlinked.

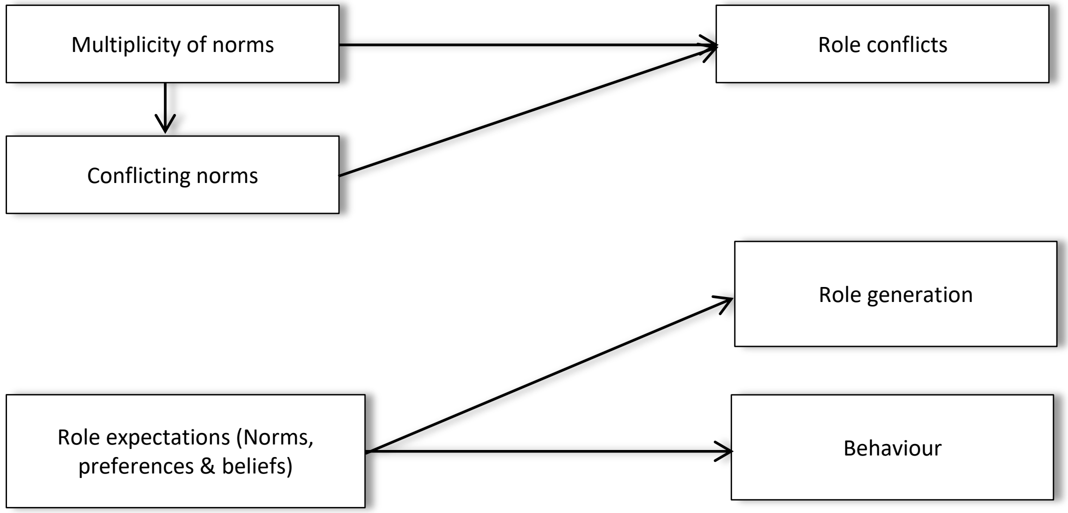


Figure 3.5: Summations from Biddle's positions on Role theory

Role conflict and other sources of problems highlighted by Biddle (1986) are of particular importance to this study. The others are; role ambiguity (expectations not being able to guide the agent's behaviour), role malintegration (roles taken up by an agent or several agents that do not fitting well together), role discontinuity (performance of a sequence of incongruent roles), and role overload ("when the person is faced with too many expectations"). Importantly, role-related social problems also include the incongruence between assigned roles/expectations and the capacity of the agent to meet the demands of the role (Biddle 1986). Despite Role theory being limited in scope, and its assumptions largely underdeveloped into propositions by theorists (Biddle 1986), it is nevertheless relevant.

3.5 Conceptual model

Activity theory propositions together with ideas from systems thinking, and role theory, are the main bases for the conceptual model in *Figure 3.6*. The conceptual model graphically depicts the theoretical foundations of this study in which evolution of professional work practices due to BIM implementation is propositioned to be accounted for in the constraints/challenges produced by the implementation within organisations and project teams; this, in turn, creates demands for change in the existing ways of working to mitigate the constraints.

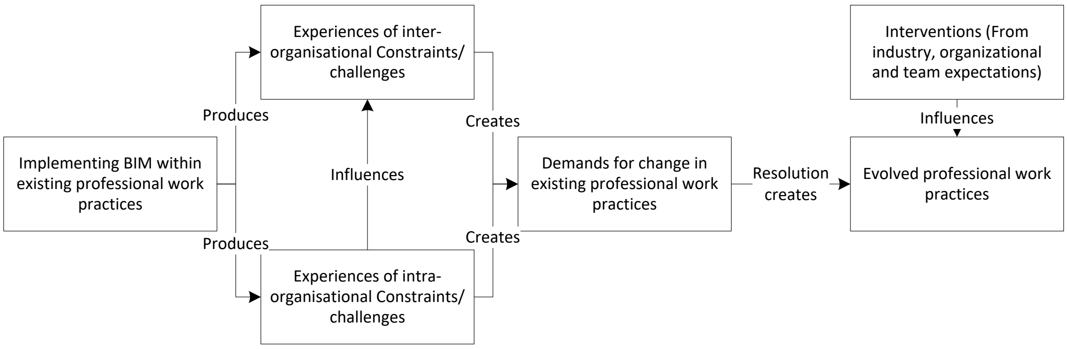


Figure 3.6: Conceptual model
Source: adapted from Akintola et al. (2015)

Experiences of intra-organisational constraints or in fact BIM benefits greatly influence multidisciplinary/inter-organisational project team experiences of implementing BIM. Furthermore, as the theoretical framework is based mainly on psychosocial theories, this study only seeks understandings of the sociocultural dynamics of change in professional work practices.

3.6 A framework for defining abstraction levels for the decomposition of activity-based DSM/MDM

The purpose of this study requires unbundling the activities of all project stakeholders involved in the existing delivery process to a medium level of abstraction has been highlighted. However, there are difficulties inherent in defining hierarchical levels of abstraction for activity-based DSM modelling (Venkatachalam and Varghese 2009). Unlike parameter-, component- and people-based matrix structures, it is challenging to unbundle the constituent components of human activity at lower levels of information that describe how project activities are carried out. This difficulty stems from the 'routinization' of work activities through the developmental evolution of work practices (Bardram 1998; Kaptelinin and Nardi 2006). Thus, aspects of human activity that drive the behaviour of the system are carried out automatically and are therefore tacit in nature (Bardram 1998). This is the level of human activity that describes how work is done; that is, the specific steps taken to accomplish tasks either by individuals or a project team.

Previous studies based on activity DSM are vague about how the process of decomposition was carried out. However, in defining levels of abstraction for design activity, Venkatachalam and Varghese (2009) presented a concise framework within which abstraction levels were described as an aid for hierarchical decomposition of project design activity. The difficulty in defining levels abstraction and eliciting information about activity DSM was acknowledged. To avoid these, a six-level hierarchical decomposition framework that assists in decomposing the design activity for fast-track construction projects was developed. However, while the framework provides a good way to decompose the design activities for the purpose of design management, it does not cover the interactions between the process, people and documents produced in delivering construction projects. A framework for decomposing the project delivery process into planned actions, rather than planned deliverables is required.

3.6.1 Defining hierarchical levels of project delivery processes

Following the background on the basic principles of activity theory, this section introduces the ideas surrounding the relationship between activities, actions and operations. Bardram (1998) asserted that in the structure of human activity, 'activity' defines the '*why'* of human endeavour; 'actions' define the '*what'* we do to achieve the purpose of the endeavour while 'operations' are the steps that define '*how'* work is actually carried out. Further, activities are directed at motives, actions at goals, while operations are directed at specific conditions of work. These, therefore, explain why information about work practices (only clearly described in operations) is considered tacit, and difficult to conceptualise. Nonetheless, an activity is composed of a sequence of actions that are not immediately directed at the motive of the activity (Kaptelinin and Nardi 2006). They are instead directed at shorter term goals. The achievement of these goals leads to the realisation of the activity's purpose (Kaptelinin and Nardi 2006). Nonetheless, actions can be broken into smaller units, that is, operations, which are routine in nature and enable the fluidity of actions to specific work conditions (see *Figure 3.7*). Their orientation is towards the specific conditions upon which work is carried out. Yet, several different actions may be required to achieve a single goal.

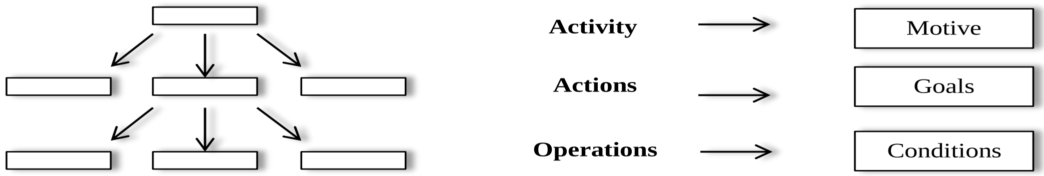


Figure 3.7: The hierarchical structure of an Activity
Source: Kaptelinin and Nardi (2006)

It is noteworthy that the concepts - activity, actions, sub-actions, steps, roles and documents – have been defined and explained here theoretically using activity theory. However, in the Architecture, Engineering and Construction (AEC) domain, they are commonly referred to as process, tasks, sub-tasks, roles and documents/information respectively. Therefore, the latter will be adopted as the terminology for this study.

Three main domains of information are of interest for capture. These include:

- Task interrelationships – This will be captured for the existing (typical) delivery workflow to establish information or material dependence to proceed or be executed. It will help in determining paths of change propagation occasioned by BIM implementation on the existing way of working and compatibility with other tasks, tools used, and team member responsibility.
- Responsibility – Roles taken up by respective professional service providers currently will be identified to aid the analysis of changes required by the implementation of BIM in the delivery of projects and compatibility with other roles, tasks and tools used to carry out the tasks.
- Deliverables – Information/Documents produced from each task or step for analysis against BIM requirements and compatibility with tasks and team member functions.

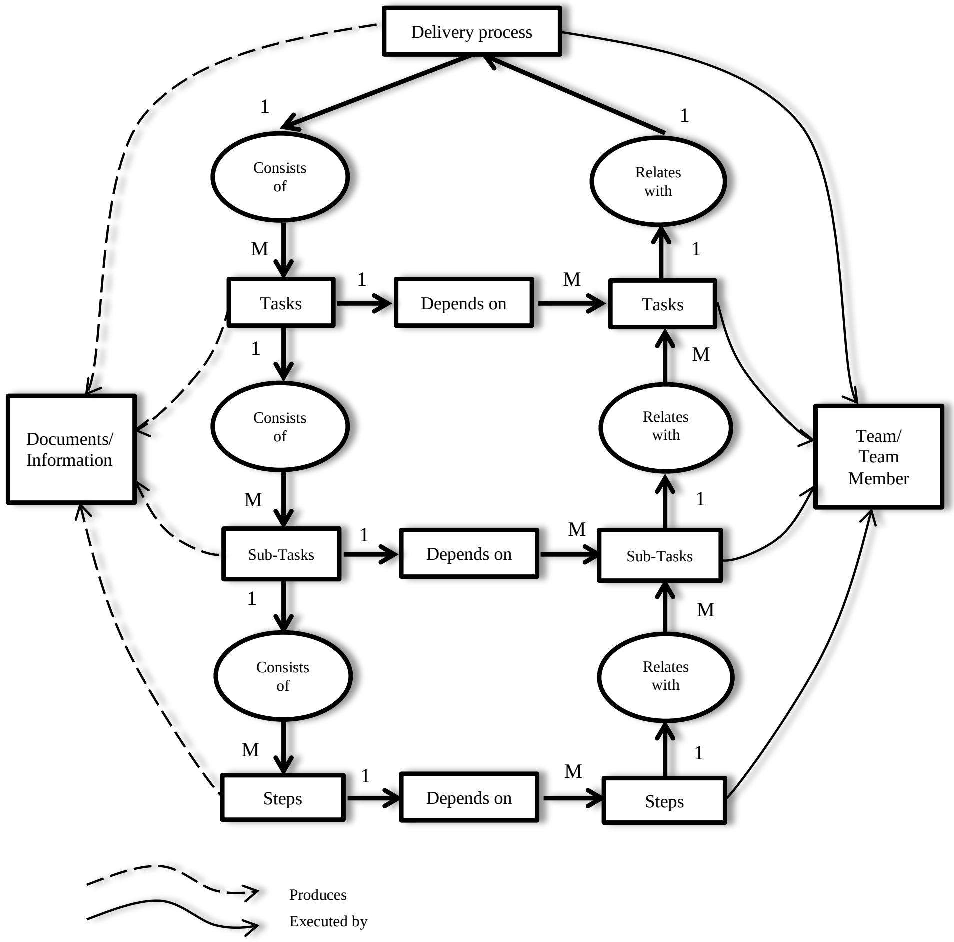


Figure 3.8: Element relationship framework for capturing DSM/MDM information
Adapted from Venkatachalam and Varghese (2009)

The element relationship framework in *Figure 3.8* above shows the hierarchical levels of the project delivery workflow as may be captured through elicitation using structured interviews. Using this framework, an MDM model can be produced; first of the pre-BIM delivery workflow, and then this would be aligned to the requirements for implementing BIM as shown generically in *Figure 3.9* shown in the next section.

3.6.2 Knowledge elicitation to populate DSM/MDM

In carrying out collective activity, a distribution of the object of the activity into a separate interlinked set of actions through the division of labour among the stakeholders is necessary (Bardram 1998). However, before work can be suitably divided among several stakeholders, an understanding of the existing way of working is a pre-requisite (Bardram 1998). The information about the domain intrarelationships and interrelationships also requires a systematic method for capture. This can be facilitated by document analysis, and one-to-one interviews to construct how the work of each stakeholder fits into each other. This method follows after best practices in knowledge elicitation methodologies (Hoffman *et al.* 1995).

	DELIVERY PROCESS	PEOPLE	DOCUMENTS
DELIVERY PROCESS	Delivery process DSM (BIM change impact on existing workflow)	Process-People DMM (BIM induced change in existing team roles & responsibilities)	Process-Information/Document DMM (responsibility for document/information production)
PEOPLE/TEAM		People DSM (project interfaces between team members and changes due to the introduction of new technology)	People-Documents DMM (Responsibility for production of information/documents)
DOCUMENTS			Documents DSM (dependence of documents on other documents for information)

Figure 3.9: Generic model of proposed MDM

The framework provides a systematic way of unbundling the tasks of project team members while matching them to team member responsible for carrying them out and the information produced by them. Specifically, the DSM/MDM modelling method will help in capturing information about existing task sequencing/flow (including information or material dependence), team member responsibilities, and documents created from each task. Once this information is elicited and modelled, it can enable the evaluation of BIM induced change in work practices by juxtaposing the pre-BIM DSM/MDM or the project team workflow against BIM requirements/demands.

3.7 Summary

This chapter provided the theoretical foundations upon which the rest of study was carried out leaning mainly on activity theory and other theoretical perspectives. The following chapter outlines the methodical choices appropriate for addressing the research question as stated below.

3.8 Research question

How do organisational and project team work practices coevolve with the implementation of new technology (BIM)?

3.8.1 Research sub-questions

1. What is the impact of implementing BIM on existing organisational and project team work practices?
    a. How does implementing BIM enable organisational and project team work practices?
    b. How does implementing BIM constrain organisational and project team work practices?
2. What is the structure of pre-BIM project team delivery workflows?
3. How can the workflows of project teams be reorganised for collaboratively implementing BIM on projects?
4. What are the differences between pre-BIM project team delivery workflows and BIM-enabled project delivery workflows

4 RESEARCH METHODOLOGY AND DESIGN

4.1 Introduction

This section begins with methodological perspectives that serve as foundations for conducting research, particularly social science research. It is from the strategies presented here that the study's methodology was crafted. First, the possible choices of strategies and their characteristics are outlined followed by method choices. It is necessary to state, however, that the methods employed in this study are allied to the position of Miles *et al.* (2014) on the impracticability of casting research designs in inflexible 'boxes' of established research design choices. Therefore it may serve researchers' purposes to make their choices eclectically, drawing from different approaches as needed.

4.2 Research strategies

Creswell's (2009) and Creswell's (2013) described research design as a plan to conduct research and an intersection of philosophical leanings, strategies of inquiry and specific methods (see *Figure 4.1*)

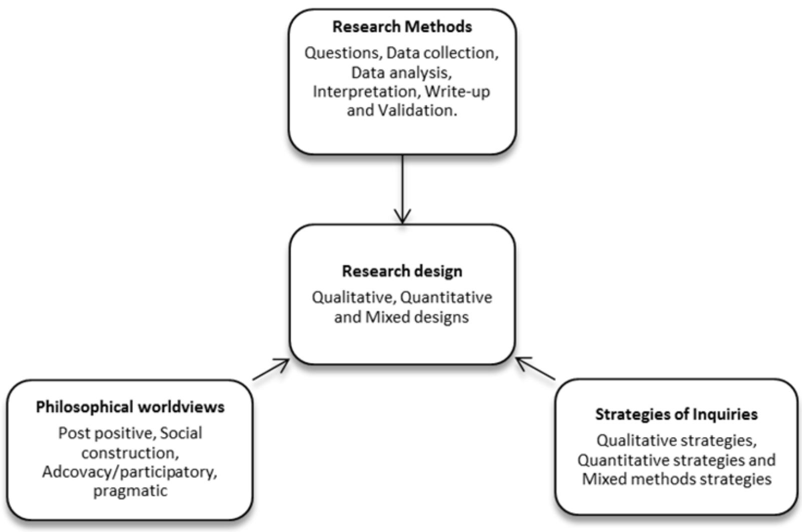


Figure 4.1: Framework for designing research
Source: adapted from Creswell (2009)

Research strategies, on the other hand, are the actual plans for action for conducting research and from there flows research method choices (Saunders *et al.* 2012). In this section, five approaches are discussed. Namely, narrative research, phenomenology, grounded theory, ethnography and case study. Going by the theoretical and conceptual leaning of this study, a qualitative type of research is intended. Creswell's (2013) framework for contrasting the five different strategies (as in *Table 11.2* of *APPENDIX 1*) regarding criteria like research focus, problem type, unit of analysis, data collection form, analysis strategy and reporting style was employed.

4.2.1 Narrative research

Narrative research strategy of inquiry is appropriate for understanding the experiences of humans as it was lived and narrated by them Creswell (2013). Essentially, the narrative emerges from interactions during which individuals tell of their experiences using their minds as a lens (Creswell 2013). Typically, data is collected through many different forms like interviews, observations, documents among others. These are subsequently time-ordered to tell an individual's life story (Creswell 2013). Through these, personal accounts of the event or a sequence of events are narrated by the researcher (Saunders *et al.* 2012). Also, these accounts may be analysed in several ways depending on the specific circumstances forming the context the 'told story'.

4.2.2 Phenomenology

Phenomenological research is focused on studying the experiences of a group of individuals about a concept or phenomenon (Creswell 2013). Such studies are defined by the following characteristics as outlined by Creswell (2013).

- Emphasis is placed on the phenomenon of interest. This is devised in the form of a single concept or idea;
- The phenomenon is explored within diverse mix of individuals who have experienced it;
- Choice of either having the investigator separate him/herself from the research situation or allowing own experiences to infuse the process needs to be made;

- Data collection methods would involve interviewing individuals who have experienced the phenomenon in some way. Other data collection methods may include observations and documents, and;
- The analysis basically sets out to distil the ‘what’ and ‘how’ of the participant's experiences of the different aspects of the phenomenon.

Creswell (2013) identified hermeneutical and transcendental phenomenology as its variants. The first involves the interpretation of texts about lived experiences while the latter attempts also to exclude the researchers’ experiences while developing ‘textural’ descriptions of participants’ experiences.

The phenomenological strategy is not without its challenges. They include the need for a broad understanding of philosophical ideas and careful participant selection. There is also need to decide on how personal researcher understandings may influence and could be infused into the phenomenological research process (Creswell 2013).

4.2.3 Grounded theory

Grounded theory is a method much more than an approach or strategy for conducting research. It is a method for systematically developing a theory as explanations for previously unexplained phenomena, processes, or actions. The focus of grounded theory is to discover a theory or theoretical explanations of actions or processes (Creswell 2013). The developed theory is grounded in the study’s data, and the method’s defining characteristics according to Creswell (2013) include:

- Following a process or action occurring over a period for which an explanation may be advanced;
- An important step in theory building is memoing during which the researcher tries out ideas and conceptualisations of links between elements of the process or action as a step towards theory building;

- A key form of data collection includes interviewing. While interviewing, the researcher constantly engages in comparisons of data being collected currently with emergent theoretical ideas, and;
- The analysis is fairly structured in nature. It involves the creation of open categories of data (through open coding), selecting one category as the theory's focus, detailing additional categories (axial coding) to form a theoretical model. The intersections of data categories (selective coding) become the developed theory or explanation.

The challenges involved in conducting this type of research include determining when categories of data become saturated and the need to carry out discriminant sampling to ascertain if the developed theory holds true for a different set of additional participants (Creswell 2013).

4.2.4 Ethnography

The focus of ethnography is the examination of shared patterns and meanings within a culture-sharing group of individuals (Creswell 2013). The ethnographic study process is one characterised by extended observations which are mostly participant observation. Ethnographic research is typically done with special attention to behaviour, language and interaction (Creswell 2013). According to Creswell (2013), the following are the defining features of an ethnographic study:

- Focus on developing complex descriptions of the group and their culture
- The ethnography seeks to establish patterns in the ideas and beliefs embedded in the group's language, activities, and behaviour;
- The target group should typically have been in close proximity and interacting for a long time, and;
- Participants' views are relied upon in the analysis of data

The challenges include the requirement for extensive time spent in the field engaging with the group, and for sensitivity to the needs of the individuals being studied (Creswell 2013).

4.2.5 Case study research

While ethnographic studies can be considered to be single case studies, in case study research, an attempt is made to investigate research issues within its real-life bounded context or setting that is also bounded by time and location (Creswell 2013). Case studies typically employ the use of multiple data collection methods to gain in-depth insight into the problem being studied. According to Creswell (2013), the strategy's defining characteristics include *inter alia*:

- Case identification regarding type and number of cases;
- Clear definition of intent;
- Provision of in-depth understanding of the problem through the case analysis;
- Cases may be either simple or layered with multiple units of information embedded within one or more cases. They may be single-intrinsic/instrumental types or multiple-collective types; and
- Rich case description.

The challenges typically associated with this strategy or approach are case selection challenges (number, type etc.), and the need to establish a sound rationale for case selection (Creswell 2013). Deciding on the boundaries of case studies may also prove to be a challenge (Creswell 2013).

4.3 Interviewing

There are about three types of interviewing when broadly categorised based on their structure. They differ by purpose conceptualisation, the structure of questioning, and method of field delivery. The three are unstructured, semi-structured, and structured interviews. Analytical methods that may be employed in making sense of data collected through the different forms of interviewing would also vary by their structure.

4.3.1 Approaches to analysing interview data

Wengraf's (2001) suggested some approaches that may be taken in analysing and making sense of semi-structured interviewing data as in *Table 4.1*:

Table 4.1: Approaches to conceptual sense-making in qualitative research interviewing

APPROACH	DESCRIPTION
Common sense hypothetico - inductivist model	▪ In this approach, theory emerges from data. This is typical of core interpretive framework strategies like grounded theory. Facts dictate or suggest theorisation.
Anti-common sense hypothetico-deductivist model	▪ Research starts with the prior body of knowledge through which hypotheses may be generated to test their truth or falsity.
Abductive approaches	▪ An alternation between inductive and deductive approach as may be required in the research cycle. This is often the case in even deeply interpretivist research.

Source: adapted from Wengraf (2001)

Interviewing and interview data analysis can be highly structured and systematic though with allowance for moments in the research process where analysis and interpretation are data-led rather than existing theory-led (Wengraf 2001). Furthermore, a method called theoretical re-description or abduction in which empirical data are re-described using theoretical concepts is relevant in this study. Abduction is the process of making inference through thought operation, wherein a particular phenomenon or event may be interpreted from a set of theoretical ideas or concepts. This raises the level of theoretical engagement beyond the thick description of the empirical entities (Fletcher 2017).

Wengraf (2001) also identified three possible objects of study for which information may be gathered through in-depth semi-structured interviews:

- Discourse – this is the manner of speech by the participant which can be analysed for identification of a deep structure beyond the surface underlying the face value interpretation of things spoken about by the participant(s) during the session. It may be argued further that since the interview interaction is a co-production process, the analysis of discourse may be influenced by many factors which may include the manner of questioning and interviewer characteristics;
- Objective referents – this refers to all objective information that may be garnered during the interview interaction by the researcher as facts, and;
- Subjectivities – in this instance, a researcher may be interested in asking questions to participants to elicit objective referents but merely as a means to eliciting their subjectivities which may lie in 'how' the participant talks

about the facts. Therefore, referents may be made of data that is not immediately evident or observable.

At different stages of data analysis, these approaches to making inference may be employed individually or combined to provide analytical insight into the data.

The next section thus presents the detailed choices covering philosophical worldviews, research strategies, and the specific methods of data collection and analysis for this study. It is an outline of the plans and procedure for conducting this research. This follows from the aim of this study which is to understand how construction professional service providers work practices coevolve with new technology (BIM).

4.4 Research design choices made for this study

4.4.1 Philosophical position

The research philosophy followed in this study is that understandings of BIM impact cannot be achieved without the involvement of the social actors. In this case, the social actors of interest are construction professional service providers directly involved in the delivery of projects in South Africa, and for which the research outcome may be useful. The intention is to enable a method of problem-solving that involves generating an understanding of structural patterns in work organisations. It supports investigating their roles, responsibilities and hierarchical relationships of individuals, which may change as a result of dysfunctions in the system.

This study was conducted in two stages. The first adopts an interpretivist epistemological position which sought understandings of meanings and in-depth sense-making of organisational and team level experiences of BIM implementation challenges and ultimately changes in patterns of professional work practices. The second is a more objective approach that sought to advance on the insight gained from the first stage. This was to objectively examine what changes in the pattern of collaborative work done by construction project teams as a result of adopting and implementing BIM. Furthermore, an abductive approach to research that supports the identification of themes within collected data and locating these in a conceptual framework was appropriate (Saunders *et al.* 2012). As required, deductive and inductive approaches were employed in the research process.

4.4.2 Research strategy

This study attempted both subjective and objective method of obtaining data or facts about processes, practices, and routines of professional workgroups. This is in part, suited to a realist ethnographic research strategy (Saunders *et al.* 2012). More so, interpretations of how members of the group carry out their activities were both subjectively and objectively studied. Nonetheless, data collection mainly involved one-to-one interviews and document analysis with reporting of results predominantly in the form of graphical conceptualisations and theoretical explanations of findings and abstractions of pre-BIM and BIM-enabled workflows. This is reminiscent of a grounded theoretical and phenomenological strategy. Yet, this study began with a preconception of theoretical explanations of the problem and therefore cannot fit into the mould of the classical version of the grounded theory method (Urquhart 2013). Neither does it conform to all the requirements for conducting phenomenological studies. It must also be made clear therefore that there is no intention of developing a new theory, but the intention is to provide theoretical explanations to the studied phenomenon. As the literature suggests, defining mutually exclusive paradigms may not be very effective (Atkinson 1988). Rather, it would be wise to draw eclectically (not following one system) from relevant paradigms to solve a practical problem (Atkinson 1988; Miles *et al.* 2014). This study, therefore, employs elements of both ethnography and phenomenological research strategies.

4.5 Research methods

Most studies that have addressed closely related research problems have been largely qualitative in design. For example, Gu and London (2010) in their work on understanding and facilitating BIM adoption within changing work practices, carried out a grounded theory research for which the method of data collection was focus group interviews. In fact, most of the related literature employed the interview method for data collection. As in *Table 4.2*, some of the studies were desk research studies, with data collection mainly by literature review (Bryde et al. 2013; Ding et al. 2015; Jung and Joo 2011; Sebastian 2011; Succar et al. 2012) and case studies (Hartmann *et al.* 2012; Linderoth 2010; Porwal and Hewage 2013; Taylor and Bernstein 2009). However, the specific research design choices for this study are made to suit the research problem being addressed while also being consistent with the theoretical choice made for the study, workflow redesign methodology and the DSMMDM method. These choices are similar in part to the works of Rekola *et al.* (2010) and Gu and London (2010).

Table 4.2: Research strategies employed in studies of similar nature

AUTHOR(S)	PROBLEM/RESEARCH ISSUE	CONTEXT	METHODS
Kaner et al. (2008)	Case studies of BIM adoption for pre-cast concrete design by mid-sized structural engineering firms	Canada/Israel	Case studies
Taylor and Bernstein (2009)	The need to focus on the interoperability of business practices to complement technological interoperability.	Global (non-specific)	Grounded theoretical research, Case studies, interviews, direct observations and documents.
Gu and London (2010)	Understanding and Facilitating BIM Adoption within changing existing work practices.	Australia	Grounded theoretical research. Focus Group Interviews
Linderoth (2010)	BIM's transformative potential is pronounced in research and practice. However, it is late in being actualised. This is linked to users' roles, relationships and competencies.	Sweden	Case study. Semi-structured interviews, participant observation, documents.
Jung and Joo (2011)	The limited efforts in defining BIM related concepts as a framework for theory and implementation	Asia	Desk research involving extensive literature review.
Olatunji (2011)	The limited focus on how BIM may affect existing construction industry business models, organisation structures and delivery patterns is the focus of this study.	Australia	Focus Group Interviews
Sebastian (2011)	The gap in practical knowledge on how to manage collaboration of project stakeholders within their changing roles in BIM implementation.	The Netherlands	Desk research drawing from real-life case studies
Barlish and Sullivan (2012)	The varied and partial nature of BIM frameworks and cases presented in literature makes establishing its effectiveness a challenge	The USA	Case study. Desk research through extensive literature review.
Hartmann *et al.* (2012)	The paucity of empirical studies that explain how different BIM tool implementation strategies work in practice is the motivation for this work.	The Netherlands	Case study (participatory) research

AUTHOR(S)	PROBLEM/RESEARCH ISSUE	CONTEXT	METHODS
Porwal and Hewage (2013)	The low BIM adoption in the Canadian construction industry is investigated against its requirement of changes in existing work practices	Canada	Desk research by literature review and case study.
Poirier et al. (2015)	Investigated BIM adoption and implementation of a speciality contracting SME	Canada	Case study using interviews, observations

This section presents a summary of the specific methods that were employed in conducting the study to achieve the set objectives.

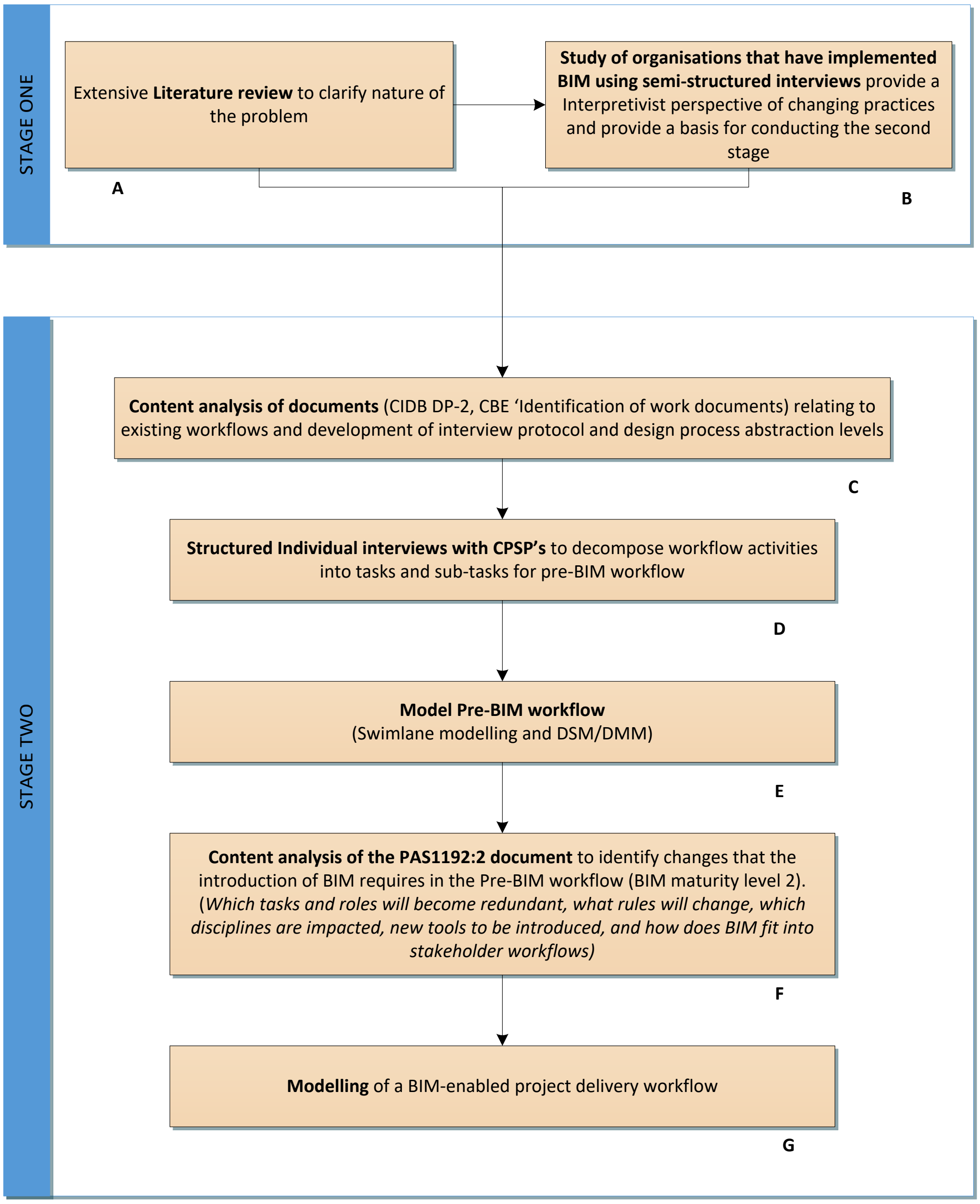


Figure 4.2: Research Concept Framework (RCF)

These decisions can be directly related to each box in the Research Concept Framework (RCF) in *Figure 4.2.*

4.6 Details of research methods used – based on the structure presented in the RCF

4.6.1 Literature review (Box A in the RCF)

An extensive literature review was conducted until the later stages of this study. This was to explore the subject area, identify gaps and provide substantiation for the research problem. Literature searches using carefully worded search terms were conducted mainly on referred journal and indexing websites. The articles were augmented by conference papers, books, and project reports. This provided insight into current BIM implementation challenges, relevant theoretical perspectives and process modelling methodologies. The content analysis of documents was assisted by computer supported by qualitative data analysis software (CAQDAS).

The articles were mainly from; Journal of Information Technology in Construction, Building Research and Information, Automation in construction, Advanced Engineering Informatics, Architecture Engineering and Design management, Building and Environment, Construction Innovation, Energy in Building, Engineering Construction and Architectural Management, Journal of Computing in Civil Engineering, Journal of Construction Engineering and Management, Business Process Management Journal, Information and Management and Journal of Manufacturing Technology Management.

4.6.2 Study of 8 cases of organisations that have implemented BIM using in-depth semi-structured interviews (Box B in the RCF)

The purpose of this was to study cases of organisations that have implemented BIM within and on multidisciplinary projects. Probing questions about their experiences on such projects as compared to non-BIM projects were asked as well as about how their organisations have been impacted since BIM was implemented. Particularly, the questioning focused on how they carried out their functions, dysfunctions experienced and specific changes they had to make in their work practices. Therefore the cases were structured to be evaluative. In this way, they were both exploratory and explanatory since the strategy was to examine change impact induced by implementing BIM.

4.6.2.1 Case selection method

The uptake of BIM in the South African construction industry as with other African countries has been slower than has been witnessed in Europe and America (Froise and Shakantu 2014; Harris 2016). The South African BIM Institute survey in 2016 revealed the *"industry's inherent traditionalism towards Building Information Modelling technologies, with many survey respondents preferring to follow trends rather than to take the lead. Many who have adopted a BIM technology strategy have done so in a silo approach"*; concluding that the local industry is a laggard regarding technology adoption and implementation (Harris 2016 p. 2). Therefore not many organisations were implementing BIM beyond the level of standalone applications for producing designs within their organisations. The approach to sampling was, therefore, a nested strategy which consisted of two levels of purposive sampling (Patton 2015 p. 305).

The nested sampling strategy is also supported by Yin (2014 p. 92). While cases of organisations may be the object of interest, data may be collected about them through individual interviews to examine how such organisations work and also how and why phenomena of interest are happening within the organisation (see *Figure 4.3*).

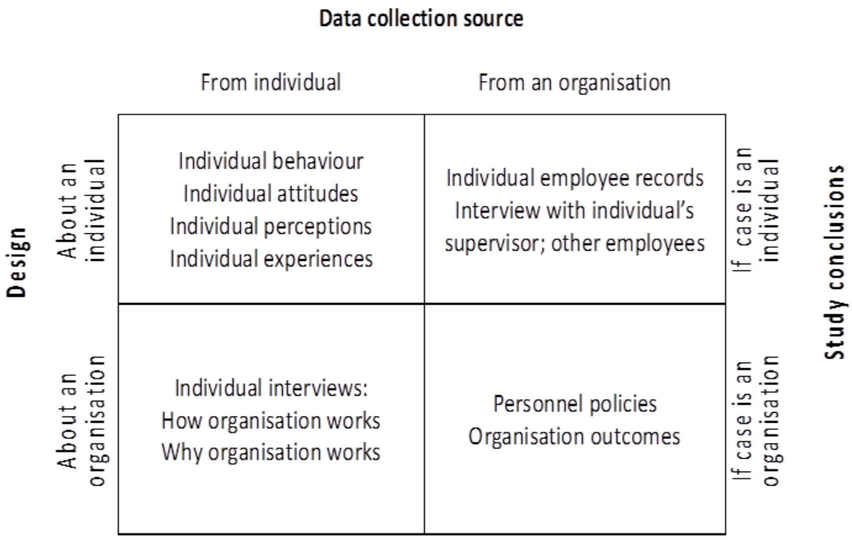


Figure 4.3: Design versus Data collection

Source: Adapted from Yin (2014)

First, comparison-focused case sampling (Patton 2015 p. 277) was done. Through this, eight purposively selected cases of professional construction organisations that have implemented BIM within and on multidisciplinary projects were studied. These included extreme deviant cases of relatively high success at implementing BIM and a notable failure at implementing BIM (Patton 2015; Wengraf 2001 p. 102). Five of these cases were multidisciplinary organisations (i.e. inclusive of Architects, Quantity surveyors, Services Engineers and Structural Engineers) and three were Architectural firms (the detailed profile of each case is provided in *Table 4.3*).

In determining the number of cases for a study like this, Patton (2015) affirms at the determination of a suitable number of cases depends on the purpose of the enquiry and availability of such cases. A further trade-off is also required between depth and breadth of data collected and its analysis (Patton 2015 p. 311). Furthermore, Patton (2015 p. 312) supports the idea that fewer than 4 cases are not enough while more than 10 cases may prove to be too much, citing several examples of field-defining studies that have employed such sample sizing.

4.6.2.2 Profile of organisations

As can be seen from *Table 4.3*, the participants represent mainly multidisciplinary and Architectural type organisations. Furthermore, the organisations' work scope covers a wide range of services as shown in the table above and most (7/8) are into multinational operations.

Table 4.3: Organisations' profile

CASE	ORGANISATION PRACTICE TYPE	ORGANISATION SIZE	SCOPE OF OPERATIONS	SCOPE OF SERVICES
ORG1	Multidisciplinary firm	Medium (400+)	Multi-national	Commercial Residential, Education, Healthcare, Industrial, Leisure & Hospitality, Oil & Gas, Power, Transportation, Water etc.
ORG2	Multidisciplinary firm	Medium	Multi-national	Energy & Environment, Industrial, Property, Transport & Infrastructure
ORG3	Architectural	Small (90+)	Multi-national	Commercial Residential, Education, Healthcare, Industrial, Leisure & Hospitality etc.
ORG4	Multidisciplinary firm	Medium (900+)	Multi-national	Transport, Aviation, Planning, Water, Environmental, Mining, Industry & Energy, Properties, Programme Management & Asset Management
ORG5	Architectural	Small (90+)	Multi-national	Commercial Residential, Hospitality & Leisure, Planning, Interior designs, Education etc.
ORG6	Multidisciplinary firm	Small (45-50)	Multi-national (presently local projects only)	A range of turnkey solutions including Commercial Residential, etc.
ORG7	Architectural	Small (~50)	Local	Commercial Residential, Education, Healthcare, Industrial, Leisure & Hospitality etc.
ORG8	Multidisciplinary	Small (< 90)	Multi-national	Technology consulting for the building, manufacturing, Infrastructure and process industries

Second, key informant sampling was done (Marshall 1996; Patton 2015 p. 284; Tremblay 1957; Wengraf 2001). Within the cases of organisations, participants (BIM Champions) were selected based on personal skill, position within the organisation, knowledge about the subject of interest and possession of a wide range of views. The specific recruitment criteria were that the participant:

- Is knowledgeable and responsible for maintaining and developing BIM implementation within the organisation. Therefore is sufficiently experienced to provide in-depth accounts of various aspects of such implementations (otherwise called BIM champions);
- Has participated in a construction project where the project team implemented BIM; and
- Is a construction professional.

The detailed profile of the key informants can be seen in *Table 4.4*.

Table 4.4: Profile of Key Informants

CASES (ORG)	BIM CHAMPION (INFORMANT)	PROFILE
OGR1	***C2 -*** ***TITLE WITHIN ORGANISATION:*** *ARCHITECT & BIM COORDINATOR*	The participant is a professional architect that was employed about three years ago with BIM expertise as a key criterion. Since joining the organisation, the participant has, in conjunction with colleagues, helped in formalising BIM adoption companywide. (It is a multidisciplinary organisation with multinational operations and the parent company in a Western country.)
ORG2	***C3 -*** ***TITLE WITHIN ORGANISATION:*** *CIVIL/ STRUCTURAL ENGINEER, VDC/BIM COORDINATOR, & DIRECTOR*	The participant is a regional director within the organisation (a multidisciplinary organisation with a multinational scope of operations and the parent company in a developed country), with responsibility and experience in facilitating Virtual Design and Construction (VDC) sessions and BIM within the organisation. The organisation has taken on a decidedly formal approach to BIM implementation by borrowing from exemplary implementation cases in company branches in countries like the UK.

CASES (ORG)	BIM CHAMPION (INFORMANT)	PROFILE
ORG3	***C11 –*** ***TITLE WITHIN ORGANISATION:*** *ARCHITECT & BIM COORDINATOR*	The participant has had experience in using BIM authoring tools for about 12 years, while the organisation (an architectural organisation with a multinational scope of operations) has been using BIM authoring software for about a decade as one of the early adopters in the country. BIM experience was one of the key criteria for which the participant was employed. Further, ***C11*** has been at the forefront of developing a formal companywide approach to BIM implementation within the organisation with the express support of top management.
ORG 4	***C4 –*** ***TITLE WITHIN ORGANISATION:*** *ARCHITECT, PROJECT MANAGER, & VDC/BIM COORDINATOR*	The participant is responsible for facilitating both BIM and VDC (virtual design and construction) coordination within the organisation (multidisciplinary and multinational scope of operations) and on multi-organisational projects. The participant, therefore, provided valuable insight and broad perspectives about implementing BIM.
	C7 – ***TITLE WITHIN ORGANISATION:*** *BIM MANAGER & ARCHITECT*	***C7*** was employed specifically to facilitate implementation of BIM by the organisation countrywide (a multidisciplinary organisation with a multinational scope of operations and providing mainly engineering services) to match the global drive of the organisation to make BIM a key strategy for delivering on clients' demands using their international branches as exemplars.
ORG 5	***C1 –*** ***TITLE WITHIN ORGANISATION:*** *BIM MANAGER*	The participant was employed about five years ago by the organisation (an architectural organisation with multinational operations), in a dedicated role to manage the day-to-day development of BIM and BIM content within the organisation, while also helping to keep the organisation abreast of BIM development internationally.
	C9 – ***TITLE WITHIN ORGANISATION:*** *ARCHITECT & DIRECTOR*	***C9*** is a professional architect and director of the organisation (an architectural organisation with a multinational scope of operations). Having been using BIM authoring software for about eight years, the participant gained considerably high experience which enabled broad views, often from a managerial perspective.
ORG6	***C10 –*** ***TITLE WITHIN ORGANISATION:*** *CIVIL/STRUCTURAL ENGINEER & DIRECTOR*	***C10*** is a director with Civil/Structural Engineering qualifications. The organisation (a multidisciplinary organisation with a multinational scope of operations) had decided on implementing BIM as a formal strategy for delivering on projects about two and a half years before the interview. However, due to severe difficulties encountered, it decided to return to using CAD tools by January 2016 (see also ***C5***).
	C5 – ***TITLE WITHIN ORGANISATION:*** *ARCHITECT*	This participant, although knowledgeable about issues around BIM and its implementation has been a user, joined the organisation (multidisciplinary and multinational scope of operations) shortly before they decided to discontinue BIM use by January 2016 (by January 2016 the organisation had gone back to using CAD for all projects).

CASES (ORG)	BIM CHAMPION (INFORMANT)	PROFILE
ORG7	***C8 –*** ***TITLE WITHIN ORGANISATION:*** *ARCHITECT*	***C8*** is a professional architect at an architectural organisation with only local operations. However, the organisation had decided to take the BIM route to delivering projects fairly recently. Being a relatively small-sized organisation compared to the rest, it hadn't taken any formal approach to adopting BIM.
ORG8	***C6 –*** ***TITLE WITHIN ORGANISATION:*** *BIM MANAGER & ARCHITECT*	***C6*** was a Senior Architectural Technologist who also had extensive experience working for a BIM consulting firm in South Africa, from where experience was gained in setting up BIM within organisations and also coordinating BIM on multidisciplinary and multi-organisational projects. The participant had only recently joined the current organisation (architectural) to help facilitate on-the-job skills development around BIM and development of uniform organisational process and design templates. For these reasons, the participant provided very enlightening and unique perspectives.

Furthermore, key informant interviewing was advantageous in providing in-depth and wide-ranging information about BIM implementation experiences, from an organisational and project team level perspectives. Audio recordings were taken during the interview sessions to ensure all information was captured and after that transcribed verbatim, while handwritten notes and preliminary reflections from the interviews were summarised into analytic memos, one per interview (Miles *et al.* 2014).

The questioning was framed to elicit participants' thoughts, based entirely on their experiences of implementing BIM rather than just perceptions. It was also designed to elicit mainly experiences, although behaviour, knowledge, feelings and opinions were also of interest. The questioning thereby sought to make the participants reflect on past events to explain and also compare them to current happenings for the assessment of BIM change impact on professional work patterns.

4.6.2.3 Data analysis procedure

Every step taken in conducting qualitative research is analytical to some degree (Kvale 2008; Wengraf 2001). Nevertheless, this section highlights key methods for qualitative data analysis and proceeds to describe specific analytical steps taken by the researcher. The analytical methods are applied as necessary following advice from Creswell (2013), Miles *et al.* (2014) and Wengraf (2001).

Data for this stage of the study were collected in two stages as in *Figure 4.4* and *Figure 4.5*; first, three in-depth interviews were conducted after each of which initial field notes were written immediately to ensure initial field reflection were fresh and clear through the analytical process. Data collected were analysed using thematic content analysis combining conceptually ordered matrix table displays with participants' verbatim responses where necessary to provide support for arguments being made.

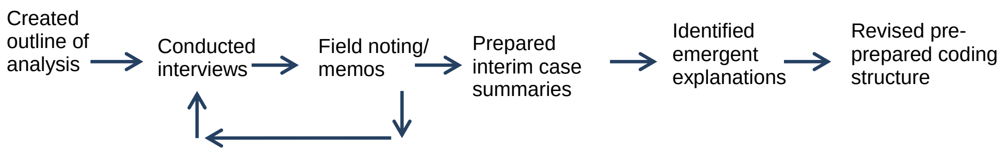


Figure 4.4: Procedure for the first stage of data collection and analysis

Next, interim case summaries were prepared to examine the quality of data collected, also identify areas of interest to pursue in-depth (Miles *et al.* 2014). After these, the pre-prepared coding structure was revised to cater for field data realities (Miles *et al.* 2014).

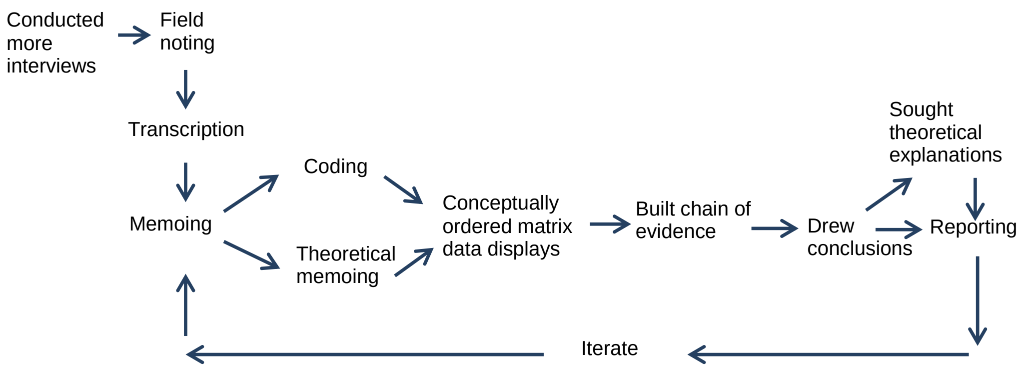


Figure 4.5: Procedure for the second stage of data collection and analysis

The second stage of the data collection and analysis continued with further in-depth interviews. Field notes were also written immediately after the interviews as in the first stage of the study. Next, transcripts were prepared. This was followed by memoing and coding in both basic analytical and theoretical forms while also repeatedly reading the transcripts. All the coding was done systematically using qualitative data analysis software. Further, conceptually ordered matrix displays of the data within and across cases were produced. Chains of evidence (Urquhart 2013) either of connections between variables of interest or explanation of phenomena of interest were constructed based on the data after which reports were written. The entire analytical process was iterative as depicted in *Figure 4.5*. It is important also to note that the results have been presented in matrix table displays to allow for a case by case understanding of the data as well as cross-case analysis of the data collected (Miles et al. 2014).

4.6.2.4 Other practical elements of the data analysis

Patton's (2015) twelve foundational steps for data analysis, which coincides with guidance from Miles *et al.* (2014) was followed as much as was practicable. The guidance enabled the following:

- Starting analysis during fieldwork enabled the constant comparison of new data to already collected data. First, this made it possible to effect minor corrections in the interview questions. Second, this step made it possible to begin the writing of analytical memos early on. It also aided the determination of the stage at which no significant new information was being collected;
- Inventory and data organisation was necessary to keep track of information collected and labelled accordingly for each participant;
- Minor gaps in the data collected were filled shortly after the first three interviews were conducted. Memos written immediately after the interviews kept information fresh in the mind for that purpose;
- From the start of data collection, a decision was made early to use computer-aided qualitative data analysis software (CAQDAS);
- As analysis progressed, records of momentary insights, theoretical reflections and the like were kept in memos/research journals; and
- It was important to maintain both a reflexive and reflective mindset to keep track of ensuing predispositions, biases and constraints that may affect the outcome of the process either from the researcher's or participant's standpoint.

4.6.2.5 Validity

Validation was achieved by triangulation of data collected at this stage with other stages and clarification of bias, among other things (See *Table 4.7*). Furthermore, the steps involved in qualitative data analysis also confirm the credibility of data collected (Creswell 2013).

4.6.2.6 Trustworthiness and Transferability

Reliability of qualitative interview research method is not normally intended (Saunders, Lewis and Thornhill 2012). To the extent that this method allows issues of considerable complexity to be studied in detail and depth, it is not realistic to pursue repeatability without undermining its strength (Saunders *et al.* 2012). Furthermore, Creswell (2013) asserts that in studies of this nature, rather than attempt to generalise findings over a population, it is more appropriate to generalise to theory. Saunders *et al.* (2012) affirm that generalisability in this type of research designs has to do with significance to theoretical propositions and locating the findings in existing theory. This position is supported by Patton (2015) and Fletcher (2017).

4.6.3 Content analysis of existing delivery guidelines from the CIDB, and CBE (Box C in RCF)

To establish the existing structure of the project delivery workflow (pre-BIM), the Delivery Management Guidelines for project delivery in South Africa (for Design by Employer framework) DP-2 was obtained for analysis. This document originates from the CIDB in partnership with the National Treasury. Four other delivery frameworks are available to choose from, namely the Project Management Method for Packages with no Design Input, Management Contracting Strategy, Design and Construct Package and Develop and Construct Package. However, the Design by Employer framework was adopted in this study for the following reasons:

- The mandatory use of the traditional method of delivery (Design by Employer) by legislation for public infrastructure projects in South Africa;

- The design-bid-build framework would also offer the most opportunities for understanding how work practices change when BIM is implemented; and
- There is a need to define a point of reference from which the change impact of BIM may be assessed

Secondly, the documents that specify how the roles of professional service providers are identified and demarcated 'Identification of Work' by the Council for Built Environment were also analysed. This is complementary to the CIDB delivery framework. The activities and roles identified there are at a high level of abstraction. Therefore there was a need to define an appropriate level of abstraction to which they may be reasonably decomposed. The framework used for capturing information and decomposition has been described in *Figure 3.8.*

4.6.4 One-to-one interviews followed by pre-BIM swimlane and MDM workflow modelling (Boxes D & E in the RCF)

Leading on from the last step, the purpose of this was to elicit tasks performed by professional services providers on a typical construction project being executed under the Design by Employer delivery framework. That is, their intra- and inter-organisational workflows at a decomposed level. This included information about interrelationships, dependencies and input/output of information within the workflow. This helped to develop the existing (as-is) workflow (for the design-bid-build framework). First, this was done to decompose the tasks to a low level of abstraction and to identify how the tasks performed by each team members fit with each other. Thus, this information was gathered using one-to-one interviews with construction professionals. Since conversations are one of the best ways of obtaining systematic knowledge (Kvale 2008), conducting interviews was best suited for data collection at this stage. Other than that, it conforms to the best practices of workflow modelling.

4.6.4.1 Participant selection

The strategy at this stage was heterogeneous purposeful sampling. This choice is suitable for the following reasons:

- Data cannot be collected from the entire population of construction professionals service providers (consultants); and
- The focus of the interview session was clear, i.e. to establish the pre-BIM workflow for a known method of delivering projects.

This strategy focused on one particular group and enabled tacit knowledge about their work practices to be elicited. It was non-probability and as such deciding on a suitable sample size can be ambiguous (Saunders, Lewis and Thornhill 2012). Therefore, a sample consisting of at least one each of the professional service providers relevant to this study was selected. Therefore the sample included at least one Architect, Quantity Surveyor, Structural Engineer, and MEP Services Engineer providing design bid build services to clients through their organisations. The specific recruitment criteria are that they are:

- Construction professional service providers;
- Practicing in South Africa; and
- Comprise at least one each of these professionals – Architects, Project Managers, Quantity Surveyors, Mechanical Services Engineers, Electrical Services Engineers, and Structural Engineers

4.6.4.2 Data collection

Data collected were in the form of information flow, dependencies and interrelationships between and within professionals' tasks. Also, the roles taken by or assigned to each professional and the documents produced from each task were elicited. This involved structured knowledge eliciting interviews with the selected consultants as in *Table 4.5* and *Table 4.6.*

Table 4.5: Pre-BIM process knowledge elicitation stage (participants' profile)

PARTICIPANT	PROFILE	ORGANISATION TYPE
KP1	Project Manager & Director (Pr.CPM, MACPM)	Private consultancy
KP2	Project Manager & Director (Pr.CPM)	Private consultancy
KP3	Project Manager (Pr.CPM)	Private consultancy
KA1	Architect (Pr.Arch)	Private consultancy
KC1	Structural Engineer & Director (Pr.Engr)	Private consultancy
KM1	Services Engineer & Director (Pr.Engr)	Private consultancy
KQ1	Quantity Surveyor & Project manager (Pr.QS, PMAQS)	Private consultancy

Table 4.6: Knowledge elicitation statistics

	KP1	KP2	KP3	KA1	KC1	KM1	KQ1
Number of tasks identified by the respective South African councils for the profession	59	59	59	62	67	67	41
Number of steps into which the CBE tasks were decomposed using structured interviews	133	145	117	116	140	104	84
Number of steps included in the final model (Pre-BIM workflow)	74	74	74	40	32	34	27

4.6.4.3 Tacit knowledge elicitation methodological issues

- The intention was to capture information for the whole project process. However, it became clear that choosing a live project would defeat the purpose. Therefore, a methodological challenge was faced in that except a selected project was just concluded, it would be difficult to capture information on all project tasks; especially those that have not been carried out at the time of data collection.
- Furthermore, all the participants were asked to and gave their responses based on the conventional design-bid-build delivery process
- Going by the original design of the elicitation methodology, participants were to be selected from active building construction project teams. On reflection from the first couple of interviews, however, it was interesting to note that selecting participants from an already constituted project team brings about a particular type of bias. This is demonstrated in that acceptance of referrals by other subsequent contacts after the first depends on the pre-existing relationships between team members or within the team. A decision was therefore made to deemphasise the requirement for selecting participants from the same project team. To this end, only two of the participants were part of the same project team;
- There is an inherent difficulty in modelling cross-functional team workflow from individual accounts of tacitly held knowledge that are elicited in separate interviews. This challenge was addressed by using a quasi-simulation methodology through which elicited information is modelled by drawing from accounts of different project team members as

would be required during the stage of delivery or sub-process being modelled;

- In certain interview cases, participants would once in a while go beyond the delivery task in focus for decomposition and therefore begin to provide information that should have fallen with other tasks. Whenever this happens, the participant is either subtly brought back to focus or allowed to complete their thoughts and narrative;

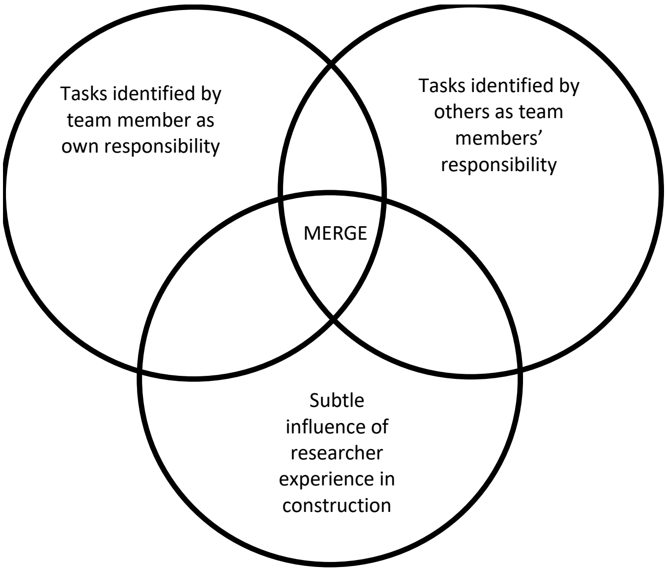


Figure 4.6: Processing methodology for elicited knowledge

- Eliciting the required information was time-consuming. The interviews were originally planned to last between 60 – 90 minutes, however, the limit was exceeded on a couple of occasions. It was, therefore, essential to recruit committed participants;
- It became clear early on from the first interview conducted that it would require more than planned 90 minutes to elicit all the information sought fully. It was, therefore, necessary to focus on decomposition of tasks into sub-tasks rather than to also capture interfaces separately;
- Not all decomposed steps from tasks could be modelled. This is because:
  - At a relatively high level of granularity, the delivery process is fluid and scenario specific. Therefore certain elicited steps could not be modelled along with others on the same level.

    - Managerial functions are typically non-specific and may apply to many different project scenarios or stages. Therefore they cannot be realistically modelled as part of the process.
    - Some elicited tasks were duplications over multiple accounts given by participants. In such cases, a decision is taken to assign the responsibility to the professional who is traditionally known to carry out the function;
- Documents/information identified and modelled as being products of project tasks also all that may be produced in the course of executing building construction projects, but that may or may not require being turned over to the client.

These practical issues shaped the data collection and modelling process and therefore should be taken into consideration when interpreting the following swimlane and MDM models as presented.

4.6.5 Content analysis of documents (Box F of the RCF)

The purpose of this step was first, to carry out a content analysis of the UK PAS1192:2 2013 specification for the delivery of capital projects at BIM maturity level 2. This was analysed to identify the likely impacts implementing BIM on pre-BIM project team work practices. The result of the analysis was presented in matrix tables. The structure of the content analysis included the identification of changes in:

Process

- Structural sequence & dependence in tasks
- Structural composition of tasks
- Redundancy of existing tasks
- Changes in time taken for tasks

People –

- Requirement for new, change in, or expansion of roles and responsibilities
- Change in frequency of interaction with others

Documents/Information –

- Redundancy of existing documents/information
- Requirement for new document(s)/information
- Requirement for change in structure of existing document(s)/Information
- Requirement for change in format of document(s)/information

The UK PAS PAS1192:2 2013 specification for the delivery of capital projects was chosen because it was developed through fairly rigorous processes involving the UK government and industry professionals and as such, it has become one of the notable exemplars of BIM implementation across the world. The CIC BIM protocol (2013) was also analysed to incorporate BIM-enabled project requirements and demands.

4.6.6 Modelling swimlane and MDM representations of BIM-enabled project workflow (Box G of the RCF)

This stage was intended first to juxtapose what has been identified as the pre-BIM way of working (based on the design-bid-build framework) over findings drawn from the first stage (cases of organisations' implementation experiences) of the research in which the researcher engaged with BIM users in the South African context. Second, identified change impacts from the content analysis carried out on the PAS1192:2 2013 and CIC BIM protocol as exemplars of BIM maturity level 2 way of working were aligned to the pre-BIM workflows.

4.6.6.1 Data analysis

Collected data were analysed in swimlane and DSM/MDM representations of the delivery process. This analysis was assisted by LOOMEO complexity modelling and analysis software.

4.7 Standards of research quality

The burden of every research that seeks to be impactful is the demonstration of quality in the process and output. Standards of research quality for qualitative and quantitative research aim to establish more or less the same thing even though the measures are mostly not the same. Typically, research work is evaluated for quality based on two key criteria, validity and reliability. Therefore, it is common for qualitative research quality evaluation criteria are expressed regarding quantitative research evaluation criteria (see *Table 4.7*) (Creswell 2013). The typically quantitative research criteria of validity and reliability are expressed as credibility, transferability, authenticity, criticality *et al.* for qualitative research (Creswell 2013).

Table 4.7: Arguments for the quality of this research's findings

MEASURES OF QUALITY	ARGUMENTS MADE FOR THIS STUDY
Prolonged engagement in the field	This study was conducted in two phases involving more than one year of data collection put together. This enabled a constant comparison of data currently being collected to already collected data. Further, it allowed time for researcher reflexivity and reflections on data collected
Triangulation using multiple sources of data collection and investigators	The study was preceded by a smaller pilot study to the first stage. This involved data collection by honours level research students. Although the study was of a limited scope compared to that reported in this study, the results are to a large extent comparable to this study's findings in part (Stage one). Further, the results of the pilot were reported in a peer-reviewed conference paper (Akintola *et al.* 2016).
Peer review	Parts of this study have been put through peer-review successfully for three conferences and one journal publication (in Journal of Construction Engineering and Management (ASCE)).
Clarification of researcher bias	The researcher has had more than four years training and practical experience in the construction industry. Further, the researcher holds a graduate degree in construction management. These, without doubt, have played important roles in the selection of the research area.
Rich and thick descriptions of data/findings	This study employs data matrix displays as well as verbatim quotes where necessary. The method follows the recommendations of Miles *et al.* (2014). In parts of the study where the method of analysis tended to be inductive, efforts were also made to ground the explanations in existing theory.
Does the study contribute to 'our' understanding of important questions?	This study contributes theoretical and practical knowledge to the understanding of how new technology (BIM) drives evolutionary changes in professional work activities in the construction industry.
Did research questions drive data collection?	The research questions were founded on established theory. Therefore the conceptualisation of the research questions and methods are grounded in the theory that also drove data collection and sense-making (for example see *Chapter three – adapted Engestrom's cycle of expansive learning*).
To what extent are the data collection and analysis competently applied in a practical sense?	The data collection and analysis followed to key methodologies put forward by Wengraf (2001) and Miles *et al.* (2014). The process, as was applied in the field is explained concisely above diagrammatically. This was important since the procedure followed in collecting and analysing data for qualitative research often helps to form an opinion of research quality.
Is the study valuable in informing and improving practice?	This study, beyond mere academic research contributions, may be useful to construction industry professionals as indicative of the impacts of implementing BIM on their work practices as organisations and as project teams.

MEASURES OF QUALITY	ARGUMENTS MADE FOR THIS STUDY
Did the researcher influence the content of the participants' descriptions in such a way that the accounts do not truly reflect their actual experiences?	This is important. Before the start of data collection, the researcher took classes in qualitative research interviewing while also supplementing that with texts. Particularly Wengraf (2001) which provides in-depth guidance on conducting semi-structured interviews. Efforts were made not to ask leading questions during the interview while much time was spent listening rather than talking. Furthermore, the balance of power between interviewer and interviewee was recognised and well managed to ensure quality data was collected.
Is the transcription accurate and does it convey the meaning of the oral presentation in the interview?	Verbatim transcripts were produced personally through repeated listening to the audio recordings of the semi-structured interviews.
In the analysis of the transcriptions, were there conclusions other than those offered by the researcher that could have been derived? Has the researcher identified these alternatives?	Alternative interpretations of data are possible for all types of data. However, care was taken to be reflective on the data to weigh alternative interpretations of data objectively. The analysis of negative evidence ensured that alternative arguments were embedded in the data collected and analysed.

Validation strategies based on Creswell's (2013) ideas

The foregoing argue the quality of this study mainly following Creswell's (2013) text on qualitative inquiry and research design. Since relevant strategies were drawn from eclectically for this study, the standards of quality argued in *Table 4.7* draws from the requirements these strategies, such as phenomenology and ethnography.

4.8 Ethical considerations

By its nature, qualitative research potentially exposes personal, sensitive and possibly confidential data (Urquhart 2013). Thus, it was pertinent that ethical issues relating to the maintenance of privacy and the protection of study participants be addressed. In particular, some ethical concerns that needed to be mitigated about the participant selection and data collection procedures were evident. These were as follows:

- The study targeted purposively selected key informant participants within organisations who possessed knowledge that is scarce in South Africa. Therefore there was a risk of attempting to pressure potential participants into participating and signing consent forms;
- Interviews were conducted within the premises of the interviewees' organisations which meant a risk of disrupting their work settings and schedules;

- Interviews are conversations characterised by power negotiations and imbalances;
- The potential disclosure of sensitive information (e.g. commercial); and
- Potential of reporting harmful information about the participants.

Specifically, Cone and Foster (2006) recommend an evaluation of the ethical acceptability of the research, assessment of the degree of risk involved for participants, obtaining clear, fair, informed and voluntary agreement by participants to participate and maintaining strict confidentiality of information about participants and study subjects. This study was carried out within these principles to minimise the risk of harm to participants.

Nonetheless, a key element of ethically conducted research is informed consent (Creswell 2013; Rovai *et al.* 2013; Saunders *et al.* 2012; Urquhart 2013). During this process, prospective participants were informed about the scope of their involvement in the research and obtaining an agreement to participate in the study. Following from the guidelines put forward by Cone and Foster (2006) and Creswell (2009), the informed consent form provided to the study participants for this work included:

- An identification of the researcher, institution, and method of selection of participants
- A description of the study and its purpose
- A guarantee of confidentiality
- A description of potential risks and benefits to the participant
- A statement of voluntary participation and the ability of the participant to withdraw at any time
- Names, email addresses and phone numbers of contact persons for further information.
- An explanation that the summary of results and findings will be made available on request

Importantly, since this study requires interviewing of participants in work settings, efforts were made to acknowledge and minimise the disruption of the physical setting and intrusion on the flow of activities. This is an important consideration.

All of these issues have been addressed as in *APPENDIX 3*. These include all research instruments, protocols, participant information sheets and consent forms. Lastly, an ethics clearance certificate was applied for and obtained from the University of the Witwatersrand research ethics committee for this study. The University of the Witwatersrand ethical clearance procedure required that an ethical clearance application was submitted to the university's research ethics committee, after which the committee sat, considered the application and clearance were given upon their satisfaction.

5 BIM IMPACT ON ORGANISATIONAL AND PROJECT TEAM WORK PRACTICES

5.1 BIM adoption properties of represented organisations

Organisations are adopting BIM in ways that largely mirror findings in existing literature (as in *Table 5.1*). This is in that the main motives driving BIM adoption both in organisations and by project teams are the expected benefits and advantages of the implementation (Cao *et al.* 2015). Some of the key motivators for adoption include BIM's potential to help in delivering on increasing client demands, the ability of the authoring tool to provide competitive visual representations for clients when bidding for jobs (sometimes this is combined with 3D printing technologies).

For most of the multi-national organisations with parent companies in western countries such as the UK and Netherlands, implementing BIM has for long been adopted through organisational-wide strategies for providing their services. Therefore theirs was a move towards measuring up to the standards set by their organisations internationally. Nevertheless, BIM is also regarded as a company value entity. For most of the organisations, adoption is also being led by the company leadership (7/8 of the cases). This is a strong indication that the top-down approach to implementation is the most favoured for adoption and implementation, in fact, both within organisations and on multidisciplinary multi-organisational projects where the client is said to ideally take responsibility for driving BIM implementation. According to ***informant C11***:

> *It has to be a top-down approach…Our directors, even though they are not BIM users, (they) have a lot of foresight, and that's also why I think **ORG 3** as a company has grown so quickly and so successfully. They (directors) can see forward into the future, they are not scared of that, in fact, we always... in everything that we do, whether it's our design or building technologies we are always looking forward from project to project. So it has to be a top-down approach. If you do not have that top-down*

(approach), it is costly to implement, and it takes time for people to get efficient. - ***C11***.

Table 5.1: Adoption properties of the organisations

CASE	ADOPTION YEAR	MOTIVES FOR ADOPTION	ADOPTION STRATEGY	SOFTWARE
ORG1	▪ About 2.5 years as a formalised organisational way of delivering projects	▪ The expected benefits and advantages ▪ Adopted as a company value ▪ It is a strategy and key method providing services ▪ Flows naturally from the Architectural practice to other disciplines	▪ Formalised adoption system within organisation ▪ BIM management position created in-house	▪ Revit Suite and associated software
ORG2	▪ About ten years as a formalised organisational way of delivering projects	▪ It is the group's (company's) culture to lead rather than follow ▪ Mandated by senior leadership as a pillar of group strategy for delivering projects, and it is being pushed and driven throughout the business ▪ It provides competitive advantage ▪ It is a means for reducing organisational costs	▪ Formalised adoption system within organisation ▪ BIM management position created in-house	▪ Bentley ▪ Revit Suite and associated software
ORG3	▪ About ten years as a formalised way of working within the organisation	▪ The expected benefits and advantages ▪ A way to streamline organisational processes to reduce team sizes, and deliver information more efficiently ▪ Driven by organisation's director's foresight & leadership ▪ It made commercial sense to the leadership to go the BIM route	▪ Formalised adoption system within organisation ▪ BIM management position created in-house	▪ Revit Suite and associated software
ORG4	▪ About 2.5 years as a formalised way of working within the organisation	▪ As a strategy and key method for providing services ▪ The expected benefits and advantages ▪ It is seen as capable of helping with the challenging construction market (competitiveness) ▪ Helps in meeting increasing client demands to push down on fees	▪ Formalised adoption system within organisation ▪ BIM management position created in-house	▪ Revit Suite and associated software
ORG5	▪ About eight years as a formalised way of working within the organisation	▪ Perceived to be the next level of development ▪ To provide better quality information on projects	▪ No formal organisation plan to implement ▪ No BIM management position created in-house	▪ Revit Suite and associated software

CASE	ADOPTION YEAR	MOTIVES FOR ADOPTION	ADOPTION STRATEGY	SOFTWARE
ORG6	▪ About 2.5 years as a formalised way of working within the organisation	▪ Expected benefits, particularly increased productivity	▪ No formal organisation plan to implement ▪ No BIM management position created in-house	▪ Revit Suite and associated software
ORG7	▪ About two years as a formalised way of working within the organisation	▪ The expected benefits and advantages	▪ No formal organisation plan to implement ▪ No BIM management position created in-house	▪ Revit Suite and associated software
ORG8	▪ Less than a year as a formal way of working within the organisation (Participant has had several years of experience before joining the organisation)	▪ Helps in meeting increasing client demands on for discounts ▪ Expected Benefits and advantages ▪ Response to the industry shift to BIM	▪ In the process of creating a formal adoption and implementation plan for the organisation ▪ No BIM management position created in-house	▪ Revit and associated software

It is also important to note that that considering the key leadership position architects often take on projects, adoption by other professions flows naturally from the Architectural practice to other disciplines. This is even more so as BIM authoring software developments in construction arose naturally from Architectural design solutions. ***ORG 6***, a multidisciplinary organisation has however discontinued implementing BIM after experiencing severe difficulties and frustrations in using the BIM authoring software to do work that previously seemed far simpler using CAD systems. This can be linked to user attitude to technological innovations, lack of sufficient technical support and lack of formal organisational structures to support the implementation despite spending hugely on the procurement of BIM authoring software as will be expounded on later in this chapter. It is also notable that half of the organisations represented by the participants had drawn up formal plans for implementing BIM within their organisations. As predominantly multinational organisations with parent companies in developed economies, they have benefitted greatly from influences from other company branches.

For instance, ***ORG 1*** and ***ORG 4***, while not having a formal organisation plan for BIM at the outset, took on a more formal approach later on as implementing BIM became a next level developmental strategy for the organisation. Coupled with that, a BIM manager was then employed to facilitate day to day development of the implementation within the organisation along with BIM content and standards development. Importantly, organisations who have adopted formal adoption and implementation strategies within their organisation appear to have implemented at a more advanced level than those who have not. The data also suggests that they have also achieved more successes at the multi-organisational project level.

As explained previously, the disposition of the participants varied from the optimistic to the pessimistic about BIM. In some way, judging from their narratives about how BIM has been adopted and implemented, a link may be drawn between their disposition, their experiences and coping mechanism. The challenges experienced by the informants are such as may be expected of the implementation of any new technology or innovating within an organisation. Key challenges being experienced in this regard are difficulties in training and skills development requirement for staff which is a common experience among all participants. Another prominent challenge is the high initial cost of BIM authoring software tools, hardware and software update, while there is also a general difficulty in transitioning from CAD to BIM. This is mainly because the change induced by BIM impacts on several organisational processes rules guiding their practice and also expands the responsibilities of the organisation's staff. Further, resistance to change is also prominent among the challenges to implementing BIM.

5.2 Characterisations of BIM by participants

Even though the main analytical thrust of this study was not to analyse discourse, it is essential to make sense of participants' descriptions of BIM and its implementation from their own point of view, and in their idiolect as in *Table 5.2*. Regardless of individual disposition towards BIM, virtually all the participants, from experience, characterised 'BIM' as some powerful tool. Even though it has been argued that BIM is a process rather than a tool, and rightly so, the process of developing construction components to simulate planning through to building operations (Azhar and Sketo 2008) is inextricable from the tool that facilitates it. BIM is first a system of tools before it becomes, or drives a process.

Table 5.2: Characterisations of 'BIM' and implementation experience

INFORMANT	BIM CHARACTERISATIONS
C1	▪ "BIM as an ideology" ▪ "massive beast of an idea"
C2	▪ "a very clear advantage" ▪ "a complex system" ▪ "a very exciting thing"
C3	▪ "a pillar of group strategy" ▪ "very important" ▪ a "paradigm shift" ▪ "as big a shift" ▪ "a mind prosthetic design aid" ▪ "a tool"

INFORMANT	BIM CHARACTERISATIONS
C4	▪ an "ideal tool" ▪ a core element of integrated design" ▪ "a whole paradigm shift" ▪ an intelligent system
C5	▪ "a way of standardising interactions" ▪ the "language we speak" ▪ "incredibly powerful tool"
C6	▪ "I'd equate it (the old way of working) to like a simple math equation ...whereas with your Revit, it's more of an algebraic expression…and different equations will apply for different disciplines " ▪ "complicated" ▪ "a formula 1 car"
C7	▪ a bunch of concepts
C8	▪ "it's quite complex" ▪ "powerful"
C9	▪ "it's a tool" ▪ "quite powerful"
C10	▪ n/a
C11	▪ "fish out of water" (Initial experience for large firms implementing BIM)

Further, there is a perception of BIM and its implementation as complex, and complicated. It is important to consider this in interpreting how professionals approach implementation issues including their experiences and disposition towards BIM. Nevertheless, a number of the participants had quite interesting ways to describe BIM. For instance, ***Informant C3*** describes BIM as "a mind prosthetic". This speaks to the capability of BIM tools to enhance designers' cognitive functions. That is, it considerably enables better expression of conceptions in the mind of a designer. In support, Kaptelinin and Nardi (2006) alluding to the seminal works of Leontiev posit that tools, among other aspects of culture, fundamentally impact on the mind of an actor and its development. Furthermore, that training to use a tool and the tool's form contribute to shaping the way humans relate to the world. This typifies the influence of BIM on CPSP work practices.

While ***Informant C6*** describes BIM as a "formula 1 car" when compared to designing in CAD, he also equated it to a quadratic equation in comparison to CAD which is likened to a simple math equation. On the other hand ***Informant C11*** describes the experience of implementing BIM at the initial stages as "fish out of water". This is indicative of an initial lack of understanding of the full implications of the implementation by construction professionals at the outset. This is one of the ways in which this study contributes to knowledge in context.

5.3 Concerns for BIM implementation development in the South African context

BIM implementation is evidently still in its budding stage of development in South Africa despite the fact that some CPSP organisations have been using BIM authoring software tools for about a decade and currently exclusively for all their projects. Nevertheless, when asked directly about their thoughts on the key concerns for BIM implementation in South Africa from their experiences, the participants' responses bordered on a range of pertinent issues that clearly highlight the peculiar nature of the South African construction industry context in relation to BIM implementation.

Table 5.3: General Concerns for BIM Implementation in the local South African industry

INFORMANT	CONCERNS
C2	▪ Lack of drive for BIM adoption in South Africa ▪ Doubts about the value of government mandating BIM use ▪ Scepticism about councils, or other government bodies' competence and capability to receive and assess such information as might be produced from a BIM project ▪ Doubts about the value of issuing intelligent models as submissions to council
C3	▪ Lack of drivers for BIM in the Africa region generally ▪ Scepticism about governments knowledge of BIM ▪ Need for supportive BIM legislation, and general guidance from government bodies ▪ Organisations will not change without client demand ▪ ◆Organisations will not change without knowledge of BIM potentials
C4	▪ Relatively low maturity of BIM implementation in the country ▪ Need for supportive BIM legislation, & general guidance from government bodies ▪ Need to use organisation's influence to promote BIM with clients

INFORMANT	CONCERNS
	▪ Need for the Public Works Department to buy-in and start developing their staff competencies ▪ Need for government to work towards legislating BIM use for all their projects ▪ Many organisations in South Africa are not using BIM
C11	▪ Scepticism about council's ability and skill to receive and assess electronic (BIM generated) information & submissions ▪ Uptake by government would require huge investments by them ▪ "What would motivate the government to buy-in into BIM?" ▪ There is a need for more integration of BIM implementations within and between teams in the industry ▪ Implementing BIM is difficult in South Africa and generally in the Africa region as its being driven solely by the private sector ▪ There is no demand from the authorities to implement BIM ▪ There are no incentives from government to implement BIM ▪ No government budget for driving BIM R&D ▪ Need for incentivising change and development towards adoption and implementation ▪ Small organisations lack the resources to drive the implementation ▪ High staff & organisational investment costs may prevent smaller organisations from adopting and implementing
C7	▪ The industry as a whole is yet to realise what BIM is ▪ Lack of exposure of government (and associated institutions) to BIM ▪ Lack of knowledge about BIM within government (and associated institutions) ▪ Need to rethink procurement methods ▪ Need for clients to begin driving BIM implementation ▪ Government bodies have not realised the value in implementing BIM ▪ Need for clients to start demanding BIM
C9	▪ Poor quality artisan workmanship on site hinders the potential gains from BIM (in the Africa region) ▪ Poor skills development in the country is a challenge ▪ Political & Economic issues around getting government to deal with skills development
C1	▪ Lack of local BIM standards ▪ Organisations in South Africa are forced to borrow from international standards and protocols

INFORMANT	CONCERNS
	▪ The changes being experienced through BIM outside the Africa region will make it difficult for sceptics to provide services in countries leading in BIM ▪ There is a definite need for guidance through the BIM process ▪ Proprietary materials/components manufacturers have no incentives to begin developing BIM content
C8	▪ BIM diffusion through the industry may be slow ▪ Need for incentivising adoption and implementation
C5	▪ None
C10	▪ BIM use ought to be project specific*

*=Coming from a sceptic

Several key issues of substantive significance were raised in the responses gathered. One important issue raised by virtually all the participants is the lack of local standards, specifications and protocols guiding BIM practice in the South African construction industry that could cater for the peculiarities of practice by project stakeholders in this context. This is also closely related to the lack of an influential driver for BIM either from the public or private sector clients. For the most part, BIM adoption and implementation is being driven by private consulting organisations that have found, and are largely motivated by potential and experienced benefits, first at an organisational level and after that extended to multi-organisational project settings. Valid arguments for either a public sector or private sector-led BIM initiative to promote widespread adoption and implementation within the construction industry are plausible. In the first instance, it is clear from the literature that government support and provision of necessary legislation are capable of speedily driving adoption and implementation of innovations. Such is the case of the UK BIM mandate for all public sector projects to be run at a BIM level 2 from April 2016 (Cabinet Office 2016).

Nevertheless, in the South African context, a stronger argument may be made for a complement of efforts from the public and private sector clients in driving BIM adoption and implementation. This deduction is drawn mainly from the premise that the South African Property Owners Association claim control of the largest portion of commercial and industrial real estate investment in the country (SAPOA (South African Property Owners Association) 2017). Therefore, an exclusively public sector client driven initiative may not be as effective as a joint effort might prove to be. Further, construction works clients are the main beneficiaries of BIM benefits even though the benefits do in fact cut across all stakeholders. Clients are also the project stakeholders with both motive and opportunity to influence the actions other project stakeholders. However, the findings highlight the scepticism of professionals about the ability of government clients and associated institutions like the councils to drive BIM adoption and implementation countrywide judging by their perceived lack of understanding and proficiency in BIM.

Other issues raised as concerns for BIM implementation in South Africa are the need for clients demand for BIM to facilitate CPSP organisations and contractors to shift to BIM, low level of usage of BIM among construction industry organisations, lack of clear motivation for government buy-in, a lack of understanding of BIM and its implications and the futility of implementing BIM if the quality of work done on site suffers as a result of incompetent workmanship by artisans. Importantly, the challenge for small sized organisations to make the shift to BIM considering the high cost of investment in BIM authoring software tools (BASTs) and human capital development through training was identified. This is a conundrum as there is evidence in the data to suggest that migrating to a BIM-based organisational strategy for delivering on projects is best done when an organisation is not quite large (***ORG3***).

5.4 Experiences of BIM implementation challenges within CPSP organisations

Table 5.4 presents a case-by-case summary of the challenges experienced by participants not verbatim, but in a form that is as close as necessary to how they were expressed in the participants' idiolect. Nevertheless, the challenges above in *Table 5.4* are not all peculiar to BIM. Therefore, only the key issues raised that are peculiar to BIM implementation and pivotal to this study were given careful consideration as discussed in further detail below.

5.4.1 Initial loss of productivity

When organisations first make the initial decision to implement BIM, the evidence collected suggest that they lack a holistic understanding of its immediate and long-term implications. A focus mainly on the expected benefits accruable from implementing BIM without careful appraisal of the key challenges involved as an organisation is counterproductive. There were, for instance, reports of an initial loss of productivity (Jensen and Jóhannesson 2013). This ensues from time spent learning new software while also trying to apply the knowledge, difficulties in getting presentations right, and reversion to CAD-based methods to fix perceived short-term problems with BIM modelling, among other issues. In fact, the need for an expert appraisal before implementation is evident from the overall findings.

For instance, within ***ORG6*** (representing an extreme negative case) there were experiences of severe frustration (which was an on-going event at the time of the data collection) inability to accomplish the most mundane of design activities with BIM authoring software tools. Some reasons might account for these experiences; and pessimistic disposition towards BIM, and the decision of the organisation to discontinue implementing BIM in the next few months. One of the key reasons is that despite deciding on the implementation at the management level at the outset, formal organisational strategy outlining standards and protocols were not set up to support the implementation and on the other hand, training and post-training support were evidently inadequate. For new adopters of BIM, therefore, experiences of initial loss of productivity while transitioning could hinder complete acceptance and continued implementation. Evidently, some of the major challenges for organisations are related to a lack of proficiency among staff, training, and post-training support issues.

To buttress this argument, a close examination of the data suggests that organisations have a difficult time transitioning from legacy methods of delivering organisational outcomes to BIM-driven methods. An important example may be made of ***ORG2*** that has, with help from the parent company (with branches in western countries), been able to achieve an advanced level of implementation within the organisation and on multi-organisational projects.

> *The whole BIM philosophy (requires) a broad range of components that have to fall into place for you to realise the true vision of BIM. So, the transition is difficult ... where we (have found) ourselves now (in an attempt) to extract value out of our models is to be populating (BIM) components with the correct attributes so that we can draw off those kinds of benefits that ... (are accruable) later on in the project lifecycle for example for facilities management. –* ***Informant C3***

This is also corroborated by ***Informant C6*** who has had considerable experience as an expert BIM consultant. ***Informant C6*** also reports that transitioning for ***ORG8*** is difficult (transition was ongoing) and as such, it has taken up more than two years to create organisational standards, protocols, templates and generic content libraries.

5.4.2 Need for changing organisational workflows

The findings indicate the need for changing organisational workflows as one of the major challenges associated with implementing BIM since it is driven by a significantly different work process from the norm. Most of the participants affirmed that BIM impacted on their organisations' workflows. Nevertheless, as can be seen from the verbatim evidence below, they found it difficult to articulate what they believe has changed in their workflows as a result of implementing BIM in sufficient detail. The following are responses to the question of what changes had taken place in their work practices and workflows.

> *I think for me the biggest change is ... in architecture, I see it ... we don't see (it) directly with the naked eye... we don't see an impact. (However) there is a massive impact. But it's not visible. I believe that BIM has had a massive impact in terms of contextual design and how these designs fit in with the environment. –* ***Informant C3 (ORG3)***

> *Yes...no, definitely there have been changes. Essentially, from the design (perspective) … we did a lot of the engineering (design) at the same time as the architectural design.* ***– Informant C2 (ORG1)***

> *Absolutely! From a production side, even the way we tackle our drawing standards…, how we do our naming conventions of our drawings... it's not completely unique because drawing standards are drawing standards, naming conventions are naming conventions, but there's definitely a twist in terms of how Revit does it because you've got all your drawings in one program and browser organisation, organising by stage. We've spent a lot of time creating our Revit template, so that really when people start a new project… it's already prompting you in terms of how you should be working…How you should be naming your drawings, how you should be, you know, issuing your drawings, that kind of stuff… it's become so second nature now in our office, but when I think about how it used to be, to what it is now, and how we've struggled... I think there's a lot or youngsters here in the company who just take a lot of that for granted because they've never had to work in any other kind of environment. So maybe they'll probably tell you no, nothing's changed, it is the way it's always been. But from where it was before to now, certainly yes. Absolutely, I mean I'd say the way our teams are structured, you know... you've got your central files so everyone's working in the same environment, working together in order to produce one building, of course, yeah, and again I think a lot of it just become the norm.* ***– Informant C11 (ORG3)***

The inability to clearly articulate changes in workflows in detail by some of the participants can be explained using activity theory as work routinisation whereby newly created work practices (actions) become the automatized or become automatic operations after some repetitions (Bardram 1998; Kaptelinin and Nardi 2006).

5.4.3 Professional fees management challenges

As a result of the need to change organisational work practices and workflows, organisations have to manage their finances differently to suit the unique demands of implementing BIM. The analysis suggests that BIM requires a considerable amount of effort to the early stages of a project delivery process. This shift in effort is at odds with the conventional fee payment structure which spreads out payment in a way that suits the conventional approach to delivery. For this reason, a case may be made for a review of the standard fee payment structure to suit the demands of executing BIM-enabled projects. The evidence collected suggests that organisations have a difficult time managing finances across BIM-enabled projects. ***Informant C8*** captures it succinctly thus:

> *But there is that pay scale… I agree with a lot of architects saying that the initial stage is really intense and quite a lot of hard work, but it doesn't really align with what you would be paid for.* ***– C8***

This result confirms the findings of Sebastian (2011) and is an important factor to consider for organisations in achieving their business objectives on BIM-enabled projects.

5.4.4 Approaches used in coping with BIM challenges

With experiences of myriad challenges, it is clear that achieving success with BIM within the organisations requires planned approaches to its management. Nevertheless, many of the key challenges being experienced by the organisations can either be linked directly or indirectly to the lack of unified local South African BIM standards, guidelines and protocols based on which organisations implementing BIM may fashion their business processes. This has demanded the creation of adaptive coping methods by the organisations in a drive towards BIM implementation success, first as an organisation, and as part of multi-organisational project teams. A number of the methods used in coping with BIM induced challenges are not particularly different from what may be employed when introducing any new technology or innovation into an organisation.

Therefore, the present discussion would highlight mainly, methods that are of unique significance or are peculiar to the BIM implementation case as in *Table 5.4*.

While some of the measures taken to address the identified challenges were of, on one part, a technical nature, others were non-technical in tandem with the type of challenges they were meant to address. To address challenges of a technical nature, the methods for coping included ensuring model completeness, adaptation of BIM authoring software to suit local standards, third-party application development (APIs) which also requires employing the services of in-house programmers, and breaking up large model files into manageable file sizes. However, some of the measures resorted to in alleviating challenges by some of the professionals are in fact counterproductive. An example of these is the occasional reversion to old CAD-based methods to fix immediate BIM modelling problems. These quick fixes may render work unusable later on in a multidisciplinary project environment, thereby, requiring much rework.

Successes have been achieved in addressing non-technical challenges by devising companywide plans for implementing, adopting a top-down approach to implementing BIM, implementing in stages, instituting a dedicated team within the organisation to manage the setting up process, and ensuring senior management understand the business benefits. Others are investing time into creating companywide standards and templates (to ensure uniformity of practice and ultimately technical and business process interoperability) and developing a relational approach to collaborating with other organisations to deal with intellectual property rights issues. Also significant is the suggestion that creation of in-house BIM roles in some cases, employment of expert consultant BIM managers, and tailoring financial/fees management (to suit changed work sequence) are important to the success of implementing BIM within organisations.

Table 5.4: Experiences of challenges from Implementing BIM and coping methods at the organisational level

CASE	DISPOSITION	CHALLENGES EXPERIENCED WITHIN ORGANISATION	COPING MECHANISMS
ORG5(Informant C1)	MODERATE	***ORGANISATIONAL LEVEL*** ▪ Difficulties with implementing BIM to its full potential ▪ Difficulty with grasping several BIM standards as against simpler CAD requirements ▪ The need to 'upskill' staff on BIM authoring software use ▪ BIM changes the way the industry works ▪ Completely different workflow makes several people 'get stuck' ▪ It takes a significant amount of time to transition to BIM ▪ Implementing without setting small targets could be frustrating ▪ Initial lack of understanding of the implications of implementing BIM on organisational business processes ▪ Some of the trainers are not construction industry professionals (also see ***C10***) ***INDIVIDUAL LEVEL*** ▪ Difficulties with mastering the software ▪ Initial difficulties with getting drawing presentation right ▪ Reversion to CAD to fix modelling problems	▪ Determination and resilience to continue regardless of challenges ▪ Devising a formal strategic plan for implementing BIM within the organisation ▪ Implementing BIM in stages
ORG1(Informant C2)	OPTIMIST	***ORGANISATIONAL LEVEL*** ▪ It is a slow rollout as people gradually discover the real potentials of BIM ▪ Difficulties in setting the organisational BIM workflows up ▪ Getting senior management to understand the potentials of BIM ▪ Challenges relating to training staff ▪ Management of BIM expectations within the organisation ***INDIVIDUAL LEVEL*** ▪ It requires a change in mindset about the approach to design ▪ Lack of awareness of individual benefits	▪ Investment in skills development ▪ Promoting awareness of benefits ▪ Instituting a dedicated team to manage the setting up of processes and procedures ▪ Ensuring that the buy-in of the organisation’s management is obtained ▪ Ensuring senior management understand the benefits accruable from implementing BIM ▪ Having a full understanding of the value of the BIM system

CASE	DISPOSITION	CHALLENGES EXPERIENCED WITHIN ORGANISATION	COPING MECHANISMS
ORG2(Informant C3)	OPTIMIST	***ORGANISATIONAL LEVEL*** ▪ There is a broad range of requirements needed to fall into place to realise the true potentials of BIM ▪ Transitioning to BIM from CAD-based methods is difficult ▪ Realisation of true potentials require putting significant effort into model completeness and correctness (Extending to O&M) ▪ Need to develop local standards for implementing BIM ▪ Lack of guidance for implementation in the Africa region ▪ No drivers for implementation in the industry ▪ Clients are not demanding BIM on projects ▪ Resistance to change within the organisation ▪ Existing organisational processes need to be discarded and replaced with a new workflow ▪ Problems with localising the authoring software ▪ Resistance to changing legacy methods of delivering projects especially with experienced staff ▪ Standard output from BIM does not conform to local industry standards and thus needs to be adapted ▪ The BIM authoring software are still evolving and thus have some deficiencies ▪ BIM authoring software are not being developed as fast as desired ▪ Need for change in IT systems within the organisation ***INDIVIDUAL LEVEL*** ▪ *None mentioned*	▪ Ensuring model completeness ▪ Adapting the software to suit local standards' requirements ▪ Third party application development (application interface development) ▪ Employing programmers in-house ▪ Training and skills development ▪ Effective communication of new processes and procedures to staff ▪ Mentorship programs within the organisation ▪ Creation of knowledge sharing groups within and between different organisation's branches
ORG4 (Informant C4)	OPTIMIST	***ORGANISATIONAL LEVEL*** ▪ Transitioning to BIM is difficult in a large organisation with people stuck with their old methods ▪ People within the organisation often fall back to old methods when in a hurry	▪ Managing the level of design detailing in accordance with fees being received across projects ▪ Knowledge sharing countywide (to all branches) through presentations by the BIM manager ▪ Creation of the BIM manager role

CASE	DISPOSITION	CHALLENGES EXPERIENCED WITHIN ORGANISATION	COPING MECHANISMS
		▪ It requires internal education and training programmes ▪ Current remuneration structure does not allow for infinite detailing ▪ It requires creating awareness within organisation ***INDIVIDUAL LEVEL*** ▪ *None mentioned*	▪ Ensuring hardware and software components of the implementation are the right specification ▪ Training and skills development ▪ Knowledge sharing with colleagues in advanced countries
ORG6 (Informant C5)	CRITICAL	***ORGANISATIONAL LEVEL*** ▪ Implementation is very cumbersome to manage ▪ Experiences of downtimes & loss of productivity when first transitioning to BIM ▪ Requires rethinking established organisation processes & procedures ▪ High costs of authoring software are a stumbling block ▪ The shifting of some design effort to the initial stages is not consistent with the current fee structure ▪ It is unclear if the responsibility for training lies with the tertiary institutions or with professional practices ▪ BIM may affect the methods of practice of certain industry practices in years to come ▪ Several people have taken an approach to adopt and implement by feel and instinct rather than by formal guidelines ▪ It is difficult to employ capable staff with high staff turnover in the industry ▪ It is difficult to employ highly skilled staff and immediately get them involved in organisation processes and procedures ▪ BIM training for staff was probably inadequate ▪ It was difficult to manage the output and documentation from BIM authoring software at the outset ***INDIVIDUAL LEVEL*** ▪ It constrains intuitive design freedom ▪ BIM model-authoring is time-consuming at the outset	

CASE	DISPOSITION	CHALLENGES EXPERIENCED WITHIN ORGANISATION	COPING MECHANISMS
		▪ It forces one to make certain design decisions earlier unlike the conventional way of design development	
ORG8 (Informant C6)	OPTIMIST	***ORGANISATIONAL LEVEL*** ▪ Setting up organisational templates, standards and protocols takes a long time (up to 2 years) ▪ Downtimes & loss of productivity were experienced when first transitioning to BIM ▪ Difficulty in re-hiring when trained staff leave the organisation ▪ High BIM authoring software costs ▪ Trade-off between employing trained staff and training existing staff needs to be made ▪ Loss of staff acquired BIM knowledge in the absence of projects to apply them ▪ It is difficult to quickly get staff up to the required skill levels to meet specific organisation outcomes ▪ Trained employees are not guaranteed to remain with the organisation ▪ Organisations have to invest hugely in training & equipping employees ***INDIVIDUAL LEVEL*** ▪ Experiences of initial struggles working with BIM ▪ Trade-offs between detailed design and maintaining manageable file sizes have to be made ▪ CAD is a more precise tool than BIM is ▪ BIM proficiency is becoming a requirement for employment ▪ Construction students do not get the practical knowledge necessary to function in the industry ▪ BIM knowledge acquisition is expensive ▪ Need to be BIM ready at the point of employment ▪ Staff sometimes model in BIM-based on CAD methodology ▪ Deciding on level of modelling detail is a challenge ▪ Setting up drawing templates in BIM can be time-consuming	▪ Breaking up large models into manageable file sizes, ▪ Systematic introduction of the new processes and procedures in stages ▪ Making the sacrifice to understand the new way of working ▪ Investing in employees ▪ Creation of new BIM management roles ▪ Drawing up new organisational standards, guidelines and procedures

CASE	DISPOSITION	CHALLENGES EXPERIENCED WITHIN ORGANISATION	COPING MECHANISMS
		▪ One can design faster on paper than using BIM authoring software ▪ It takes a long time to learn ▪ It is quite complicated to learn and apply	
ORG4 (Informant C7)	OPTIMIST	***ORGANISATIONAL LEVEL*** ▪ Poor implementation outcomes due to the lack of training and proficiency ▪ Need for redistribution of responsibilities among staff ▪ More man-hours are expended on BIM-based design development, hence more project expenses ▪ Existing drawing practice manuals and the like are largely irrelevant for BIM execution ***INDIVIDUAL LEVEL*** ▪ Loss of information from design sketches made on paper (See ***C6***'s comment on sketches)	▪ Knowledge sharing with colleagues in advanced countries ▪ Creation of new BIM management roles
ORG7 (Informant C8)	MODERATE	***ORGANISATIONAL LEVEL*** ▪ BIM modelling disrupts existing design procedures ▪ Smaller firms struggle to implement all aspects of BIM ▪ Need to get adequate training ▪ Not many firms get projects large enough to apply BIM knowledge gained fully ▪ Difficulty with training ▪ Incomplete training ▪ Eventual reduction of models to 2D CAD drawings wastes design effort ***INDIVIDUAL LEVEL*** ▪ Designing in BIM is a departure from the conventional way of designing conceptually ▪ Designing in BIM gets complex quite quickly ▪ BIM modelling requires dealing with design detail early on in the design process sometimes to the detriment of the project ▪ Transitioning from CAD to BIM takes much time ▪ BIM knowledge was not taught in the tertiary institution ▪ It was difficult adopting BIM initially	▪ Adapting designers' schedule to accommodate the change in workflows ▪ Converting the model to 2-dimensional form for the benefit of a team member who is not using BIM

CASE	DISPOSITION	CHALLENGES EXPERIENCED WITHIN ORGANISATION	COPING MECHANISMS
ORG5 (Informant C9)	MODERATE	***ORGANISATIONAL LEVEL*** ▪ High software costs ***INDIVIDUAL LEVEL*** ▪ *None mentioned*	▪ Instituting a strong team to develop the guidelines and components required within the organisation as a support system
ORG6 (Informant C10)	PESSIMIST	***ORGANISATIONAL LEVEL*** ▪ Certain key professionals in the organisation that have been working the conventional way have a difficulty with converting to BIM ▪ Implementing BIM requires an upgrade of all computer hardware in the organisation ▪ Designing with BIM authoring software is time-consuming ▪ It is expensive for smaller firms ▪ Adopting and implementing BIM are expensive for smaller organisations ▪ Doubts about whether training consultants are construction industry professionals ▪ It takes longer to deliver on projects ▪ Doubts about trainers' abilities ▪ Implementing BIM impacted productivity negatively ('it slowed everyone down a lot') ▪ File size challenges ▪ There is too much optimism among the younger generation about BIM ▪ Difficulty with getting the older professionals in the organisation to transition to BIM ▪ Lack of proficiency led to much frustration within the organisation ***INDIVIDUAL LEVEL*** ▪ Sometimes there is too much information on a printed (site) drawing ▪ Inadequate training ▪ Poor modelling standards by others are problematic ▪ Responsibility for inconsistencies in modelling from other team members gets transferred	▪ Retraining of staff

CASE	DISPOSITION	CHALLENGES EXPERIENCED WITHIN ORGANISATION	COPING MECHANISMS
		▪ Certain design tasks are easier and less complicated to accomplish in CAD ▪ Lack of proficiency leading to much frustration	
ORG3 (Informant C11)	OPTIMISTIC	***ORGANISATIONAL LEVEL*** ▪ Payment for periodic increase in software costs is difficult ▪ It is difficult for smaller firms to adopt and implement ▪ High training costs ▪ The organisation has struggled to find the right pool of people over time ▪ Training and skills development are challenges ▪ Despite over 10 years' experience within the organisation, there is still need for more training ▪ The organisation is not yet in the clear with challenges being faced ▪ Hiring highly skilled staff without BIM modelling knowledge has been problematic ▪ Implementing BIM was not without pain, it took a few years before the organisation was able to implement projects entirely on BIM ▪ It takes time to get efficient at implementing BIM; it has to be a top-down approach within the organisation ▪ It takes time to implement BIM within the organisation ▪ High software & hardware costs ▪ The organisation has struggled to get to the present point where all project are now mandatorily executed on based on BIM ▪ Resistance to change ***INDIVIDUAL LEVEL*** ▪ Highly skilled senior technicians without BIM modelling knowledge have their confidence challenged	▪ Top-down approach to implementation within the organisation ▪ Prompt BIM authoring software updates ▪ New staff are required to have prior BIM modelling knowledge ▪ Investing time and money into weekly training and skills development ▪ Ensuring software are up to date ▪ Ensuring consistency between guidelines, protocols, designs standards and information standards ▪ Re-producing old drawings in BIM once the organisation transitioned to BIM ▪ Making hard decisions to design only in BIM authoring software ▪ Understanding that the benefits outweigh the challenges ▪ Continual improvement of design standards ▪ Creation of the BIM coordinator role ▪ Investing time into creating companywide drawing templates as prompters for how to do work ▪ Organising periodic workshops for staff with software designers, ▪ Developing a relational approach to collaborating (regarding intellectual property)

CASE	DISPOSITION	CHALLENGES EXPERIENCED WITHIN ORGANISATION	COPING MECHANISMS
		▪ There are still some BIM authoring software inadequacies ▪ Initially, it could be very frustrating to design in BIM	

5.4.5 Linking organisational adoption and implementation strategies with their BIM implementation success

Through the repeated reading of the transcripts, analysis, further reflection, and leaning on the strength of the researcher as a key instrument in a research study conducted under an interpretive framework, some inferences can be drawn. In the first instance, the organisational disposition towards BIM appeared to vary with their relative level of success at implementing BIM as in *Figure 5.1*. However, this is not a direct link. The data strongly suggest links between the disposition of the organisation towards BIM and their adoption strategy, implementation strategy, nature of their experiences characterised in the extent of challenges and the methods with which the challenges are coped with as in *Figure 5.1*.

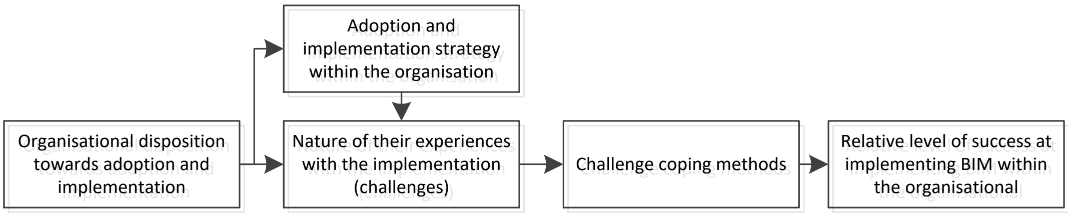


Figure 5.1: Linking disposition towards implementing BIM and relative level of success at implementing BIM

Typical cases in point are ***ORG3*** and ***ORG6***. ***ORG6*** adopted BIM for implementation within the organisation about five years prior as a top management decision, but by January 2016, the implementation had failed and had been discontinued entirely with complete reversion to legacy methods for providing their services. This case was essential in identifying the reasons why a BIM implementation within an organisation may fail. Some reasons (see also *Table 5.4*) may be adduced in explaining the failure of the implementation. These include the lack of a formal organisational plan to implement BIM within the organisation, lack of trust in the training and support professionals and consequently inadequate training.

Their experiences are a stark contrast to ***ORG3*** which is a provider of architectural design services, unlike ***ORG6*** which is a multidisciplinary organisation. Relatively high levels of successes have been achieved within ***ORG3,*** and in fact, all their projects are executed with coordinated BIM models (visualisation, collaboration, simulations, model integration and up to 4D in some instances) with the buy-in of all project participants. In their case, BIM was adopted formally and communicated as a new way of working from top management down the organisation hierarchy. Other key characteristics of their BIM adoption are the development of standards, guidelines and processes for the organisation and execution plans for multidisciplinary construction projects. It is noteworthy that both organisations employed the services of the same training consultancy firm at the initial stages of the adoption respectively. Importantly, there seemed to be a companywide optimistic disposition towards BIM.

5.4.6 BIM induced change within organisational workflows

In evaluating and analysing actual change that has taken place within organisations as a result of implementing BIM within the organisations, experiences of changes as related by the participants will be discussed under the headings of procedural and socio-cultural changes as in *Table 5.5*. Changes of a technological nature are self-evident and not peculiar to South Africa. Therefore, they are not discussed at length here. Nevertheless, they include hardware upgrades/procurement and software upgrades/procurement, both of which are *a priori* knowledge given the context and nature of the study.

Table 5.5: BIM induced changes within organisations

INFORMANTS	PROCEDURAL CHANGES	SOCIAL-CULTURAL CHANGES
ORG5 (Informant C1)	▪ A completely different design workflow was required to implement BIM	▪ Change in organisational mindset to suit a completely different design workflow ▪ The creation of the BIM manager role which also alters organisation structure
ORG1 (Informant C2)	▪ BIM streamlined the design process	▪ The appointment of a BIM manager and coordinator also impacts on organisational interrelationships
	▪ BIM drove a different process/system for design quality management, design development and design progress monitoring	▪ Individual roles have expanded along with expanded job descriptions

INFORMANTS	PROCEDURAL CHANGES	SOCIAL-CULTURAL CHANGES
ORG2 (Informant C3)	▪ Old legacy processes were replaced with new workflows	n/a
ORG4 (Informant C4)	▪ It is a paradigm shift in the way of working	n/a
ORG6 (Informant C5)	▪ Getting the result of design is done in a "roundabout way" rather than a direct way ▪ Modelling in BIM reorders the sequence for designing building elements ▪ The design process is sped up by modelling in BIM ▪ BIM required entirely new organisational work processes	▪ BIM influenced expectations from clients of project deliverables
ORG8 (Informant C6)	▪ BIM drove a completely different process compared to CAD ▪ Designing in BIM shortens the time required to produce outcomes	▪ A BIM manager/coordinator's role impacts on the line of authority and leadership within the firm (*"If it's in a company, you are sitting one below the director, because you do need to call people to task"*) ▪ The appointment of a BIM manager and coordinator (impacts on organisational relationships) ▪ Individual roles have also expanded with expanded job descriptions
ORG4 (Informant C4)	▪ Changed Workflows ▪ Requires the modification organisational practice manuals	▪ The appointment of a BIM manager and coordinator in turn impacts on organisational structure and relationships ▪ Individual roles have also expanded (with expanded job descriptions) ▪ Some job descriptions like tracers are "starting to fall away"
ORG7 (Informant C8)	▪ Sequence of the design detailing (you delve into more detail quite quickly ▪ The structure of the company's processes are organised around BIM modelling workflow	n\a
ORG5 (Informant C9)	n\a	n\a

INFORMANTS	PROCEDURAL CHANGES	SOCIAL-CULTURAL CHANGES
ORG6 (Informant C10)	▪ Implementing BIM has altered work sequence	n\a
ORG3 (Informant C11)	▪ BIM drives a different design workflow ▪ Pre-prepared BIM guidelines & drawing templates are such that it prompts for a new method of working ▪ The printing process is less tedious with BIM ▪ Within the organisation, it is possible for several designers to work off a central file in the same environment	▪ Working with central files impacts on interrelationships within the organisations ▪ The appointment of a BIM manager and coordinator (impacts on organisational interrelationships) ▪ Individual roles have also expanded (with expanded job descriptions) ▪ Implementing BIM has impacted on the way the work teams are structured within the organisation ▪ Some job descriptions like Tracers are "starting to fall away"

In line with activity theory and institutional theory positions on the coevolution of institutions (inclusive of organisation structures) with technology, some changes that demonstrate BIM's impact in that regard were evident in the accounts of participants' experiences. Further, in consonance with suggestions in the literature on BIM's impact on organisational structures (Aibinu and Venkatesh 2014; Demian and Walters 2014; Rogers *et al.* 2015), it is evident that BIM drives significantly different organisational procedures. In particular, the evidence gathered confirm literature in that several tasks which used to be done much later within delivery processes are done much earlier albeit at a higher speed. In essence, legacy organisational processes are being replaced with new workflows within the organisation in what is described as a paradigm shift.

On the other hand, it is significant that South African construction professionals have found it useful in some cases, to create new BIM roles within their organisations as an expansion of an existing role or function. These are to facilitate, adoption, implementation and institutionalisation of new work practices or creation of an entirely new role for BIM management. This is a key impact as organisational lines of communications, interrelationships between staff and in effect organisation structures are altered. Thus it may be surmised, expectedly, that BIM prompts a new way of working and there is clear evidence of organisations and individual professionals coevolving with new technology and associated processes while new practices are being created. Put in other words, the finding is a confirmation of the theory that dysfunctions create needs states within activity systems and that their resolution paves the way for change within organisational structures (see *Figure 5.2*). This will be explored in more detail in the next chapter.

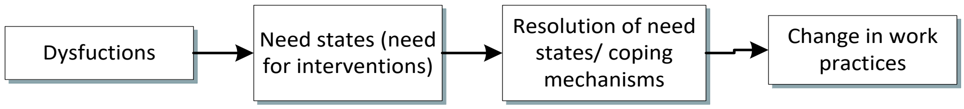


Figure 5.2: Theoretical explanation of change within organisational work practices

5.5 Experiences of BIM implementation challenges within project teams

Many of the challenges experienced at the organisational level translate to the project team level experiences. *Table 5.6* shows a case-by-case matrix of challenges experienced by the organisations along with their corresponding attitude towards BIM as a method of working. Also shown in the table are the methods with which the experienced challenges are being addressed. This, as with the analysis on the organisational dimension of the challenges, is in line with the main theoretical thrust of this study. This is in that the responses to dysfunctions and subsequent demands created in the system of project team work practices are the motivating forces for change and development of the activity (Engestrom 2000; Kaptelinin and Nardi 2006). That is one of the key reasons why it was important to elicit BIM challenge response/coping mechanisms from the participants through objective and subjective referents. An in-depth assessment of these challenges, their responses and the researcher summation of the general level of success achieved in implementing BIM by each of the CPSPs will form a basis for conceptualising success factors for implementing BIM-based mainly on research findings across extremes of cases reported in *Figure 5.3*.

Further, an overall examination of informant accounts of their experiences in implementing BIM suggests a strong link between organisational level BIM implementation characteristics and team level experiences. Nonetheless, the consequences of BIM challenges experienced within organisations are felt more at the inter-organisational team level. Evidently, the challenges being experienced by the organisations are inextricably linked to the knowledge, skills, and proficiency levels. This further trickles down to impact on interoperability of inter-organisational business practices and the level of integration within BIM-enabled projects.

There are two key challenges identified in the analysis of participants' account of their experiences and subsequent researcher reflection. First are the varying levels of proficiency or experiential knowledge of BIM authoring software tools (BAST) and BIM project processes by project participants in the recent experiences of the team members. It is strongly connected to non-interoperability of organisations' business practices on BIM-enabled projects. This inevitably has a knock-on effect on information flow and questions the achievability of the potentials for which BIM is widely advocated. Second, the lack of uniform standards, specifications and protocols for executing BIM-enabled projects is one of the greatest challenges in South Africa, second only to skills deficiencies. That is when compared to construction industries in the developed countries where there are several parallel initiatives to standardise information and BIM practice.

Without these efforts, significant levels of success with BIM may remain out of reach despite the high investment costs involved for collaborating organisations. In the inter-organisational project team setting, this has serious consequences as it contributes to reliance on adaptations of international standards and guidelines discretely within each collaborating organisation. Prominent challenges also include difficulties in getting entire teams to work on the same platform and a low level of integration of different organisational work practices. The evidence shows to a large extent that BIM-enabled project teams are "only as strong as its weakest link" in collaboration. Experiences of organisations coming into projects with other organisations with different kinds of approaches and standards to BIM execution were cited by participants.

Table 5.6: Experiences of inter-organisational challenges while implementing BIM

CASES	DISPOSITION	CHALLENGES EXPERIENCED BY THE PROJECT TEAM	COPING MECHANISMS
ORG5 (Informant C1)	MODERATE	▪ Lack of guidelines and standards for implementing BIM ▪ Teams have to rely on international guidelines and standards ▪ It is challenging coordinating design with BIM ▪ Disability to exchange information among team members ▪ The team is "only as strong as its weakest link" in collaboration (*"it can be great but it just takes one guy to run AutoCAD or something similar, and there's complete breakdown...of information flow"*) ▪ Difficulty in getting every team member to buy into and provide their services based on BIM ▪ There's a slow shift by proprietary products and component manufacturers to producing BIM content	▪ Borrowing from other countries' guidelines and standards ▪ Training and skills development at the organisational level
ORG1 (Informant C2)	OPTIMISTIC	▪ Varying levels of proficiency among project team members ▪ Balancing training while also applying knowledge gained on a real-life project to produce outcomes that are tied to deadlines ▪ Getting team members to the same skill levels ▪ BIM slightly impacts the sequence of activities	▪ Identifying current skills level and providing the right type of training at the project level ▪ Different layers of modelling are done to resolve issues around level of detail ▪ Aligning the processes to fit with new demands
ORG2 (Informant C3)	OPTIMISTIC	▪ Lack of proficiency among team members ▪ Varying levels of proficiency among project team members	▪ Breaking up BIM model into manageable sizes ▪ Time and effort have been put into educating clients on

CASES	DISPOSITION	CHALLENGES EXPERIENCED BY THE PROJECT TEAM	COPING MECHANISMS
			BIM potentials
		▪ Interoperability issues around setting project specific standards	▪ Meeting with other team members to discuss their different approaches to BIM execution and make concessions to agree on a uniform method
		▪ Different organisations come with diverse kinds of approaches and standards for BIM execution	▪ Agreeing to break models down into manageable sizes at various stages of the project
		▪ Difficulty with coordination between team members	▪ The organisation is currently aligning with contractors to drive the BIM agenda
		▪ Sharing of huge file sizes	▪ A technical debate is held and an agreement reached when two organisations propose different approaches to BIM execution on a project to examine the merits of both approaches
			▪ The psychology of wanting to be identified as a leader in the industry makes organisations want to do their best in getting results
ORG4 (Informant C4)	OPTIMISTIC	▪ Success at implementing BIM is limited to the level of BIM modelling proficiency	▪ Converting CAD drawings from other team members to BIM models so all designs can be coordinated
		▪ Coordination is impacted negatively when not all team members use BIM	▪ Quantity surveyors are required to sit in design coordination meetings to give inputs on their requirements
		▪ Low industry BIM maturity level	▪ BIM manager takes incompatible drawings/models and converts it to such that will allow design coordination in BIM

CASES	DISPOSITION	CHALLENGES EXPERIENCED BY THE PROJECT TEAM	COPING MECHANISMS
		▪ It is frustrating to the BIM manager when other team members use incompatible software ▪ Integration with Quantity surveyors is still not optimal ▪ Project teams do not always plan their workflow around BIM ▪ Difficulty in getting competent BIM managers for projects	▪ Countrywide training and skills development for rolling out BIM/VDC iRooms
ORG6 (Informant C5)	CRITICAL	▪ Different organisations present different approaches to collaborating with BIM ▪ Need for uniformity and integration in training to standardise the processes across disciplines ▪ It requires a lot of time-consuming planning ▪ Designing in BIM currently takes more time to produce outputs	
ORG8 (Informant C6)	OPTIMISTIC	▪ Different team members have different requirements and expectations for a BIM project ▪ Manufacturers have not started developing their products as BIM content ▪ Difficulties in getting the entire project team to work on the same platform ▪ Downtimes spent converting poorly produced models or CAD drawings into such that enables design coordination with BIM ▪ Getting the buy-in of clients into the BIM process	▪ Converting CAD drawings from other team members to BIM models so all designs can be coordinated ▪ Deciding to improve sub-standard models or use them as is. Rework to fix poorly produced models from other consultants ▪ Networking with professionals in first world countries where BIM standards exist ▪ Converting BIM models into CAD for team members who are not collaborating with BIM ▪ Creation of the BIM manager role within the project setting

CASES	DISPOSITION	CHALLENGES EXPERIENCED BY THE PROJECT TEAM	COPING MECHANISMS
		▪ Delivering projects with BIM can be complicated ▪ Current standards adapted from other countries do not cater to the peculiarities of the South African context ▪ BIM authoring software are still inadequate in some respects ▪ There is a gap between BIM authoring software developers and users	
ORG4 (Informant C7)	OPTIMISTIC	▪ Lack of understanding of the potentials of BIM in the industry ▪ Difficulties in changing from old methods of working (traditional procurement/delivery methods) ▪ Downtimes spent converting poorly produced models or CAD drawings as such that enables design coordination Engineers are more rigid towards changing existing processes ▪ Difficulties with team design coordination ▪ Modelling can be time-consuming ▪ Lack of demand and drive from clients ▪ The current fees structure does not quite cater to the demands of BIM ▪ Having to deal with entirely different forms of RFIs despite not having the responsibility to produce shop drawings ▪ The drive for implementing BIM comes from the team rather	▪ Creation of the BIM manager role within the project setting ▪ Converting BIM models into CAD for team members who are not collaborating in BIM ▪ Implementing to a level permitted by available fees from the client ▪ Converting CAD drawings from other team members to BIM models so all designs can be coordinated

CASES	DISPOSITION	CHALLENGES EXPERIENCED BY THE PROJECT TEAM	COPING MECHANISMS
		than from the client ▪ Lack of confidence in the correctness of design analysis done in BIM ▪ Engineers are sceptical in that it may label them as modellers rather than designers	
ORG7 (Informant C8)	MODERATE	▪ It is a struggle integrating the designs when other team members like the engineers do not implement BIM on projects ▪ It is a struggle getting the buy-in of other consultants ▪ Much work goes into the initial project phases ▪ The fee structure is at odds with BIM implementation ▪ No client demand ▪ Huge file sizes are difficult to manage ▪ Conversion of 2D CAD drawings into BIM models for coordination is frustrating ▪ There are no standards and protocols to guide practice in South Africa	▪ Conversion of models to 2D CAD for the benefit of team member(s) that are not designing in BIM
ORG5 (Informant C9)	MODERATE	▪ Integrating the models when other team members do not implement BIM on projects is challenging	▪ Conversion of 2D CAD drawings into BIM models for coordination. This is frustrating
ORG6 (Informant C10)	PESSIMISTIC	▪ Model file sizes are difficult to manage ▪ Sometimes BIM models give much more information than the	▪ Conversion of BIM models to 2D CAD as a result of huge file sizes that can’t be communicated my email

CASES	DISPOSITION	CHALLENGES EXPERIENCED BY THE PROJECT TEAM	COPING MECHANISMS
		contractor needs to have ▪ Coordination was very difficult with several designers working on a single model ▪ Ambiguities on which workflow to employ in working with BIM ▪ Ambiguities in task allocation in BIM workflows	
ORG3 (Informant C11)	OPTIMISTIC	▪ Challenge around team collaboration with other consultants ▪ The information contained in models make protection of intellectual property rights is a big challenge ▪ Intellectual property rights considerations hinder seamless collaboration ▪ There had been previous projects where BIM was implemented but not carried through to project closeout ▪ Professionals like the cost consultants are still a little backwards ▪ Clients are yet to tap into the benefits of BIM for facilities management ▪ Time is sometimes wasted 'cleaning up' substandard models received from other consultants ▪ Improperly modelled designs contributed by other consultants and associated contractual liability ▪ Inaccuracies in integrated models from team member design	▪ Approaching collaboration with a relational mindset ▪ Striving for technological interoperability ▪ 'Cleaning up' substandard models from other consultants ▪ In-house standards and guidelines are developed to guide practice within the organisation and on projects ▪ Creation of the BIM coordinator role (and others) ▪ Consulting with UK organisations that have had some success with BIM ▪ Streamlining the processes around BIM to avoid rework ▪ Re-definition of design scope for team members ▪ Making BIM a pre-requisite for organisations intending to provide professional services on projects (as lead consultants)

CASES	DISPOSITION	CHALLENGES EXPERIENCED BY THE PROJECT TEAM	COPING MECHANISMS
		inputs ▪ There are still workflow problems ▪ There is no government support for BIM implementation in South Africa ▪ At the outset, it is difficult transitioning to BIM ▪ It is particularly difficult for old experienced hands to transition to BIM ▪ Full coordination is impossible without the buy-in of all team members with uncertainty of contractual liability ▪ Not many contractors have bought into implementing BIM on projects ▪ There is no drive for BIM in the industry	

Several methods are being used to cope with challenges to achieve reasonable levels of success with BIM on multi-organisational projects as in *Table 5.6* above. However, some of the methods that professionals resort to in coping with challenges can be counterproductive. For instance, BIM models often have to be converted or reduced to 2D CAD formats for professionals who are unable to collaborate on the same platform with other professionals who are more proficient at BIM modelling and associated processes. *Table 5.7* expands on the consequential change observed at the project team level and in the experience of the participant.

Table 5.7: Team level change experienced from implementing BIM

PARTICIPANTS	PROCEDURAL CHANGES	SOCIAL-CULTURAL CHANGES
ORG1 (Informant C2)	▪ The sequence of design tasks in the delivery process is altered. Certain building elements are designed earlier than usual ▪ Design operations are different ▪ The flow of information is different ▪ Certain design functions run concurrently ▪ A lot more coordination is required from the services engineers ▪ The coordinating process has evolved	▪ The design role has only evolved regarding how work is done
ORG2 (Informant C3)	▪ Massive impact regarding contextual design and how designs fit in with the environment ▪ Design process is streamlined towards collectively developing solutions faster ▪ There are massive changes, but they are not 'visible to the eye' ▪ More complex designs are now possible with BIM ▪ Design and testing of several scenarios and costing can be done in real time and faster	▪ There is less need for physical contact between team members ▪ Project visionaries can communicate novel ideas ▪ BIM coordinators have come into play as support roles

PARTICIPANTS	PROCEDURAL CHANGES	SOCIAL-CULTURAL CHANGES
ORG4 (Informant C4)	▪ The design process has evolved with BIM	▪ With BIM/VDC, project teams collocate in iRooms to have coordination iSessions and to make faster decisions ▪ Communication among the project team is clearer using BIM/VDC
ORG3 (Informant C11)	▪ BIM is being made a requirement at the tendering stage for contractors ▪ Contractors are involved early on in the delivery process ▪ Certain tasks are shifted in sequence	▪ New roles created and therefore will impact on lines of communication and interaction among project team members ▪ Team structural hierarchy is altered because new BIM roles created
ORG8 (Informant C6)	None	▪ Lines of communication and interaction are altered because BIM managers level of leadership is very close to that of an Architect, if not second to the architect
ORG4 (Informant C7)	▪ The delivery process has evolved around BIM ▪ The design process has evolved with BIM	▪ Team structural hierarchy is altered because BIM managers level of leadership is very close to that of an Architect, if not second to the architect
ORG5 (Informant C9)	▪ No real change in the processes as existing processes are well established	▪ Better interaction among team members
ORG5 (informant C1)	▪ Certain tasks are carried out earlier in the delivery process	▪ None
ORG7 (Informant C8)	▪ There is a lot more work done in the early stages than previously ▪ It changed how information was shared among team members	▪ Fee scale structure needs to evolve with new demands**
ORG6 (Informant C10)	▪ None	▪ None
ORG6 (Informant C5)	▪ None	▪ Fee scale structure needs to evolve with new demands**

** = These are not experiences of change but participants' perceptions of what should be

5.6 Experiences of BIM implementation benefits within organisations and project teams

As can be seen in *Table 5.8* and *Table 5.9*, the findings of this study confirm the benefits often associated with implementing BIM both within their organisations and as part of inter-organisational project teams. Although it is not pivotal to the argument being made in this study, BIM impacts may be accounted for in its enablement of organisational and team work practices. Nevertheless, virtually all the organisations indicated beneficial experiences. Expectedly, participants with critical to pessimistic dispositions to BIM had little to report as experiences of benefits from implementing BIM. This in effect buttresses the argument that implementing BIM does not guarantee the many potential benefits often put forward by advocates and in the literature.

Table 5.8: Experiences of benefits from implementing BIM within organisations

CASE	INDIVIDUAL BENEFITS	ORGANISATIONAL LEVEL BENEFITS
ORG5 (Informant C1)	▪ Automatic update of changes in all views of the model	▪ A lot fewer errors are made in the design process
ORG1 (Informant C2)	▪ Provides a clear advantage in smart modelling ▪ Faster design of repetitive elements ▪ Automatic update of changes in all views of the model ▪ Reduces errors ▪ Cuts down on checking of work ▪ Provides and advantage in intelligent & parametric modelling ▪ Modelled elements are re-usable ▪ Design processes are streamlined ▪ Enables testing of design options ▪ Material component scheduling is possible through BIM ▪ Rich information content ▪ 3D visualisation ▪ Extensible to measurement of construction work (for Quantity	▪ It streamlines the design development process ▪ The output is a definite improvement on the quality of conventional construction drawings ▪ It helps to deliver the organisation's services faster

CASE	INDIVIDUAL BENEFITS	ORGANISATIONAL LEVEL BENEFITS
	Surveyors)	
ORG2 (Informant C3)	▪ It helps to deliver a better quality product ▪ It helps to deliver products faster	▪ It is a productivity aid ▪ It provides competitive advantage ▪ The Organisation is able to deliver a better project faster
ORG4 (Informant C4)	▪ None	▪ VDC/BIM helps to improve client service
ORG6 (Informant C5)	▪ It is highly customisable	▪ None
ORG8 (Informant C6)	▪ None	▪ It helps to meet increasing client demands on shortening project lifecycle and cost reduction ▪ Coordination exercises are better done visually
ORG4 (Informant C7)	▪ None	▪ None
ORG7 (Informant C8)	▪ None	▪ It saves a lot of time
ORG5 (Informant C9)	▪ Automatic update of changes in all views of the model ▪ Production of 3D visualisations is faster ▪ With accurate and coherent models, everything else becomes relatively easy ▪ Everything from documentation to presentation becomes simpler ▪ Problems can be appraised better and more easily ▪ It helps to make better and clearer decisions	▪ It helps to provide world-class perspectives for clients and faster
ORG6 (Informant C10)	▪ None	▪ None
ORG3 (Informant C11)	▪ It saves time ▪ It is very intuitive	▪ It improves organisations efficiency in delivering designs and information ▪ It streamlines organisational processes ▪ The organisation is able to run with smaller teams

CASE	INDIVIDUAL BENEFITS	ORGANISATIONAL LEVEL BENEFITS
		▪ It cuts down on staff salaries, so it makes commercial sense ▪ It has contributed to organisation's quick growth ▪ It helps to save time ▪ It has been helpful at the conceptual massing stage

Further, the benefits experienced by the organisations may be summarised into improvements in the areas of productivity, integration/coordination, error/rework reduction, visualisation, competitive advantage, efficient use of human resources, and better information flow. The benefits reported are beginning to extend into the transfer of built asset information into facilities management stage (reported in 1/8 of the cases). This is an interesting find as achieving BIM benefits at the facilities management stage of the building lifecycle is still very infrequently achieved even for organisations in the developed countries where there are significant support and advocacy for BIM. From the subsequent analysis, a conceptualisation of success factors for implementing BIM mainly from primary data was constructed. It may be argued (although limited to the data) that the more favourably disposed towards the idea of BIM as a method of working an organisation is, the more likely it is to overcome obstacles and achieve reasonable success at the implementation.

Table 5.9: Team level benefits experienced from implementing BIM

CASE	PROJECT TEAM LEVEL BENEFITS
ORG5 (Informant C1)	▪ Being able to do certain tasks early on in the process makes it team activities a lot easier ▪ It provides a design audit system ▪ It helps to keep track of changes
ORG1 (Informant C2)	▪ It helps to deliver projects faster ▪ It helps to deliver a higher quality project ▪ It helps to improve delivery workflows
ORG2 (Informant C3)	▪ The approach to design development and coordination projects makes solving problems easier ▪ It ensures important aspects of design are not overlooked ▪ It is an aid to brainstorming ideas and problems by the team ▪ It helps in testing the workability of solutions to project constraints in collaboration ▪ It helps to reduce rework

CASE	PROJECT TEAM LEVEL BENEFITS
	▪ Design development for complicated structures have become faster ▪ Improves feasibility of complex structures ▪ Helps to foresee potential construction problems ▪ It helps to communicate design intentions and requirements to and from the client ▪ 4D BIM helps to simulate placement of site structures (cranes, etc.) ▪ Scheduling of materials components of structures ▪ Information content is transferred to facilities management as an intelligent model for the client's benefit ▪ It helps to visualise design in context ▪ It eliminates much guesswork ▪ It has bridged the gap between visionaries and implementers of such visions to produce designs that fit expectations ▪ It has made it easier to produce very complex design forms ▪ It has impacted the analysis of how designs fit with the environment ▪ It helps with resource use management ▪ It helps to test the feasibility of different design options ▪ It improves efficiency ▪ It improves the quality of delivered product
ORG4 (Informant C4)	▪ It is the ideal coordination tool between team members (better coordination) ▪ It helps to make quick changes ▪ It is an important aid to Virtual Design and Construction ▪ It helps to solve problems upfront ▪ Intelligence of the model is an advantage ▪ It helps with construction sequencing ▪ It aids integrative design effort ▪ Lesser site variations ▪ It helps to save cost ▪ Central modelling aids collaborative design ▪ Helps to detect design clashes upfront ▪ It reduces the number of queries and variation orders onsite ▪ It shortens all communication channels (with VDC) ▪ Deliverables are produced faster ▪ It is more effective (than CAD methods) ▪ It is more accurate (than CAD methods) ▪ Visualisation capabilities help clients understand presentations better ▪ BIM information is useful for facilities management ▪ It saves time and cost while improving quality ▪ It is an aid to achieving competitiveness ▪ It enables clearer team communication when team is collocated in the iRoom ▪ It improves the contractors understanding of project scope It is added value to the project
ORG6 (Informant C5)	▪ It helps to simulate entire building in detail before money is expended
ORG8 (Informant C6)	▪ It reduces abortive works cost ▪ It helps to reduce coordination time ▪ It helps to simulate an entire building ▪ It improves the coordination exercise ▪ It reduces costs

CASE	PROJECT TEAM LEVEL BENEFITS
	▪ Less documentation supplied for building on site
ORG7 (Informant C7)	▪ The visual aspects help to communicate with clients ▪ The way of working is completely turned around to improve quality
ORG5 (Informant C8)	▪ None
ORG5 (Informant C9)	▪ BIM and virtual reality improve site operations ▪ Automatic update of changes on all model views ▪ It makes team interaction easier
ORG6 (Informant C10)	▪ None
ORG3 (Informant C11)	▪ It saves costs ▪ It saves time ▪ It improves quality ▪ Better design decisions are made faster ▪ The visual aspects make it easier to convince clients of the feasibility of complicated design intentions ▪ It helps to make correct design decisions ▪ It aids in finding efficient solutions to problems upfront ▪ It helps the client in making informed design decisions

5.7 Conceptualising BIM implementation success factors

As in *Figure 5.3*, the conceptualisations of success factors, are researcher-based inferences drawn from objective and subjective information (referents) given by the participants. These include inferences made from narratives about experiences of implementing BIM by each informant. It also leverages on the researcher as a key form of instrument in qualitative research.

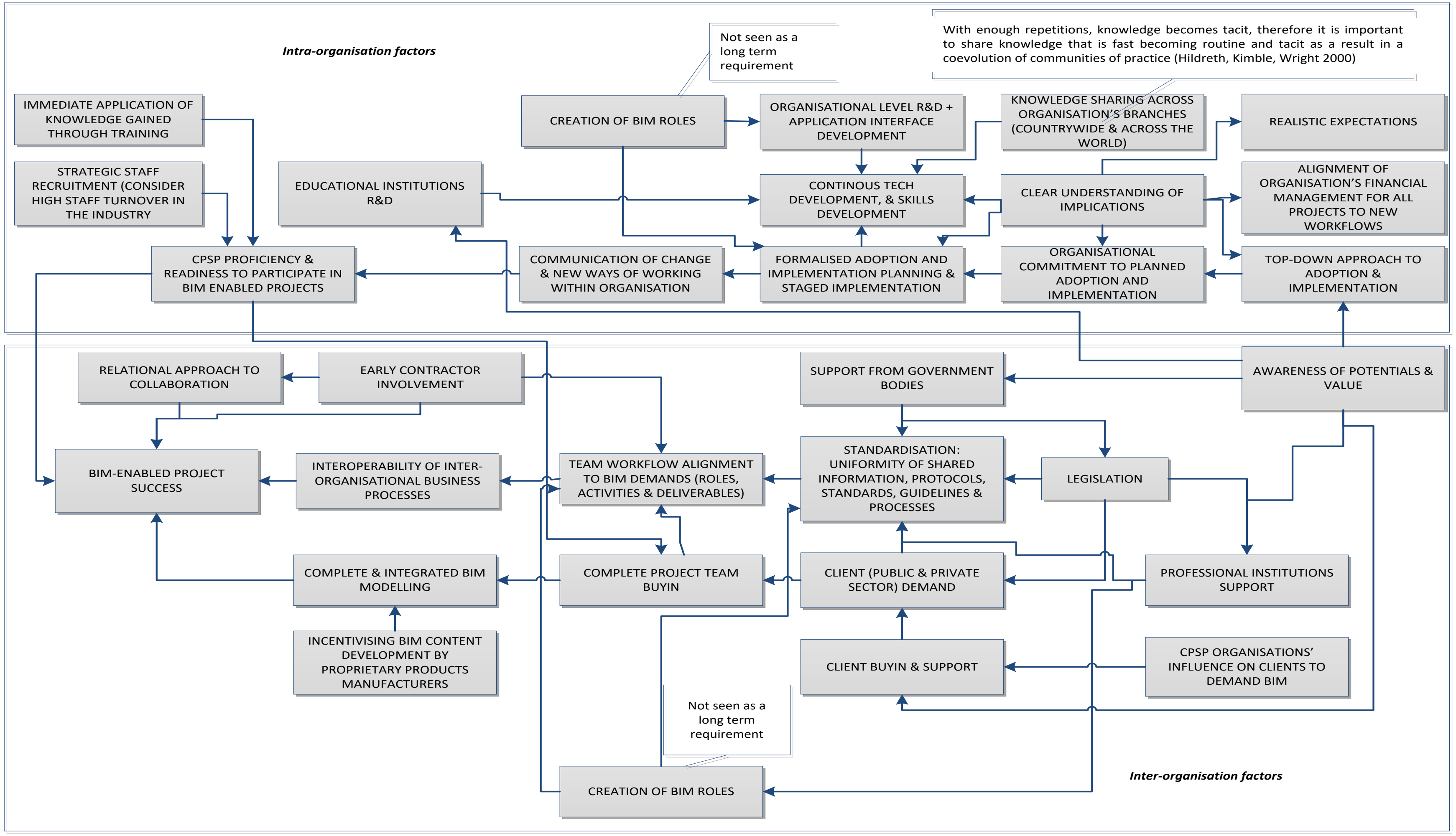


Figure 5.3: Conceptualisation of the interrelationship between BIM implementation success factors

Notably, *Figure 5.3* suggests that professionals' proficiency and readiness to participate in multidisciplinary BIM-enabled projects and the standardisation of information and process at the project team level are two of the most important factors necessary for achieving success at implementing BIM.

5.8 Summary

This study began with a review of BIM implementation challenges and claims made in the literature about BIM induced change impact. Furthermore, in Chapter 3 the theoretical and conceptual frameworks were introduced from which it was propositioned that evolution of professional practices can be accounted for in the constraints/challenges experienced due to the implementation of BIM and their resolution. Therefore after presenting the descriptive findings of the study in this regard, in *Table 5.10*, changes made according to the accounts given by the participants on the organisational and project team levels are then associated with respective constraints and methods with which they were mitigated.

Table 5.10: BIM implementation constraints, their resolution and associated changes in work practices

<table>
<tr><th>CONSTRAINTS</th><th>RESOLUTION OF CONSTRAINTS</th><th>ASSOCIATED CHANGE(S) IN WORK PRACTICES</th></tr>
<tr><td colspan="3">Organisational level</td></tr>
<tr><td rowspan="2">BIM authoring software modelling methodology and its inherent prompting on how to model and design</td><td rowspan="2">Seeking top-down management buy-in and decision to modify design delivery workflows; in-house standards and guidelines are developed to guide practice within the organisation and on projects</td><td>Changed design workflows; changed process for design development and design quality management; changed design progress monitoring; structure of organisational process are re-organised; change in contextual design and design fit with environment</td></tr>
<tr><td>Working with central files changes organisational norms regarding formal and informal interactions and interrelationships</td></tr>
<tr><td>Incompatibility of BIM modelling methodology to existing organisations' design practices; Existing drawing practice manuals and the like are largely irrelevant for BIM execution</td><td>Seeking top-down management buy-in and decision to rework practice manuals</td><td>Change in organisational practice manuals</td></tr>
</table>

CONSTRAINTS	RESOLUTION OF CONSTRAINTS	ASSOCIATED CHANGE(S) IN WORK PRACTICES
Lack of proficiency of professionals; time-consuming transition from CAD to BIM; difficulties in implementing BIM to its full potentials; initial lack of understanding of BIM impacts; Setting up organisational templates, standards and protocols takes a long time;	Creation new BIM roles within organisations;	Changed leadership and authority structure; changed organisational norms regarding formal and informal interactions and interrelationships; changes in remuneration
	Expansion of existing professional roles within organisations to include BIM management	Changes in staff remuneration; changed leadership and authority structure
Designing in BIM is a departure from the conventional way of designing conceptually; BIM constrains intuitive design freedom	Training and shift in mindset	Cognitive changes in the way design and construction is conceived and approached by construction professionals
Project team level		
BIM authoring software inherent modelling methodology and it is prompting on how to model and design; ambiguities on which workflow to employ in working with BIM; ambiguities about task allocation in BIM workflows	Agreement at the start of BIM-enabled projects between stakeholders on the demand and supply sides of the delivery chain to implement a BIM-based project workflow; Design of formal BIM implementation/execution plans for BIM-enabled projects	Changed design workflows; changed process for design development and design quality management; changed design progress monitoring; less need for physical contact between project team members; massive change in contextual design and design fit with environment; evolved design coordination processes; certain building elements are designed earlier than usual
Challenge in coordinating design with BIM; disability to exchange information among team members; difficulty in getting every team member to buy into and provide their services based on BIM; varying levels of proficiency among project team members; Interoperability issues around setting project specific standards; varying levels of proficiency among project team members; different organisations present different approaches to collaborating with BIM	Creation new BIM roles within project teams for BIM coordination; alteration of contract documents	Changed team authority structure; changed project team norms regarding formal and informal interactions and interrelationships; change in leadership structure
	Expansion of existing project team member roles to include BIM management; alteration of contractual documents	Changes in project fee structure; changed leadership and authority structure

The findings, therefore, show that change in patterns of professional work practices can be linked to the nature of professionals' experiences of challenges and that more changes were experienced at the organisational level than at the project team level based on the data that were analysed. Theoretical explanations and re-description of these findings are presented in the next chapter using ideas drawn mainly from institutional theory and activity theory.

6 THEORETICAL ANALYSIS AND RE-DESCRIPTION OF FINDINGS

6.1 New BIM roles' legitimacy and changing power dynamics on BIM-enabled projects

6.1.1 Synopsis

In response to the demands of implementing BIM, new roles and job titles have emerged. However, it can be argued that these roles fundamentally fall within the scope of the traditional functions of existing core professional service providers, although being carried out through different means and methods. This study examines the circumstances that have created the necessity for these new roles in the South African context and also questions the sustainability of their legitimacy. A deep conceptualisation and new theoretical insight are developed on the phenomenon of new role creation and legitimation. This establishes that new BIM role takers are legitimated to exercise authority within project teams and organisations mainly by leveraging on superior knowledge as a strategic resource. By implication, they will remain legitimate only as long as the constraint prompting their creation subsists, i.e., core professionals' BIM knowledge deficiencies, thereby affirming that the new BIM roles are transitory and unsustainable.

6.1.2 Introduction

The analysis in this section is premised on the arguments made previously, in that there have been significant advancements in construction-related collaborative technologies among which is Building Information Modelling (BIM). As a result, BIM is particularly important in its potential to address the perennial challenges of the construction industry (Gallaher *et al.* 2004; Jacoski and Lamberts 2007). These challenges include the need for changing the procurement culture, lack of understanding of roles and responsibilities, the need for investing hugely in training and skills development, and the need for changing work practices among others (Gu and London 2010; Khosrowshahi and Arayici 2012; Lawrence *et al.*

2012; Mahalingam *et al.* 2015; Porwal and Hewage 2013; Rowlinson *et al.* 2010; Singh *et al.* 2011).

The foregoing suggests that BIM drives a significantly different delivery process compared to conventional delivery processes. Particularly, Sebastian (2011), in a very closely related study of changing roles of clients, architects and contractors through BIM, found that the roles of construction professionals are evolving to suit the demands of BIM-enabled projects. Although the study does not quite describe, in sufficient detail, how their traditional roles have changed through implementing BIM, it does put forward a strong argument. It recognises that the necessity of a new BIM role such as 'Model manager', either as an expanded role for existing professional service providers or as an independent/standalone role, is not entirely an accepted norm for BIM-enabled projects. Regardless, in coevolving with new technology, the new roles and responsibilities have been created to ensure the success of the organisational transition to BIM-based methods and BIM-enabled projects and have since continued to proliferate. Some of the nomenclatures used are BIM coordinator, BIM manager, task information manager and information manager among others. However, the functions attached to the new roles vary quite widely in practice, and it has become unclear how their functions should be demarcated from those of existing professional service providers like the architects, engineers and project managers.

Fox (2014) provides a largely compelling argument against fallacious claims about BIM capabilities and its envisaged impact on construction industry structure from a critical realist perspective. This and like arguments make investigating the circumstances or processes that led to the creation of the new roles quite important, as is investigating how they fit into the existing cultural framework of practice, within which project teams and construction industry organisations conventionally function. Therefore, this section of the chapter takes a critical look at the circumstances that provide legitimacy for the new roles, and their impact on project team power dynamics by their inclusion in multidisciplinary projects based on findings.

6.1.3 Theoretical perspectives

This section draws its theoretical foundations from two theories: activity theory and Institutional theory. An attempt is therefore made to explore the convergences in some of their key assumptions and positions to provide an in-depth understanding of the phenomena being studied; that is, changing patterns of construction professionals' work practices and new practice creation. First, activity theory posits that activity systems, the class to which project delivery processes and procedures belong, are internally contradictory and naturally in constant development (Engestrom 2000; Kaptelinin and Nardi 2006). When new tools are introduced into such a system, they bring forth conflicts and contradictions within and between other system elements, which in turn create demands for change in the system. The resolution of the system's dysfunctions is, therefore, the driver for change and development (Engestrom 2000; Kaptelinin and Nardi 2006). The foregoing presents activity systems as constantly evolving regardless of external stimuli. It also means a change in the system can be accounted for in the demands created by conflicts and contradictions within and between other elements of the system as a result of external stimuli, such as a change in the means by which work is done (e.g. new tools like BIM).

These ideas find support in the work of Nelson (1994) on the coevolution of technology, industry structure and supporting institutions, which fits well within this theoretical framework. Its main thrust is that new technology develops along a fairly typical path through its lifecycle and that firm and industry structures coevolve with technology. These assertions are akin to those espoused in the early functionalist theory of organisations, in that a change in one component of a system of interconnected organisational components or structures would require a complementary adaptation of other related components, while change is also accounted for in structural dysfunctions within the system (Tolbert and Zucker 1996). Although Tolbert and Zucker (1996) support that the development and promotion of new alternative structures or new means to fulfilling a purpose may prompt the discarding of older structures, the converse may also apply. If existing organisational structures can get around to fulfilling the socially recognised purpose (Lounsbury and Crumley 2007) or need for which the new alternatives were required, then the new alternatives lose relevance.

Greenwood *et al.* (2008), in their review on legitimacy in the context of organisational intuitionalism, described legitimacy as a socially constructed idea which relies on the extent to which the existence, functioning and authority of organisational entities are culturally or collectively reasoned, explained and accepted. A view buttressed by Tyler (2006). According to Tyler (2006), institutional arrangements or social actors that seek to influence others, or the actions of others, need to achieve legitimacy to be successful. Social actors seeking legitimation could, therefore, benefit greatly from scarcity and conflict situations. This idea can also be extended to complement the key argument drawn from Activity theory; namely, that new roles (as new social objects or structures) may emerge in response to the demands for change in the project delivery system to resolve the challenges created in the system as a result of implementing BIM tools and associated processes.

Johnson, Dowd and Ridgeway (2006) also explained that new social objects are created and legitimated into the existing cultural framework of practice through a process of collective social construction by the relevant stakeholders, as typified in *Figure 6.1*.

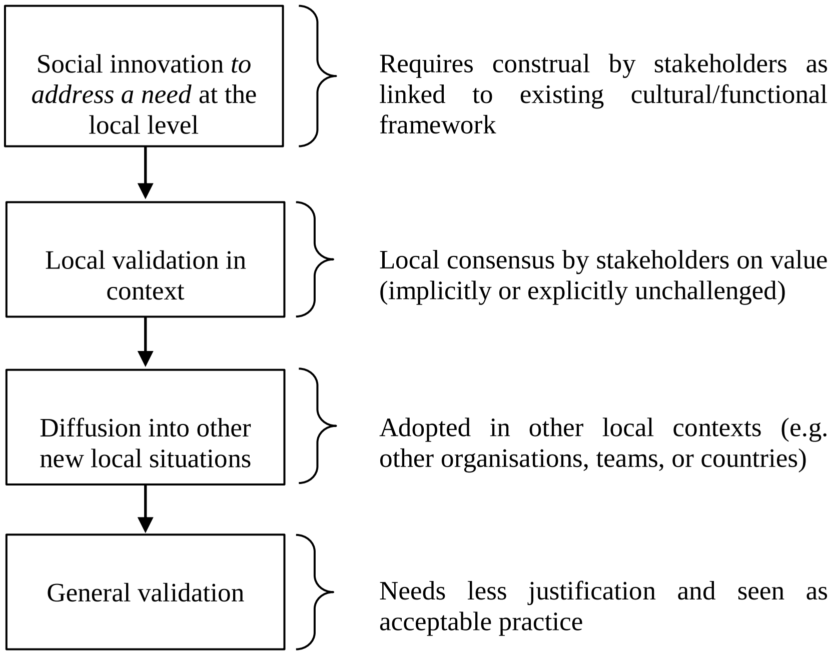


Figure 6.1: Legitimating newly created social objects
Adapted from Johnson et al. (2006)

It can, therefore, be deduced from the theory that sustaining the legitimacy of a newly created role, within an existing industry cultural framework of practice, requires that the situation or demand for which the role emerged continues to subsist. In addition, new patterns in project activities, developed as roles and functions, will remain relevant only if the difference in competencies or knowledge resource advantage between existing professional service providers and BIM related role takers remains unchallenged, is socially accepted and becomes the norm (Johnson *et al.* 2006). These theoretical arguments make it essential to question empirically: what in practice are the needs or demands that the new roles are intended to cater to, how sustainable are they, and how do the new roles fit into the existing project cultural framework? Furthermore, this study leans on the *a priori* assumption that the achievement of legitimacy comes with authority and power to act and influence the actions of others.

6.1.4 Evolution of new practices through BIM

Although construction industry practices have evolved from master craftsmanship to split responsibility design and construction (Howard *et al.* 1989; Nawi *et al.* 2013), and more recently to collaborative systems, they have remained well established in recent years. Similarly, Hughes and Murdock (2001), in their analysis of the comprehensiveness of work descriptions and responsibilities of CPSPs, highlighted the difficulty of the construction industry in organising work processes other than the conventional way. In addition, construction industry practices as they currently exist have emerged as a result of key demands in the industry. For instance, quantity surveyors are noted to have developed in response to a demand for overall cost management of structures, structural engineers to the need for specialised knowledge of structures, and project managers to the need for overall management of increasing team size and number of project interfaces (Hughes and Murdoch 2001). These reasons have instituted the above professions in the industry's cultural framework of norms and beliefs, and therefore guaranteed their sustenance and legitimacy (Johnson *et al.* 2006; Tolbert and Zucker 1996).

The UK Specification for information management in the capital/delivery phase of construction projects using BIM (the PAS 1192:2), made publically available to guide BIM project practice, outlines some new roles for information exchange activities on BIM-enabled projects with attached responsibilities. The outlined functions include, *inter alia*, the configuration of information for project outputs, the population of information exchange formats for information models, the direction of the production of task information in compliance with standards and methods, management of spatial coordination, and suggestion of solutions to coordination clashes (BSI 2013). These functions are attached to the roles of information management, task information management and interface management. However, the roles, particularly that of information management, are not intended to be standalone roles. Rather they are expected to be part of the roles of existing project team members, except in peculiar circumstances (BSI 2013).

In the same vein, the CIC (Construction Industry Council) UK document outlining the scope of services for the role of information management specifies that the new role taker may, among other things, establish a common data environment for information exchange among team members, initiate and implement a project information plan, enable integration of information with the project team, enable a collaborative working culture, and assist with establishing information exchange processes (CIC 2013a). Furthermore, through a practical case study research, Sebastian (2011) also identified the responsibilities assigned to a standalone BIM Model manager on a project as to:

- Catalyse and facilitate BIM;
- Integrate the information supplied by different project participants into BIM;
- Integrate information or partial models into the model;
- Assist the PM in communicating with project team members and clients in preparing 3D visualisations;
- Maintain clear protocols for information exchange;
- Deliver the BIM model and additional documents (drawings and specifications) to the contractor;
- Prepare as-built BIM to be used for facilities management;
- Develop standard modelling structures of the object library, and;
- Convert BIM objects contributed by project team members based on agreed standard structure.

Clearly, these functions are not distinctly demarcated from the traditional functions of existing professionals such as designers and project managers. The pertinent questions are therefore as follows: what guarantees the acceptance of the standalone BIM roles by existing professionals in the project setting? Are they sustainable new practices? How does the creation of standalone BIM roles affect project power dynamics? The following section outlines the methods adopted for an empirical investigation of the questions raised.

6.1.5 Discussion of relevant findings from empirical data

In this section, findings from empirical data are presented along with their theoretical and practical implications. The inferences drawn are from both objective (factual) and subjective referents from the participants' accounts of their experiences. First, a description of the dimensions of new BIM roles that have been created is provided to contextualise the lack of clear demarcation of functions between the new BIM role takers and existing core professional service providers (hereinafter called core professionals). In summary, the findings further explicate that:

- The needs prompting the creation of new BIM roles are BIM knowledge deficiency and a perception of the complexity of BIM tools and processes by core professionals.
- There is no clear evidence of conflict on account of the poor demarcation of roles of new BIM role takers from those of core professionals, thereby affirming the acceptance of the new role takers into the cultural framework of practice.
- New BIM role takers derive legitimacy and authority to act and influence the actions of others because of their knowledge resource advantage over core professionals.

Therefore, with the increase in the knowledge and capabilities of the core professionals, new BIM role takers would become less relevant and unsustainable. It is hence concluded that new BIM roles are transitory social objects that would lose relevance and acceptance once the purpose for which they were created no longer exists. Support for these arguments is presented below in themes.

6.1.6 Dimensions of newly created BIM roles

The dimensions of functions that have been associated with and performed by newly created BIM role takers are presented in *Table 6.1*. These were reported in two distinct areas, i.e., functions carried out within the organisations (as task information managers or task team managers) and those carried out as part of project teams. While the tasks are similar for both, the roles performed within the organisation also include setting up of organisational standards, procedures and templates, a lengthy process which could take up to about two years. According to a BIM facilitator:

> "*Setting up BIM standards and protocols within organisations takes about two years… As coordinator, you sit there … managing the BIM content to a*

degree where when it gets to the coordination … (and to a point where) it's already set up" – ***Informant C6***

Interestingly, the ability to write software programs (application program interfaces) and adaptation of BIM authoring software is considered a required skill for anyone who would take up a BIM coordination or management role. In all, the roles identified as being performed by the BIM coordinators/managers are quite similar to those contained in the PAS1192:2 and CIC documents. Nonetheless, there are peculiarities mainly in the broader scope of responsibilities these individuals bear within organisations. This is mainly because there are no uniform countrywide standards, specifications and protocols guiding BIM implementation in South Africa. Instead, they are borrowed predominantly from the UK standards, specifications and protocols for adaptation by the BIM role takers within South African organisations. This in itself is a source of varying levels and patterns of implementing BIM by collaborating team members on BIM-enabled projects, since each organisation comes onto projects with different methodologies, requirements and plans for implementing BIM.

Table 6.1: Characterisations of new BIM roles as presently practised

PARTICIPANTS	CHARACTERISATION OF NEW BIM ROLES		USED NOMENCLATURE
	WITHIN A MULTIDISCIPLINARY TEAM	WITHIN THE ORGANISATION	
ORG1	▪ Overseeing BIM workflows and systems ▪ Making sure that protocols are being implemented (as intended) ▪ Design and setting up of processes ▪ Checking the congruence of integrated models from various team members	▪ Overseeing organisational BIM workflows and systems ▪ Making sure that the organisation's protocols are being implemented (as intended) ▪ Setting up & maintaining organisation standards for BIM	▪ BIM coordinator
ORG2	▪ Basic management of drawing production	▪ Software adaption (should have strong programming capabilities) ▪ Model navigation ▪ Model population & update	▪ BIM manager
ORG4	▪ Development and management of BIM execution plans ▪ Setting up standards for BIM	▪ Implementation and business development around BIM ▪ Setting up & maintaining organisation standards and processes for BIM ▪ Alignment of organisational work processes with BIM requirements	▪ BIM manager
ORG3	▪ Driving BIM collaboration between project team members	▪ Development of organisational standards and workflows around BIM ▪ Alignment of work processes	▪ BIM coordinator
ORG8	▪ Integrating and managing BIM content uploads from various team members ▪ Manages model completeness and congruence ▪ Exchange standards management ▪ CAD interface with non-adopters ▪ Development and management of BIM execution plans	▪ Setting up & maintaining organisation standards for implementing BIM up to a specified level ▪ Setup and manage BIM standards and protocols within the organisation ▪ Development of organisation specific drawing templates and styles ▪ Facilitating the 'Upskilling' of organisation's staff ▪ Support	▪ BIM manager ▪ BIM captain ▪ BIM coordinator

PARTICIPANTS	CHARACTERISATION OF NEW BIM ROLES		USED NOMENCLATURE
	WITHIN A MULTIDISCIPLINARY TEAM	WITHIN THE ORGANISATION	
	▪ Setup and manage BIM standards and protocols for the team ▪ Dictate the way of working with BIM ▪ General assistance to all project team members on BIM	▪ Resource allocation ▪ Creating and managing BIM library components	
ORG5	▪ None	▪ Day-to-day development of BIM in the organisation ▪ Development of BIM content/components ▪ Help to keep the organisation abreast of BIM development internationally	▪ BIM manager
ORG7	▪ None	▪ None	▪ No roles created
ORG6	▪ None	▪ None	▪ No roles created
ORG6	▪ None	▪ None	▪ No roles created

Similar to Sebastian's (2011) findings, some of the functions being performed by the new role takers are not clearly demarcated from those of existing core professionals. For instance, drawing production management, model population and update, and the integration of BIM content uploads from project team members are not new functions, but are simply old ones being done differently in the BIM implementation process.

However, while some organisations are planning to make the BIM management functions part of the job descriptions of persons within the organisation currently carrying out the tasks, ***Informant C3***, VDC (Virtual Design and Construction)/BIM facilitator for a multinational consortium, stated also that their organisation has been sceptical of attaching titles to such persons carrying out BIM related tasks due to their temporary nature. A key implication of this finding is that even though they have gained acceptance (Tyler 2006), the new BIM roles are transitory; a position that will be explored further in the following sections to provide insight into how new BIM role takers are accepted into the existing cultural framework of practice in the industry.

6.1.7 Core professionals' lack of proficiency and perceptions of BIM complexity

Shortfalls in knowledge and skills have been, and remain one of the biggest impediments to successful implementation of BIM within and outside the South African construction industry context (Akintola *et al.* 2016; Kekana *et al.* 2014; Rogers *et al.* 2015). In fact, all of the participants acknowledged this to be a problem, as illustrated by ***Informant C1***:

> *"One of the biggest challenges with BIM is going to be about 'upskilling' and training ..."* – ***Informant C1***

Expectedly, lack of proficiency is strongly linked to the challenge of varying levels of proficiency among collaborators within organisations and multi-organisational project team settings. Although it is important for collaborators with BIM to create and manage information at the same level of maturity, this is often not the case. In the experience of ***Informants C2*** and ***C3:***

> *"it's not an easy thing because you have different people with different skill levels, even in CAD (Computer Aided Design) they would have had different skill levels, and transferring that in a (high) pressure environment where you always have to produce something for the project, it is not the easiest thing"* – ***Informant C2***

> *"…on other projects, we've seen a challenge (in that), not all the professionals have the same level of BIM proficiency"* – ***Informant C3***

To provide further context, the participants' characterisations of BIM and the implementation thereof were gleaned (mainly verbatim) from the data collected. As is evident from *Table 6.2*, it could be surmised that although BIM is perceived and experienced as useful, it is also viewed as a complex tool or process.

Table 6.2: Characterisations of BIM and implementation experience

BIM CHARACTERISATIONS BY PARTICIPANTS	
▪ BIM is "an ideology"	▪ "fish out of water" (Initial experience for large firms implementing BIM)
▪ "massive beast of an idea"	▪ "complicated"
▪ "a very clear advantage"	▪ "a formula 1 car"
▪ "a complex system"	▪ "bunch of concepts"
▪ "a very exciting thing"	▪ "it's quite complex"
▪ "a pillar of group strategy"	▪ "powerful"
▪ "very important"	▪ "it's a tool"
▪ a "paradigm shift"	▪ "quite powerful"
▪ "as big a shift"	▪ "a whole paradigm shift"
▪ "a mind prosthetic design aid"	▪ "an intelligent system"
▪ "a tool"	▪ "a way of standardising interactions"
▪ an "ideal tool"	▪ the "language we speak"
▪ "a core element of integrated design"	▪ "incredibly powerful tool"
▪ "a whole paradigm shift"	▪ the "language we speak"
▪ "an intelligent system"	▪ "a way of standardising interactions"
▪ "I'd equate it (the old way of working) to like a simple math equation ... whereas with your Revit, it's more of an algebraic expression and different equations will apply for different disciplines"	

Furthermore, the perception of great difficulty in implementing BIM is typified in the comments of ***Informants C5***, who held a critical view of BIM as a tool and way of working:

> *"In theory, it's a fantastic idea, but in practice, it needs a lot of ... prior planning to set up the parameters for a project and that unfortunately in my experience is really time-consuming"* – ***Informant C5***

Perceptions and experiences of complexity and great difficulty respectively influence the self-efficacy of core professionals; that is, their belief in their ability to produce desirable outcomes with BIM without external help. Lack of, or low self-efficacy in working with BIM creates a need to bridge the zone of proximal development between their ability to produce outcomes with BIM independently (as individuals and organisational entities), and that which is achievable through external help from new BIM role takers such as BIM coordinators. Additionally, when asked, ***Informants C11*** and ***C6*** linked the motivation for creating new BIM roles to complexity and complicatedness as illustrated below:

> *"…because it is a complex system, and it needs monitoring…"* – ***Informant C11***

> *"The downfall is that it takes so long to understand something that complicated and companies don't actually have the time to do that"* – ***Informant C6***

This is interpreted as a contradiction between the new BIM tools and existing (pre-BIM) knowledge and skills (intangible tools). The resolution of this contradiction necessitated the creation of new roles and an alteration of the subject element of the activity system. That is by the inclusion of new BIM role takers as actors in the activity, thereby also changing the nature of the activity.

6.1.8 Derivation of authority by new BIM role takers and change in power dynamics

With the creation of BIM management positions within organisations and teams, hierarchies and authority structures are being altered, while their assigned functions also bestow authority to act and influence the actions of other professionals. Construction industry professionals are however known for their territorial disposition to work demarcations, with traditional functions being rarely shared with others. It is therefore interesting to find no clear evidence of role conflict since BIM management functions are not entirely new but are old functions being performed in new ways, by different means, although with improved outcomes. Changes in hierarchies and authority structures due to the creation of new BIM roles are typified in the accounts of informants. For example:

> *"I think (it) has had a massive effect already on architecture. I don't think you have that position anymore of the architect that controls centrally … the central control of the architect has been shifted already"* – ***Informant C8***

> *"I would put the BIM manager's level of leadership very close to, if not second to the Architect"* – ***Informant C6***

While the above may be an unusual position for traditional project leadership role takers to accept, for new BIM role takers, along with leadership comes the power to act and influence the actions of others on projects and within organisations, as illustrated thus:

> *"…like Harry who is carrying a lot of ... authority when it gets to BIM, people respect that. So if he says to the project manager – this is the way we have to do it, they normally just follow suit"* – ***Informant C4***

> *"If it is as part of a project team then you are there dictating to the rest of the design team what the BIM protocol is, how you work in this BIM field … that's where you find yourself, and you do call quite a big shot there"* – ***Informant C6***

However, the redefinition of hierarchies is still not always clear-cut. Leadership roles may change depending on current demands. For instance, ***Informant C4*** affirmed that:

> *"I would have the architect lead, and the BIM guy must fall in with that. Once we get to technical drawings and coordination, I would like the BIM guy to lead, and the project manager must (follow)"* – ***Informant C4***

In addition, the architect's or lead designer role as can also be threatened when they are less proficient than other team members in the use of BIM authoring software and collaborative practices. This buttresses the knowledge resource dependency of the BIM implementation process:

> *"There's been other projects where we've worked with ... engineers, (when) maybe the structural engineer's strongest in terms of Revit for example, but the architects are now new in adopting the program, and it becomes hard ... to assume the role of principal consultant, if you're not the strongest in terms of Revit, if you are weak in Revit… I think it helps to have a strong architect who assumes that role … for the project"* ***– Informant C11***

Contrary to the foregoing, however, some of the findings indicate that BIM management roles are merely support roles, and as such possess no authority as depicted by ***Informant C3*****:**

> *"Perhaps these new roles have come into play where you'd have a BIM coordinator, like on the 'X' project, where we've got a BIM coordination team, they don't ... they don't have any position of authority as such … they are a support role" –* ***Informant C3***

Nevertheless, the creation of new BIM roles has not been entirely without resistance from core professionals, albeit with no clear evidence of conflict from the accounts of participants' experiences. Such cases of resistance to the leadership are quickly resolved upon realisation of their purpose and superior knowledge of BIM tools and processes. ***Informant C6*** illustrates this succinctly:

> *"Yeah, you do get resistance as it were but look; the resistance is overcome through acknowledging that this role is there for a purpose –* ***Informant C6***

Therefore, issues of role conflict in the "potential triangle of conflict" (***Informant C4***) between the architect, project manager and BIM manager are existent but not pronounced at the moment because they have gained acceptance within the organisational and project settings. This buttresses the question on the source and sustainability of new BIM role takers' acquired legitimacy and authority.

Furthermore, the evidence shows that due to the alteration of the role element of the project context activity system, a corresponding contradiction between the altered roles and the rules guiding project and professional practices (alteration of hierarchy and authority structure) ensues. This produces an opportunity for further transformation of the activity system through the modification of contract systems, documentation and reward systems.

6.1.9 New BIM role takers' leverage on knowledge as a strategic resource

Apart from being the purpose for which new BIM roles are being created, core professionals' knowledge deficiencies also guarantee their acceptance, relevance and sustenance. In this vein, the new role takers claim superior knowledge as a resource advantage and are thereby able to assert authority, as depicted in the quotes and *Figure 6.2*:

> *"We as the knowledge experts come in there with a strategy or plan… in terms of – yes, we've done this before; this is the way to do it. You get slotted in because your Revit skill set is like way above everybody, you learn the program 110%, you've got knowledge and experience...." –* ***Informant C6***

> *"…because of guys like Harry (BIM manager), as a company, we are quite far advanced in terms of usage even though we don't do it in high volumes, but we are well advanced in terms of implementing a multidisciplinary BIM in terms of all your disciplines" –* ***Informant C4***

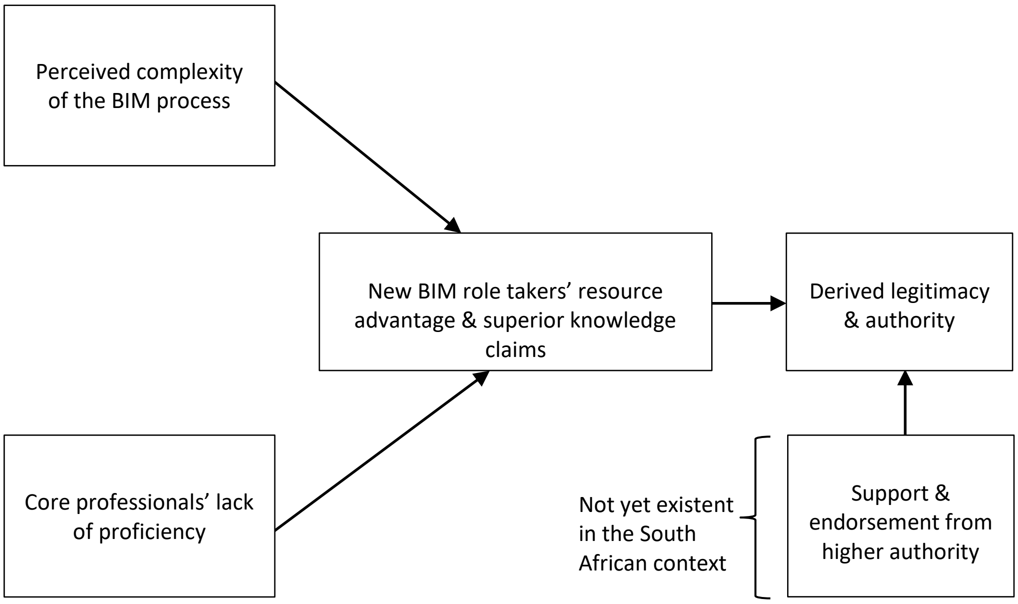


Figure 6.2: Conceptualisation of new BIM role takers' derivation of legitimacy and authority
Source: Akintola et al. (2017)

The legitimacy of newly created social objects like roles also benefits from support and endorsement by higher authorities (e.g. professional institutions). This is similar to that which may be found in UK government initiatives, BIM guidelines and protocols. However, this is not the situation in the South African context.

6.1.10 Transitory nature of newly created BIM roles

Drawing from the foregoing discussion, a logical argument is that BIM managers and the like draw legitimacy to exercise power and authority as a result of the lack of proficiency by core professionals and the perceived complexity of the BIM process. They thereby leverage knowledge as a strategic resource to legitimise their positions and have gained the power to make and influence decisions within organisations and on multidisciplinary projects (Tregaskis 2003). However, despite their present acceptance and relevance, a key question being asked in this thesis is: How sustainable are the new roles? In answer to this, it is posited that as the level of proficiency of core professionals increases, these new roles may gradually lose legitimacy and thereby eventually be reduced to that of a mainly technical support role in the operation of a project's common data-sharing platform. This is because regardless of the eventual loss of relevance of new BIM roles, the huge dependence on sophisticated technological infrastructure for implementing BIM may remain. In essence, they may yet evolve to provide similar support for future innovations in the construction industry which may or may not be linked to BIM. This is taking into consideration that some of those who used to be known as CAD managers now perform BIM management functions (***Informant C3***).

It can be argued further that new BIM roles are transitory and only relevant while industry practices and competencies evolve through learning and development. They will ultimately only remain relevant as the construction industry evolves in response to the several demands of BIM for change in the system (Johnson *et al.* 2006; Nelson 1994). The sense made of the evidence is that of a learning industry in the process of coevolution with new technology. While the scope of work for professionals on BIM-enabled projects might have expanded, the real changes are in the tools that are used to produce work output and *how* work is done, rather than *what* work is done. For example, as ***Informant C3*** puts it:

> *"The new roles that have emerged ... BIM managers, BIM coordinators, BIM leads ... all kinds of BIM titles have spawned out of this new paradigm. We've been reluctant to attach what could be temporary ... titles to people who fulfil these roles because it can be seen as a transitional role. You know we had persons called CAD managers, and in essence, they manage the production of drawings under the CAD standards, the platform. And now in this new paradigm, they manage a different platform, but it's not necessarily to say that their role has really changed; the thing that changed is the software that they manage. The same with designers: we've seen companies attach BIM titles, BIM technicians, BIM designer.*
>
> *But as a group we've taken a stance that whether you're designing on CAD or BIM, you're a designer, you're an engineer, it doesn't change ... the tool that you ... that you use doesn't define the title, because 10 years from now there's a new tool again, so you don't have to go through the whole business of changing various titles. Also, there's ... concerns around ... especially the BIM management side, around what is the real definition of a*

BIM manager? And there isn't anything clear, there's no formal qualification for a BIM manager, and it varies dramatically if we look at our different regions" – ***Informant C3***

Within ***Informant C3***'s organisation, it is fully expected that with time, new practices (associated with BIM management) would become institutionalised as standard ways of working thereby requiring no external assistance. It is believed that *"as ... people (continue to) adopt this technology, it becomes widespread in their organisations (and) it becomes the kind of standard way of working".* Therefore, it can be surmised that with an increase in proficiency and competence of core professionals on the one hand, and the institutionalisation of new work practices within the existing framework for the practice of core professionals on the other, all that seems novel presently will eventually become the norm. That is; if organisational structures gain the capability to fulfil the purpose for which new roles were required, then the new BIM roles will lose relevance (Lounsbury and Crumley 2007). In that sense, the standalone 'BIM manager role' may be seen as temporary and not enduring.

This study's findings also invite a more critical examination of the path and pattern of the coevolution of organisational and project team practices with BIM technology, which is the main subject of a larger study from which this is being reported. Beyond the question of role sustainability, the findings raise broader questions on the sustainability of newly created practices associated with BIM implementation. At this point, the following argument is proffered: new BIM practices may prove to be sustainable as long as the new tools for which, or through which they have emerged, remain in use and in their current form. However, since BIM technology is in evolution, some of the associated practices may also coevolve with the tool. Arguing from an activity theory perspective, work, or work practices do not exist in isolation from the tools with which they are carried out because human activities are tool-mediated (Kaptelinin and Nardi 2006). It is for this reason that BIM practices, relationships and co-constructed interactional forms within organisational and project teams may either evolve or lose relevance with the evolution of BIM tools.

6.1.11 Summary

The findings show that key challenges to implementing BIM are the perception of the processes and procedures as complex or complicated, lack of proficiency and varying levels of experiential knowledge of BIM among core professionals. These challenges have created the demand for the creation of new BIM roles to address the gap in industry knowledge of BIM processes and procedures. Further, the knowledge resource advantage of new BIM role takers is the main basis upon which they are legitimated and accepted as part of the existing project/industry framework for practice. To this end, it is argued that the purpose for which the new standalone BIM roles are being created may reasonably be expected to cease to exist in the long run and therefore render them irrelevant.

The creation of the new social structures as standalone BIM roles has not entirely been devoid of conflict within project teams. They have also somewhat impacted on project power dynamics by their inclusion in leadership structures, and the shift of some responsibility from core professionals to them. Therefore, in both cases – i.e. new BIM roles as either expanded roles of existing professionals, or standalone – power shifts, albeit without conflict at the moment. Power is accrued by the new role takers since they then have authority to either act or influence the actions of others in ways that used to be the exclusive preserve of core professionals.

The findings are of substantive significance as they leverage on existing theoretical knowledge to deepen the understanding of new BIM practice or role creation in the construction industry. Apart from being an extension of the work of Sebastian (2011), the chapter developed a deep conceptualisation and new theoretical insight into the phenomenon of new role creation and legitimation. Using a robust methodology, it finds, from a theoretical and practical standpoint, that new BIM role takers are legitimated to exercise power and authority within project teams and organisations mainly by leveraging on superior knowledge as a strategic resource. By implication, they will remain legitimate only as long as the constraint prompting their creation, core professionals' BIM knowledge deficiencies, subsists. The new BIM roles are therefore transitory and are hence unsustainable. Particularly, the findings are important for decision-makers within construction-related organisations and project teams in making long- and short-term structural decisions about staffing, role distribution, role definition and team composition.

6.2 Understanding BIM impact on professional work practices using activity theory

6.2.1 Synopsis

Despite the potential of building information modelling (BIM) to alleviate perennial construction industry challenges, its use does not guarantee results. This study argued and confirmed from a theoretical and practical standpoint that the implementation of BIM, an evolving technology, within pre-BIM organisational and project team work practices (as activity systems) induces their evolution through dysfunctions created in the systems and their resolution. This study employed a qualitative research design involving key informant semi-structured interviewing of purposefully selected participants from eight organisational cases of BIM implementation in South Africa. This was to develop an understanding of how construction professional work practices evolve with the implementation of BIM. Dysfunctions created in professional work activities were analysed through constraints experienced by participants at the organisational and project levels. This study found that change and evolution of work practices within organisations precede that of project teams. Using activity theory, this section contributes a novel conceptual analysis as well as depictions of BIM-induced change patterns. This aids an understanding of the current implications of implementing BIM on construction professional work practices and serves as a basis for analysing future dimensions of change in professional work practices with BIM and similar work mediating tools.

The pertinent questions of interest are:

- What are the constituent elements of organisational and project team context activities?

- What are the conflicts and contradictions created within existing professional work practices as a result of implementing BIM?
- How are the conflicts and contradictions within these systems being resolved?

- How have professional work practices changed as a result of the introduction of new tools (BIM) into the activity systems?

These are based on the activity theory position that all forms of human practice are the products of 'historical development' which perpetually reform and trigger the development of the said practice. Further, that individual and collaborative human work activities are mediated and shaped by tools (Kaptelinin and Nardi 2006). In particular, activity theory is well suited to '*describe how human activity and the setting in which it is situated co-evolve over time and change the nature of future activities while participants deal with new barriers and possibilities'* (Yamagata-Lynch, 2010, p. 11)

This analysis is therefore akin to the method of theoretical re-description as explained by Fletcher (2017) in which empirical data are re-described using theoretical concepts.

6.2.2 Analysis and discussion

This section presents a concise description and explanation of collaborative professional work change patterns when such work is impacted by the introduction of new technology. Systemic constraints and contradictions within professionals' work activities, as in the findings, are employed to engage activity systems as they evolve. The methods espoused in the synthesis of different approaches to activity systems analysis were leant on, drawing from Yamagata-Lynch (2010). The organisational context activity system (OCAS) and project team activity system (PTAS) are the units of analysis. The analysis essentially traces the change of construction industry challenges from the time when new technology was required. First, depictions of the OCAS and PTAS upon which the analysis is carried out are put forward (see *Table 6.3*, *Figure 6.3*, *Table 6.4* and *Figure 6.4*), followed by an analysis of changes in the pattern of these activity systems over time through the introduction of new tools (BIM), as elucidated in the following sections.

Table 6.3: Organisational context activity system constituent elements

ACTIVITY SYSTEM ELEMENT		**CONSTITUENTS**
Tools	Tangible	▪ General work production tools ▪ Discipline-specific work production tools (CAD & related tools) ▪ Organisations' financial resources across projects ▪ Organisations' practice protocols
	Intangible	▪ Established professional knowledge and skills ▪ Organisation-specific knowledge base
Subject		▪ Management ▪ Technical staff ▪ Administrative/support staff
Object		▪ Production of designs and documentation ▪ Provision of necessary professional advice
Rules	Formal	▪ Staff reward system (remuneration) ▪ Professional and ethical guidelines ▪ Conditions of engagement of staff to firm ▪ Professional standards and specifications ▪ Hierarchies, structure and authority system ▪ Budget ▪ Organisational rules ▪ Organisations' practice protocols
	Informal	▪ Organisational norms and culture ▪ Co-constructed interactional forms
Division of labour		▪ Role distribution within organisation ▪ Role definition within organisation
Community		▪ Client/client organisation ▪ Project team ▪ Professional bodies ▪ Competitors

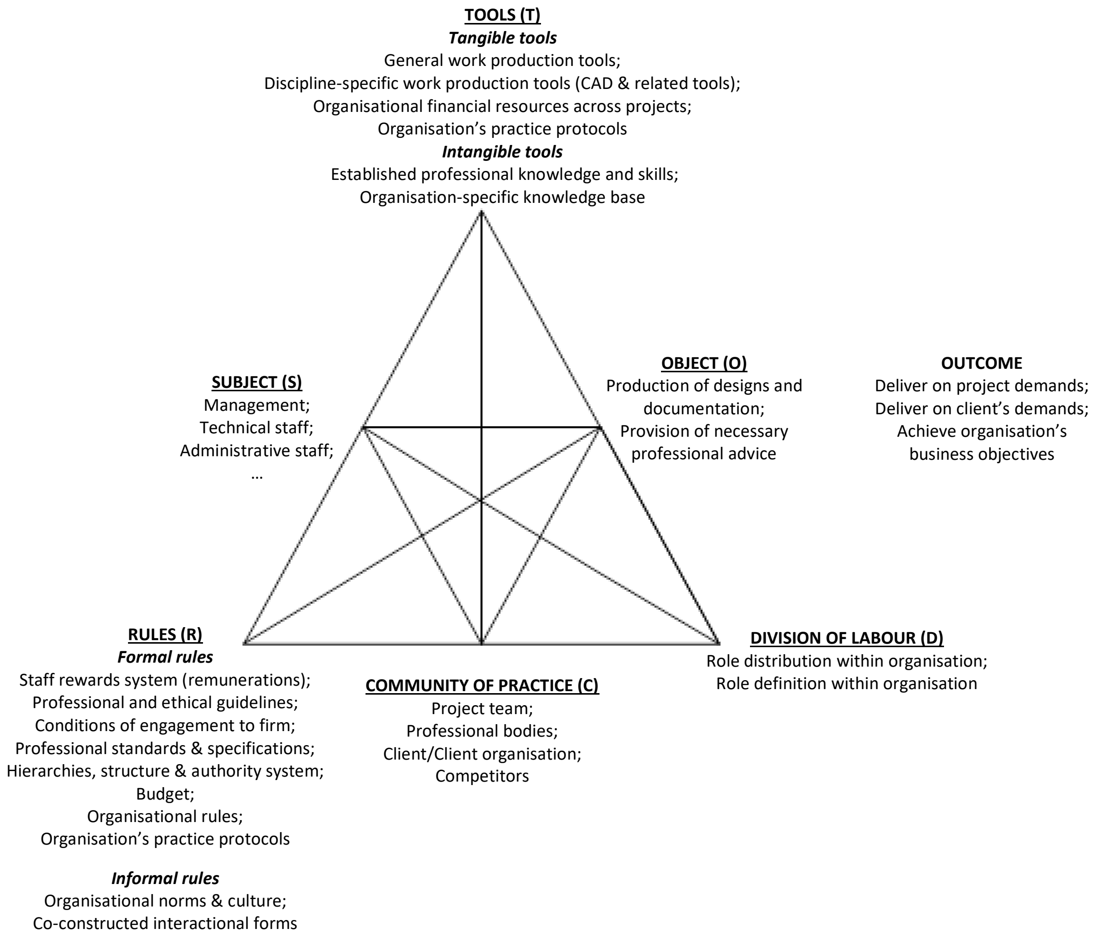


Figure 6.3: Organisational context activity system

Table 6.4: Project context activity system constituent elements

ACTIVITY SYSTEM ELEMENT		CONSTITUENTS
Tools	Tangible	▪ General work production tools ▪ Discipline-specific work production tools (CAD & related tools) ▪ Project financial resources ▪ Designs and documentation produced by separate organisations
	Intangible	▪ Teams professional knowledge and skills
Subject		▪ Client ▪ Project manager ▪ Architect ▪ Quantity surveyor ▪ Services engineers ▪ Structural engineer ▪ Contractor (s) ▪ …
Object		▪ Collaborative production of coordinated designs and documentation ▪ Construction of Building structure ▪ Supervision of the works
Rules	Formal	▪ Reward system (fee payment structure etc.) ▪ Professional and ethical guidelines ▪ Conditions of engagement with client

ACTIVITY SYSTEM ELEMENT	CONSTITUENTS

	▪ Professional standards and specifications
	▪ Hierarchies, structure and authority system
	▪ Conditions of contract
	    ▪ Project budget
	    ▪ Contract period
	    ▪ Project quality standards
	    ▪ Procurement delivery system

Informal	▪ Co-constructed interactional forms
Division of labour	▪ Role distribution within project setting ▪ Role definition within project setting
Community	▪ Professional bodies ▪ Statutory bodies ▪ Users ▪ Government

Source: Akintola et al. (2017)

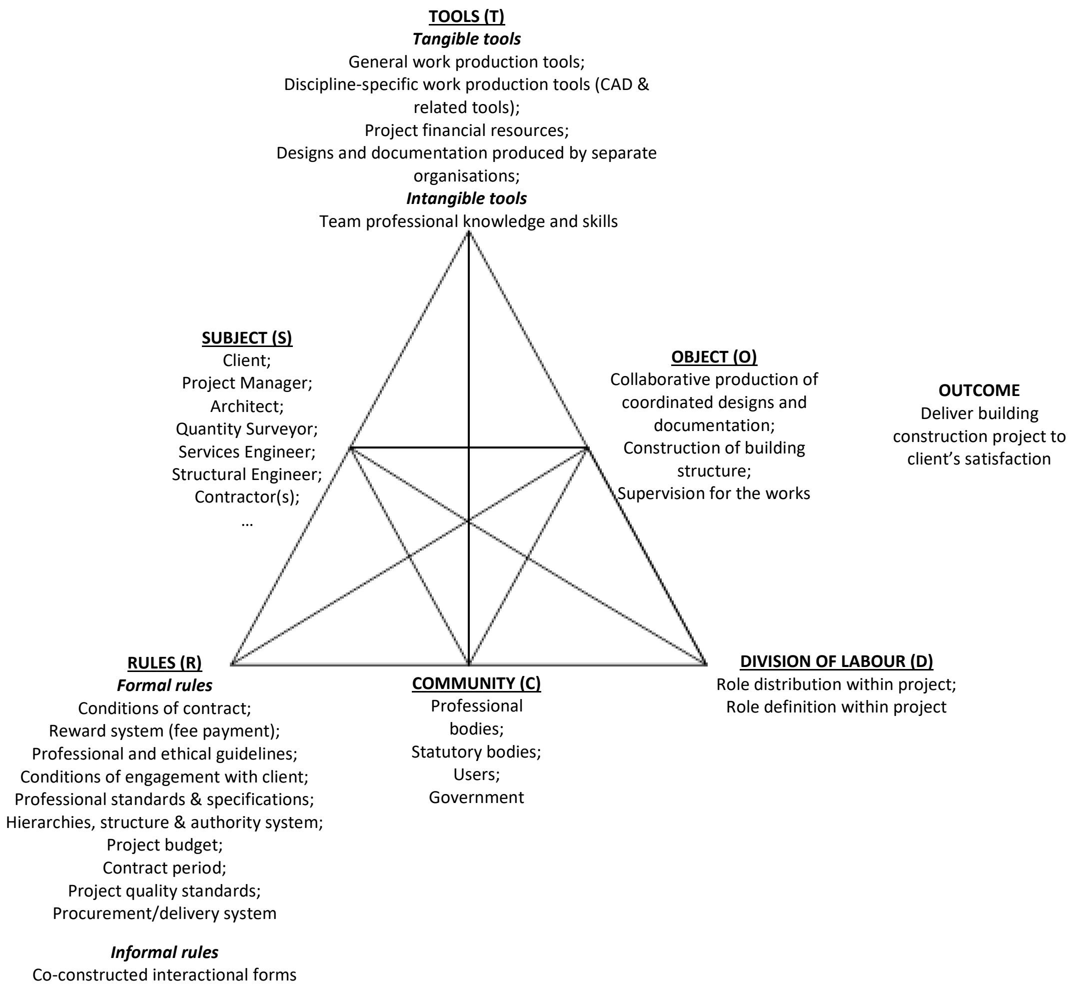


Figure 6.4: Project context activity system

6.2.3 Organisation context activity system analysis of BIM-induced change

The key motivation for introducing new tools (BIM) within organisations, and by extension the construction project team, stems from the challenges relating to delivering construction projects within the constraints of time, quality and cost while still maintaining profitability (Crotty, 2012). Allied strongly to these constraints is the inability of the actors to aggregate dispersed information across multidisciplinary project team members' organisations. This can be interpreted as a Rule *(budget, time requirement, quality requirement)* vs Object *(high performing project, organisational profitability)* contradiction in the activity system at the project level, as in *Figure 6.5* (a).

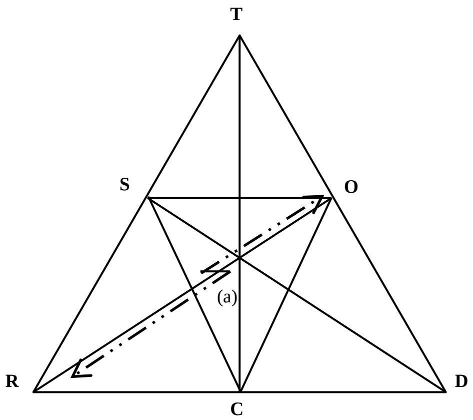


Figure 6.5: Rule vs Object contradiction necessitating the introduction of BIM at the organisational level (a)

Nevertheless, these initiatives (the introduction of BIM) originate from organisational efforts to improve their delivery of project expectations and outcomes. On the organisational front, the motivations for implementing new technology and associated applications go beyond merely meeting clients' demands to achieving competitiveness among peers (*Informants C1-11*), as depicted in *Figure 6.6* (b) and *Figure 6.6* (c). In other words, organisations are constrained by the need to achieve their objectives within the limits of scarce organisational resources while striving for competitiveness with their peers. This is a Rule *(organisation's resources/budget)* vs Object *(provision of professional* *services)* vs Community *(competition with other organisations)* contradiction.

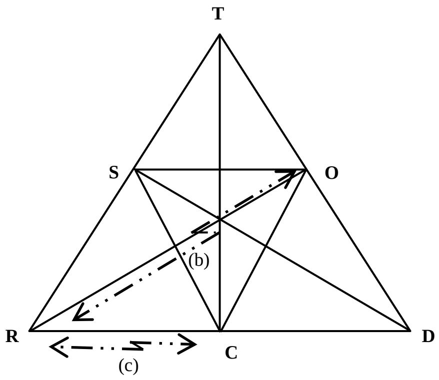


Figure 6.6: Rule vs Object; and Rule vs Community contradictions necessitating the introduction of BIM at the organisational level (b & c)

To resolve the above contradictions, BIM is introduced as a new tool, both in its form as technology and also as a process. Nevertheless, the introduction of new tools within organisations has been found to create a new set of primary contradictions, these being between the new tool(s) and existing tangible and intangible tools, as depicted in *Figure 6.7* (d).

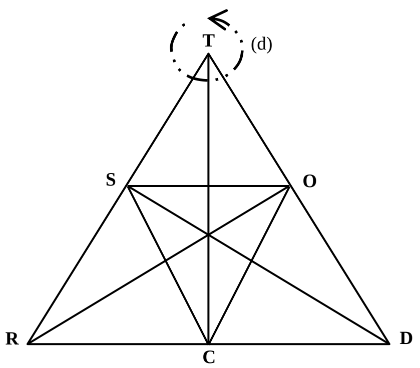


Figure 6.7: Tool vs Tool contradiction between newly-introduced tools and existing tangible and intangible tools (d)

First, for existing tangible tools, there are some contradictions brought about by the introduction of BIM. Tool *(BIM)* vs Tool *(existing CAD systems)* contradictions are experienced in the sub-optimal levels of interoperability between existing and new tools. Organisations often have to contend with the double bind of either implementing both together while gradually migrating to new tools, or else go the BIM route for all their work from the onset. This is not always an easy decision. Nevertheless, the findings show that a phased adoption and implementation strategy tends to be successful (*Informants C1, 6 &11*).

Next, there are experiences of conflicts between knowledge requirements for using the new BIM tools and established/existing professional knowledge and skills of organisations' staff; this is, in the understanding that cognitive abilities and knowledge are tools, albeit intangible. Knowledge and skills as mental tools contribute to the mediation of the relationship between Subjects *(staff)* and their Object *(endeavour to which their efforts are directed).* Coping with the 'need state' created by a mismatch of new knowledge requirements and existing knowledge requires a lot of training and development as well as organisational knowledge management to ensure skills and knowledge are transferred between staff and also retained for sustenance (*Informants C1-11*). The third Tool vs Tool contradiction relates to the reported high cost of procuring the new BIM tools (software and associated applications). While the new tool is important for achieving organisations' objectives, it is also a strain on financial resources. This is a Tool *(financial resources)* vs Tool *(BIM infrastructure cost)* contradiction.

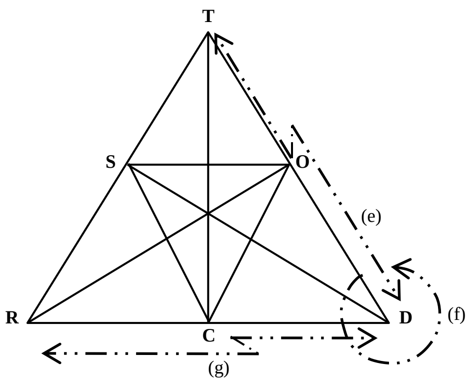


Figure 6.8: Tool vs Role (e); Role vs Role (f); and Role vs Rules (g) contradictions

With the introduction of BIM, the findings show that new BIM roles have emerged. This is often because transitioning to new technology is difficult for the organisations and the new role takers are needed to facilitate the process from within organisations (*Informants C1-7, 9 & 11*). The double-binds that come to the fore relate to either training existing staff to take up new/modified responsibilities or employing staff experienced in implementing BIM. These are

Tool *(emergent roles and competencies)* vs Role *(Role definition & distribution)* contradictions (*Figure 6.8* (e)). The findings further show that the latter is the dominant method or route taken. Therefore, roles are redistributed between existing staff and new BIM role takers within the organisation (*Informants C1, 2, 3, 4, 6, 7, 9 & 11*). This may in itself lead to role conflict; that is, Role *(existing roles/role takers)* vs Role *(new roles/new role takers)* contradictions, as in *Figure 6.8* (f). These may also create tensions within the system regarding power and authority structures, hierarchies and co-constructed interactional forms *inter alia* in a Role vs Rule contradiction (*Figure 6.8* (g)).

This notwithstanding, with the introduction of new BIM roles and the creation of new areas of professional competence (as tools) comes the need to modify existing rules within organisations. First, it is important to highlight the need to resolve the challenge in deciding between new staff hire or training existing staff against the constraints of organisational resources and budget (Tool *(resources)* vs Subject *(new staff hire)* vs Rules *(budget)*). It is important to note that financial resources are tools for organisations, whereas the budget is a rule that guides and constrains their operation. They are related, but not the same in this analysis.

Further, with the introduction of new BIM tools also comes the conflict between the demands for implementing them within existing organisational practice procedures as both tools and rules (plans and protocols are tools when they are employed to guide practice, but are rules when they are avenues to ensure compliance by organisations' staff). This conflict necessitates the creation of new practice guidelines, standards and protocols to suit the implementation of BIM. These (new guidelines and standards) become new tools and rules within the activity system. Nevertheless, certain aspects of the new technology adoption and implementation conflict with established professional guidelines and even organisational norms and culture.

Having taken the systemic constraints and contradictions from the empirical data into account, an evolved organisational context activity system is presented in *Figure 6.9*.

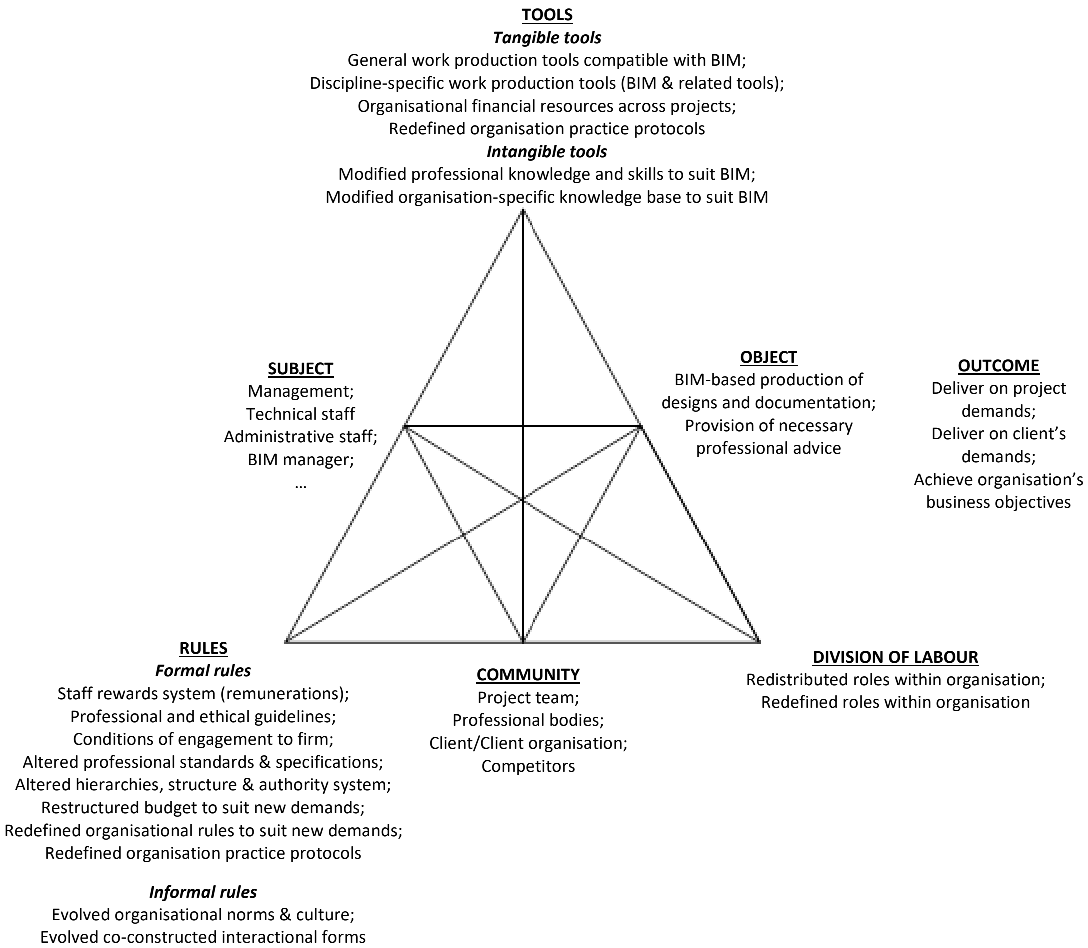


Figure 6.9: Evolved organisational context activity system upon impact by new technology (BIM)

In essence, the activity system evolves through the choices that organisations make in resolving a series of conflicts and contradictions brought about by the introduction of BIM and related applications. The analysis (as highlighted in *Figure 6.9*) confirms that the changes experienced are in terms of *how* professional work is done rather than *what* work is done or *why* work is done.

6.2.4 Project context activity system analysis of BIM-induced change

The project team activity system (PTAS) is multidisciplinary in nature and can also be either multi- or mono-organisational. The analysis provided here depicts a collaborative multi-disciplinary and multi-organisational project activity system. As has been shown in the analysis above, changing patterns of professional activity begins within individual organisations. Therefore, the successes or failures of collaborating organisations in dealing with their particular challenges may be transferred to the project team context. Further, collaborating organisations' knowledge and skills, as well as their discipline-specific work tools become tools for the project team activity, as depicted in *Figure 6.10*.

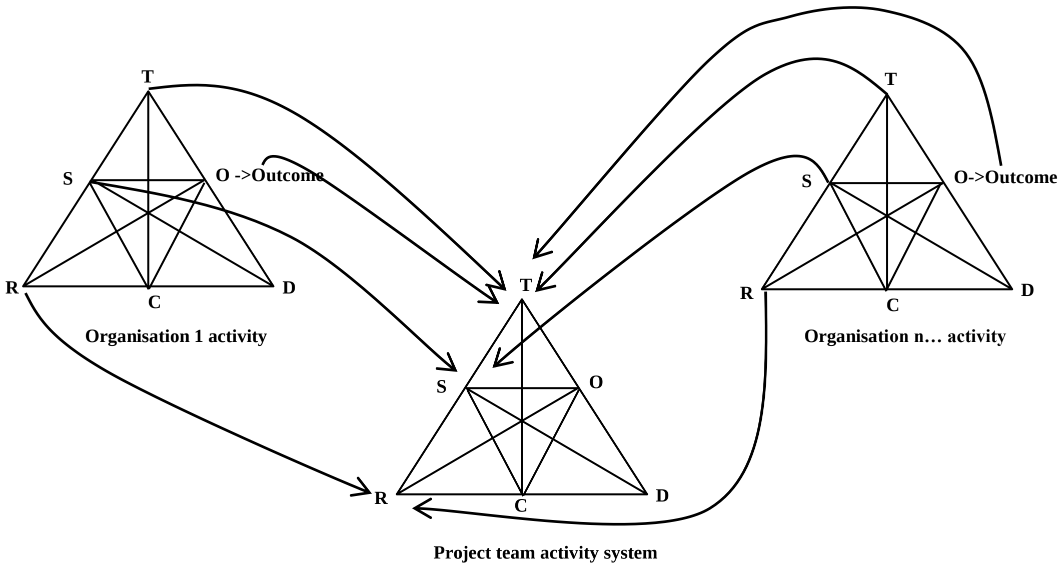


Figure 6.10: Influence of organisational activities on project team activity

(Organisation n… implies there may be any number of separate organisations involved in the team, not just two)

Furthermore, organisational-level rules are inevitably transferred in part to project level rules. For instance, in their account of one project on which BIM was implemented extensively (*Informant C11*), one of the organisations (a design firm and project team leader) impressed upon other project team members to produce information in conformance to their own pre-prepared BIM standards (as rules). Furthermore, some other organisational work production tools also became project team context activity tools. Therefore, some of the modifications made in the rules guiding organisational work also get transferred to project level activity rules. In effect, *ab initio*, the project team activity system is already changed. Nevertheless, varying methodologies exist for implementing the BIM coupled with varying levels of proficiency among collaborators brings about new contradictions within the tool element of the PTAS (contradiction between Tool *(organisation 1 tools & knowledge resource(s))* vs Tool *(organisation n… tools & knowledge resource(s))*), as in *Figure 6.11* (h). To resolve the demands of these new contradictions, several changes take place.

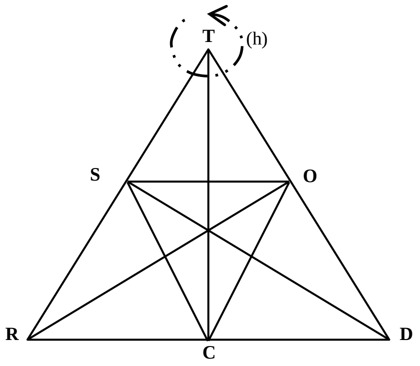


Figure 6.11: Tool vs Tool contradiction between inter-organisational tangible and intangible tools (h)

The first way of responding to these contradictions is to create new roles (within the project team structure), which in turn necessitates the redefinition and redistribution of roles to include that of BIM coordination. This further creates Role vs Role contradictions; that is, between existing professionals and newly-introduced BIM knowledge experts who take up the new roles for information coordination. Role conflict is likely in this circumstance but, since the project team is itself a self-organising entity, such conflicts are resolved fairly easily (*Informant C4*). This is even more so if the new role takers are able to demonstrate superior knowledge to command necessary power and authority to act and direct others to act (*Informants C3, 4 & 7*).

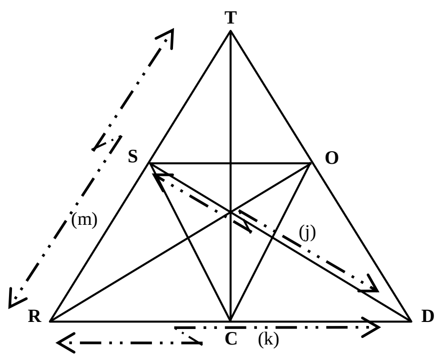


Figure 6.12: Subject vs Roles (j); Role vs Rule (k); Tool vs Rule (m) contradictions

The rules that guide work for the project team are also transformed through the resolution of contradictions. With the redistribution of roles as a result of the inclusion of new BIM role takers (*Figure 6.12* (j)), project team rules are modified to suit the new demands arising from incompatibility of new roles with existing pre-BIM Rules *(contracts, and guidance documents etc.)*, as depicted in *Figure 6.12* (k). Modifications to contractual provisions, project organisation structure and delivery procedures are made to facilitate BIM implementation on an ad hoc basis, project by project. Nevertheless, with increased use, efforts are made towards institutionalising new rules and practices by the Community *(government, professional bodies and client organisations)* to resolve the continued conflict in the system resulting from information asymmetry. Again, in the project team context activity system, a change in the system elements in terms of how work is done rather than what work is done and why it is done is evident. The evolved project team activity is shown in *Figure 6.13*.

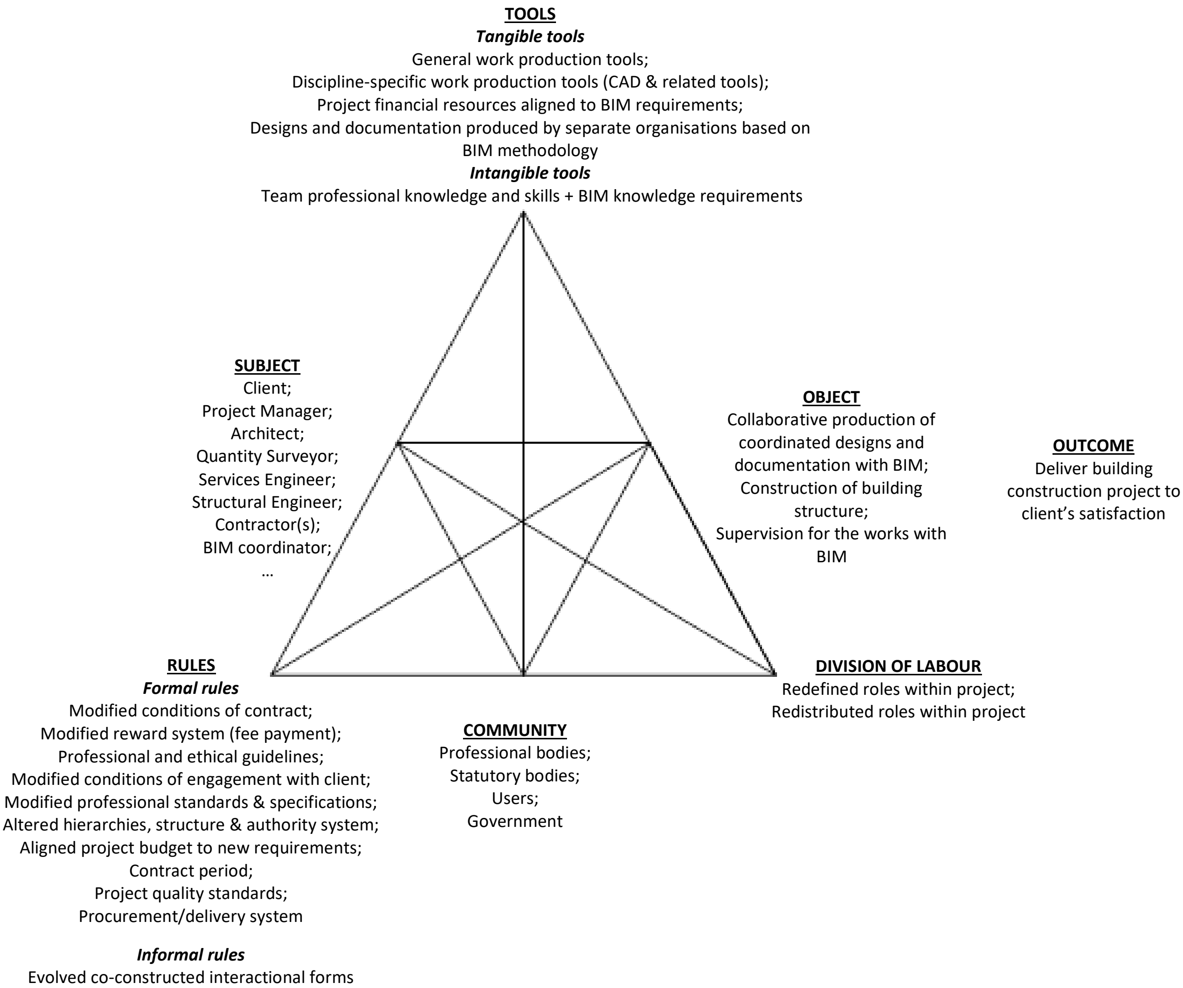


Figure 6.13: Evolved project context activity system upon impact by new technology

It is evident in *Figure 6.13* that the essence of the activity, meaning its outcome or 'why' the activity took place, remains the same. However, the means through which it is produced has evolved through the mediation of new tools and the change it propagates in the system.

6.2.5 Summary

Irrespective of any prompting, activity systems are non-static and normally in constant evolution. However, the analysis presented in this article only depicts the pattern of change due to the introduction of new technology (BIM and related applications), as was evident in the experiences of implementers. It does not account for the normal evolutionary tendencies of human work activities regardless of the induced change in the system. The analysis demonstrated the impact of implementing new technology on construction professional work practices, indicating conceptually that organisational-level evolution precedes that of project teams. It establishes that the nature of change induced by BIM is such that it does not change why work is done. Instead, the key changes are in the means through which work is done and how it is done. The findings contribute to knowledge in the following specific ways:

- They describe construction professional work activity as it evolves from a pre-BIM implementation state, to show how the dynamics of change within the different contexts of collaborating organisations can bring about the evolution of project context activity;
- An existing theory was employed in theoretically re-describing and explaining empirical findings on the impact that implementing new technology (BIM) has on professional work practices, while also providing theoretical explanation of their evolution into a newer form using a historical and analytical method; and
- This section presents a theoretical account of how activity systems analysis can be used in describing collaborative activity between construction project stakeholders, while conceptually highlighting the links between the organisational context activity system and project context activity system. It also theoretically and conceptually demonstrates the influence of organisational evolution due to BIM on project team activity or the work practices that comprise it.

The conceptual framework presented in this study is broad in its scope of possible applications. Future work would seek to explore its potentials in analysing the dynamics of work of a different nature and context in the construction industry.

The findings presented in this chapter provide unique theoretical perspectives of BIM induced change within organisations and project teams. However, as articulated in the problem statement, there is a need also for practical and objective evaluation of such changes. The need for an objective evaluation is addressed in the next chapter which employs a complement of MDM and swimlane modelling techniques.

7 MAPPING THE IMPACT OF BIM ON PRE-BIM WORK PRACTICES AT THE PRE-CONSTRUCTION STAGE

7.1 Introduction

Following from the interpretive analysis of BIM induced change in the pattern of organisational and project team work practices, this chapter presents an objective analysis of BIM impact on project team workflows is provided. In essence, an alignment of the requirements for implementing BIM to pre-BIM workflows is provided here.

7.2 Linking research findings from stage one to stage two of the study

Two key findings from the first stage of this study are being carried forward to inform this modelling stage. These are, first, that there is a need to, beyond theoretical understanding; practically understand the implications of implementing BIM on professional work practices. Second, it may be expedient to assign the role of information management to one of the core professional service providers without necessarily creating a separate (new) BIM role to perform the extra functions within project teams. This idea is supported by the PAS 1192-3:2013 document. More so, in the CIC Outline Scope of Services for the Role of Information Management, *"the role of Information Management is expected to be delivered as part of an existing appointment by a capable resource"* (CIC 2013a p. iv).

Furthermore, the CIC (2013) outlined the scope of services for the role of information manager in three key areas as follows:

Common Data Environment Management

- Establish a Common Data Environment including processes and procedures to enable reliable information exchange between Project Team Members, the Employer and other parties;
- Establish, agree and implement the information structure and maintenance standards for the Information Model;

- Receive information into the Information Model in compliance with agreed processes and procedures, validate compliance with information requirements and advise on noncompliance;
- Maintain the Information Model to meet integrity and security standards in compliance with the employer's information requirement; and
- Manage Common Data Environment processes and procedures, validate compliance with them and advise on noncompliance.

Project Information Management

- Initiate, agree and implement the Project Information Plan and Asset Information Plan covering:
  - Information structure across roles, e.g. software platforms (all levels of supply chain) appropriate to meet Employer requirements and Project Team resources;
  - Responsibility for the provision of information at each Stage;
  - Level of detail of information required for specific Project Outputs, e.g. Planning, Procurement, FM Procurement;
  - The process for incorporating as-constructed, testing, validation and commissioning information;
- Enable integration of information within the Project Team and coordination of information by Design Lead;
- Agree on formats for Project Outputs; and
- Assist Project Team Members in assembling information for Project Outputs.

Collaborative working, information exchange and project team management

- Support the implementation of the Project BIM protocol including updating the Appendices;
- Liaise with and co-operate with Project Team Members and the Employer in support of a collaborative working culture;
- Assist the Project Team Members in establishing information exchange processes, including:

    - Define and agree on procedures for convening, chairing, attendance and responsibility for recording information exchange process meetings;
- Participate in and comply with project team management procedures and processes including:
    - Risk and value management;
    - Performance management and measurement procedures;
    - Change management procedures including adjustments to budgets and programme;
    - Attendance at project and design team meetings as required; and
    - Agree and implement record keeping, archiving and audit trail for Information Model.

It is evident from the foregoing that the information management role as described by the CIC (2013a) if it would be assigned to a core professional service provider, would be best suited to the Project Manager and Lead Designer. Therefore, in the following BIM-enabled project delivery workflows, the Information Management functions have been assigned to the Project Manager while the integration of all design inputs within the team has been assigned to the Lead Designer (i.e. the Architect). Therefore, while the Architect maintains the Information Model to meet all integrity standards in compliance with the employer's information requirements, the Project Manager should still be responsible for all other non-design related Information Management functions.

7.3 Evaluating BIM impact on professional work practices based on the PAS 1192:2 (2013) and the CIC BIM Protocol (2013b)

Objectively evaluating the impact of implementing BIM on Pre-BIM delivery workflows requires the definition of a point of reference. Therefore, the PAS 1192:2 (BSI 2013) and the CIC BIM protocol (2013b) which have been developed through rigorous processes involving the UK government and construction industry professionals were selected as exemplars of BIM implementation methodology for the delivery phase of projects and at Maturity Level 2. Hence, a structured analysis of the contents of both documents was necessary. To this end, electronic versions of both documents were obtained and coded descriptively using a predefined set of codes describing impacts on the 'people', 'process', 'tools', and 'documents' elements of the pre-BIM project delivery workflow. The analytical coding structure is outlined in *Table 7.1*:

Table 7.1: Coding structure for content analysis of documents using CAQDAS

PROCESS	PEOPLE	TOOLS	INFORMATION/DOCUMENTS
SS – Structural sequence & dependence in tasks	R – Requirement for new, change in, or expansion of responsibility	CP – Software and tool compatibility issues	RDD – Redundancy of existing information/documents
SC – Structural composition of tasks	FR – Change in frequency of interaction with others	RDD – Redundancy of existing tools	RND – Requirement for new information/document(s)
RDD – Redundancy of existing tasks		RNT – Requirement for new tools to facilitate new tasks	RSC – Requirement for change in structure/content of existing information/document(s)
TM – Changes in time taken for tasks			RSF – Requirement for change in format of information/document(s)

Interestingly, the PAS 1192-3:2013 (analysed in *Table 11.3* of *APPENDIX 1*) was developed with the aim of ensuring that it requires a minimal change from existing ways of working. This analysis nonetheless shows that this is farfetched since several of the requirements extracted from the document (and so also for the CIC BIM protocol 2013) have implications on various aspects of the existing delivery process-people-tool-documents. It was therefore imperative that the highlighted issues be further analysed in-depth against existing ways of working to facilitate the understanding of BIM implementation impacts on them for collaborating teams the detailed analysis of these documents is in *Table 11.3* of *APPENDIX 1*.

The two documents were uploaded into CAQDAS (Nvivo 11) where the predefined sets of codes were assigned to highlighted portions of textual data that fit the descriptions as in each element shown in *Table 7.1*. The initial broad coding results were cross-tabulated against each other as presented in *Figure 7.1* using Nvivo 11 coding matrix functionality.

		A	B	C	D	E	F	G	H	J	K	L	M
DOCUMENTS	A : Redundancy (RDD)	2	1	2	2	0	1	0	1	1	0	0	0
	B : Requirement for change in format of documents (RSF)		6	6	3	1	5	1	6	6	1	0	1
	C : Requirement for change in structure of documents (RSC)			62	44	2	45	1	38	38	7	1	8
	D : Requirement for new documents (RND)				54	1	37	2	33	33	5	1	7
PEOPLE	E : Frequency of Interaction with others (FR)					6	6	0	5	5	3	0	4
	F : Responsibility (R)						100	1	73	73	12	3	13
PROCESS	G : Redundancy (RDD)							2	2	2	0	0	0
	H : Structural composition (SC)								82	82	11	2	14
	J : Structural sequence & dependence (SS)									82	11	2	14
TOOLS	K : Compatibility (CP)										17	4	12
	L : Redundancy (RDD)											4	4
	M : Requirement for new tools (RNT)												17

Figure 7.1: CAQDAS Cross-tabulation of the number of coded text by coding category

Figure 7.1 shows the number of highlighted sections of texts (from the two documents) that fit, and were assigned to each coding category in the diagonal edges of the matrix. Furthermore, since this is a simple cross-tabulation, the 'top of diagonal' marks are an exact transpose of the 'bottom of diagonal' marks. Tracing along each node horizontally also gives indications of the 'degree of association' of that node to other nodes converging with it vertically on respective edges along the trace. The Nvivo 11 coding matrix function (cross-tabulation) was used for this purpose since it is able to check for coding exclusivity. However, it became useful for deriving MDM-like matrices that show which coded portions of text relate to which categories of codes and to show overlaps. In this way, overlaps in coding represent some form of association between the coded concepts/constructs involved.

Using *Figure 7.1* therefore, a number of important inferences can be drawn. First, the coding category with the highest number of coded text is *'Responsibility'*, which relates to need for new, changing, or expanding responsibilities of project team members due to implementing BIM (100 items coded), followed by changes to task *structural composition, sequence, and dependence* (82 items coded for each). Next are *requirement for changes in structure/contents of existing documents* and *requirement for developing new documents to facilitate delivery* (62, and 54 items coded respectively). Further, it can be observed that coded impacts on project team responsibilities are mainly associated (and logically so) with impacts on task composition and sequence. Notably, *changes in structure/contents of existing documents* and *requirement for new documents* are mainly associated with changes in team member responsibilities. The coded chunks of textual data from the two documents were further refined and displayed in *Table 11.3* of *APPENDIX 1* along with analyses of their implications on the existing way of working for project teams. Importantly, these analyses are the main basis upon which pre-BIM workflows were remodelled into BIM supportive workflows in the following sections.

7.4 The COBie-UK (2012) requirements

One key requirement of a BIM-enabled project is for information (graphical and non-graphical) to be collected, validated and stored in a form that is transferrable from pre-construction to the construction stage and upon completion, transferred to the owner, as only then would the real value of implementing BIM be realisable (Love et al. 2014). The UK COBie data format for the publication of building model information provides an avenue for achieving this.

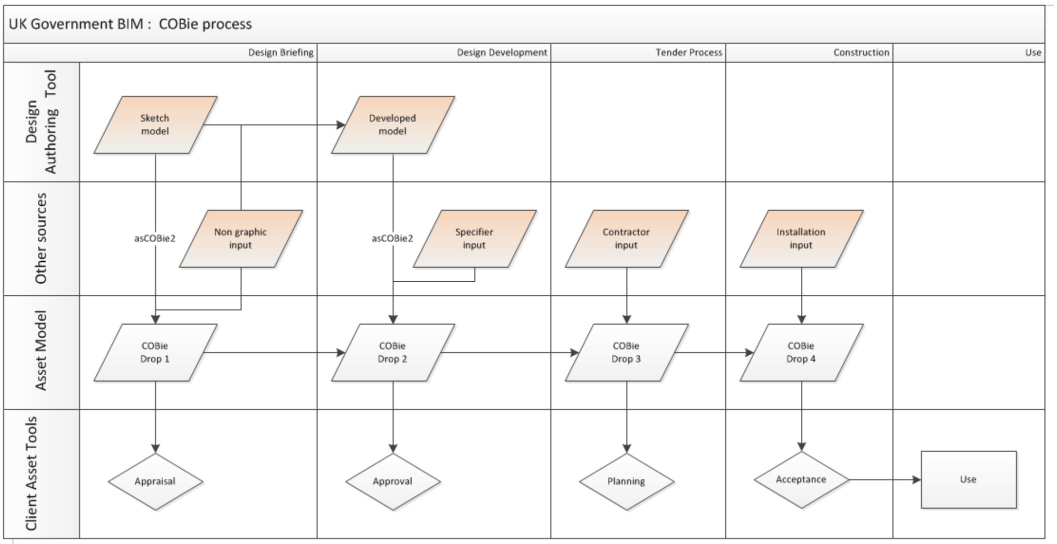


Figure 7.2: COBie data drop requirements by project stages
Source: Nisbet (2012)

From an owner-perspective, COBie may be required to be delivered by the lead designer as well as the main contractor to aid facilities management post-completion (Nisbet 2012). For this purpose, the transferred building data may be stored as delivered or integrated with facilities management and operations applications. Abanda et al. (2015) provided examples and a review of applicable systems.

COBie also enables the project team to document knowledge about the facility physically and spatially. Therefore the COBie, similar to the industry foundation classes (IFC) is *"a data schema for holding and transmitting information to the owner post-completion to aid facilities management and operations"* (Nisbet 2012 p. 8). There is a requirement for data drops (delivery of information) in about five main stages of the project lifecycle as depicted in *Figure 7.2*. These include:

- Drop 1 – brief/early design stage
- Drop 2a – design development
- Drop 2b – tender submission
- Drop 3 – Contractor's design development and planning
- Drop 4 – Handover

However, since the workflows presented in this study cover only the pre-construction stage, only the first three data drops were included. Furthermore, the PAS1192:2 recommends that COBie data drops should be done prior to issuing information to the SHARED or PUBLISHED sections of the CDE. Therefore, in the workflows that follow, COBie data drops were structured to be carried out by the Project/Information Manager prior to publishing information. In the workflows, the Data Drops are done at the Concept Design, Detailed Design and Contractor Procurement (tendering) phases.

7.5 Workflow remodelling methodology

The building construction delivery process is inherently complex. Therefore modelling all relevant aspects of the process is impractical as there are a limitless number of possible scenarios for different project processes. Thus, this process remodelling effort was directed at modelling enough detail as might be necessary to generically depict a project process at the pre-construction stage and at a medium-level abstraction. This is similar to the work of Kagioglou (2000) although this study did not seek process improvement, rather process alignment.

Expectedly, at a high-level abstraction, it was impossible to separate/demarcate the functions, roles and responsibilities for tasks within a multidisciplinary project setting. It is also difficult to objectively analyse the change in the process. Whereas, modelling a project delivery process at the very low level of abstraction would require project and scenario-specific information. Consequently, while the workflows are intended for practical applicability, the overarching aim of this analysis was to provide an understanding of how implementing BIM tools and processes impacts multidisciplinary project delivery workflows. This is with a focus on interfaces and information exchanges between professionals/organisations rather than an emphasis on intra-organisational workflows.

In the next section, the pre-BIM workflows describe how work is currently done in a multidisciplinary infrastructure project setting in South Africa while the BIM-enabled workflows show and alignment of BIM requirements to the existing way of working.

7.6 Analysing the impact of implementing BIM on existing project team workflows using swimlane models

The workflows that follow are based only on the requirements identified in documents analysed. Since this is not an attempt to replicate the contents of those documents, the workflows are therefore intended to be read in conjunction with the PAS1192, the CIC BIM Protocol, the CIC Outline Scope of Services for the Role of Information Management and the COBie UK guidance document.

The analysis in this section is presented in the following order as shown in *Figure 7.3*.

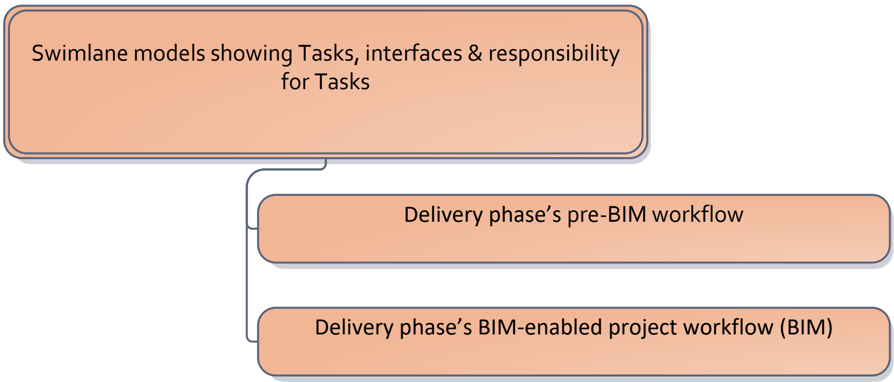


Figure 7.3: Structure for presenting swimlane workflow models

List of abbreviations

IT	Information Technology
CAD	Computer Aided Design
2D	Two Dimensions/Dimensional
3D	Three Dimensions/Dimensional
4D	Four Dimensions/Dimensional
5D	Five dimensions/Dimensional
6D	Six Dimensions/Dimensional
BIM	Building Information Modelling
DSM	Design Structure Matrix

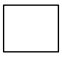
DMM	Domain Mapping Matrix
MDM	Multi-Domain Mapping Matrices
BAST	BIM Authoring Software Tool
EIR	Employer's Information Requirements
PIIP	Project Information Implementation Plan
TIDP	Task Information Delivery Plan
MIDP	Master Information Delivery Plan
CDE	Common Data Environment/platform
RFI	Request for Information

Figure key

In the following models:

Newly introduced tasks (entirely new) are colour –

Existing (pre-BIM) but modified tasks are colour – 

Unchanged tasks are colour – 

Feedforward lines are – →

Feedback lines are – ←

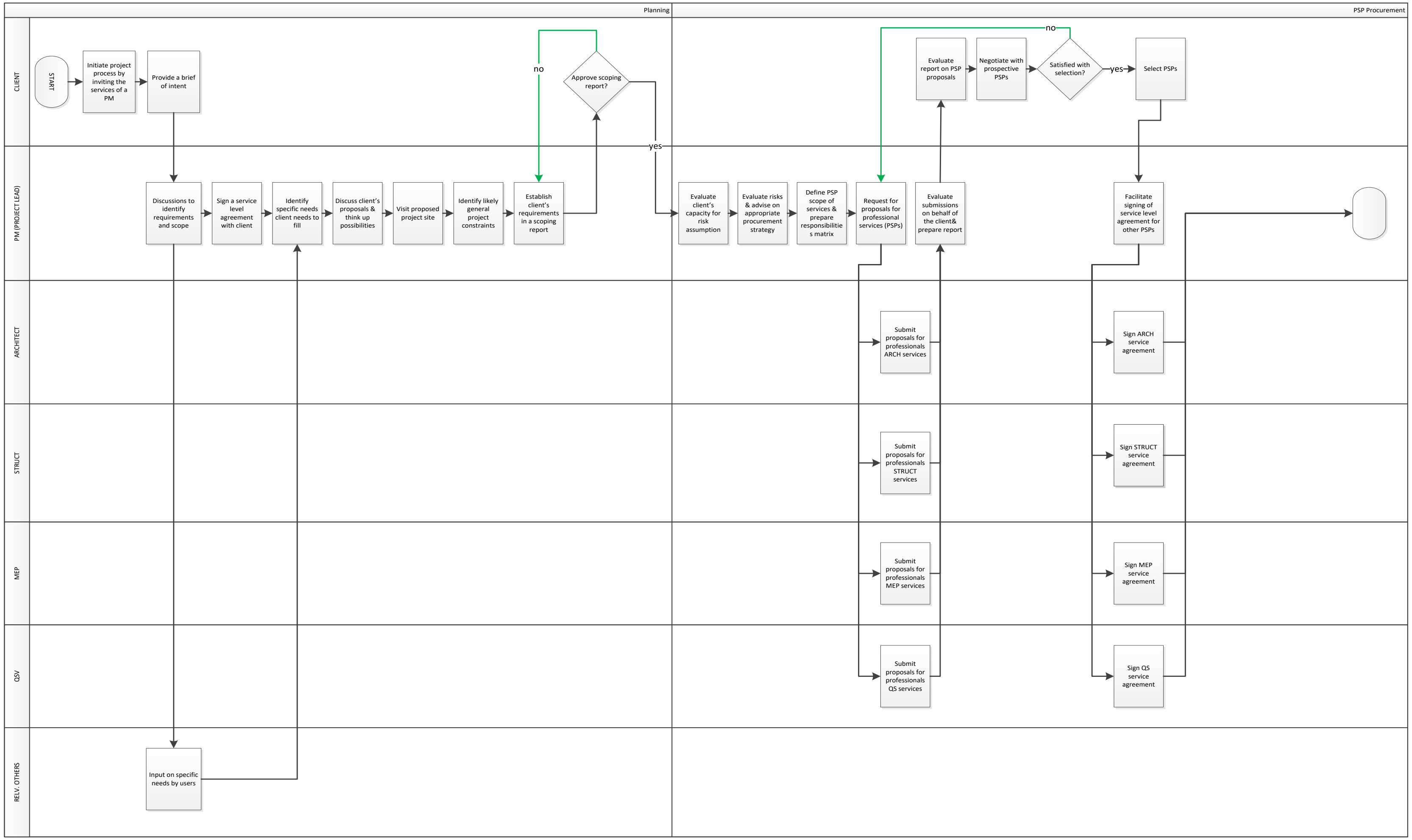


Figure 7.4: Planning & CPSP procurement workflow (pre-BIM)

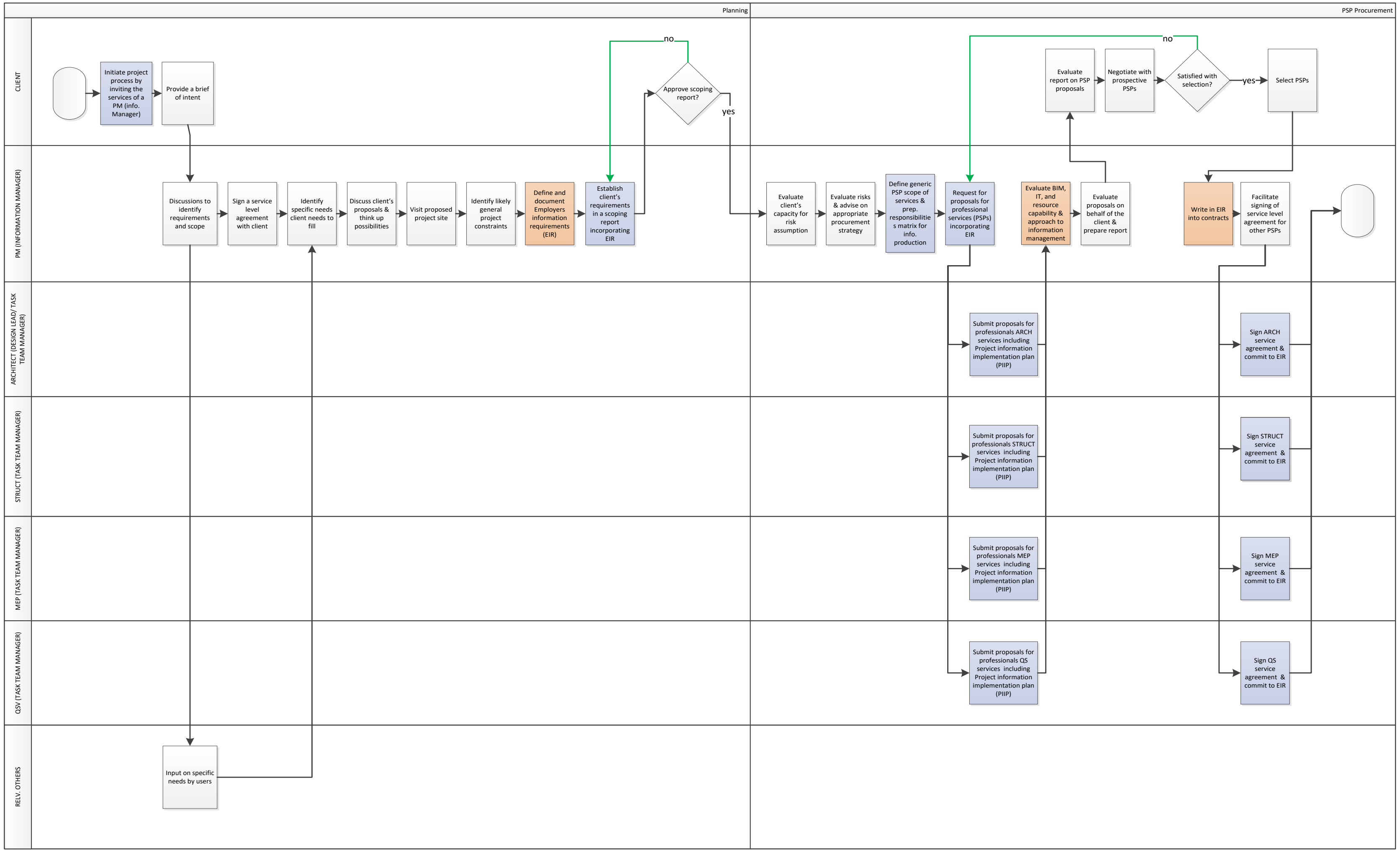


Figure 7.5: Planning & CPSP procurement workflow (BIM)

7.6.1 Project Planning Phase

At the project planning stage, there are very important modifications to the pre-BIM process to facilitate a BIM-enabled project as is evident in *Figure 7.4* and *Figure 7.5*. First, the client takes the decision to appoint a project manager ahead of other construction professional service providers (CPSPs). Importantly, the project manager is also appointed to carry out the additional functions of BIM management. This requirement already presumes the capability and capacity of the PM firm to coordinate the delivery of BIM-enabled projects with a proven track record. Although in practice, it is common for the BIM management or BIM coordination role to be standalone from core construction professional roles, the justification for the role's merger with that of project management revolves around the lack of sustainability of standalone BIM roles. This has been argued in this chapter.

One of the primary functions the project manager performs as information manager is to assist the client in developing the employer's information requirements (EIR). This is a schedule of project information requirements defined at the inception of the BIM-enabled project. Essentially, it describes in general terms, information required by the client to be created, managed and delivered by the client's agents and contractor, and in what form in the course of delivering a BIM-enabled project. The EIR should be documented and incorporated into the scoping report along with other client requirements conventionally documented in the clients brief. This is a crucial step to be taken at the inception of a BIM-enabled project as it sets the tone for the management of project information in the project lifecycle. While the EIR should typically originate from the client or client organisation, this framework was designed on the assumption that the client is not capable of articulating the project information requirements succinctly enough and would, therefore, require help from the PM/Information Manager who should be appointed early on to assist with such matters.

Specifically, the EIR should contain *inter alia*:

- Levels of detail – e.g. requirements for information submissions at defined project stages. This is needed to populate the Model Production and Delivery Table required under the Protocol;
- Training requirements – not likely to be mandatory;
- Planning of work and data segregation – requirements for bidders' proposals for the management of the modelling process (e.g. model management, naming conventions, etc.);
- Co-ordination and clash detection – requirements for bidders' proposals for the management of the coordination process;
- Collaboration process – requirements for bidders' proposals for the management of the collaboration process;
- Requirements for bidders' proposals for BIM/CDE management
- A schedule of any security and integrity requirements for the project;
- A schedule of any specific information to be either excluded or included from information models; and
- A schedule of any particular constraints set by the employer on the size of model files, the size of extranet uploads or emails, or the fi le formats that can define the size of a volume (BSI 2013).

However, it may be impracticable for all of these to be provided in detail at the inception of the project.

7.6.2 Construction Professional Service Provider (Consultants) procurement phase

For BIM-enabled projects, there will be significant changes to this phase of the delivery process (as can be seen in *Figure 7.4* and *Figure 7.5*). First, in the definition of CPSP's generic scope of services, the PM/Information Manager would need to incorporate relevant aspects of the EIR into the terms of reference base on which prospective consultants would tender for jobs. This is then further incorporated into the Request for Proposals for professionals services sent out to prospective CPSPs. The Request for Proposals for professionals' services would also include BIM and IT capability assessment forms as well as request to propose information creation, sharing, and management methodologies. This should include an indication of preferred software and IT tools all of which are written into the Project Information Implementation Plan (PIIP).

As Information Manager, the PM also has the responsibility for evaluating the PIIPs submitted by each potential CPSPs bidding for Architectural, Structural Engineering, Mechanical Electrical and Plumbing Services Engineering, and Quantity Surveying services (these are the most basic set of CPSPs for building construction projects). Particularly, the PM/Information Manager would evaluate the IT, BIM and resource capabilities stated in the PIIPs as well as their approach to information management even ahead of evaluating project-specific technical content of their proposals for providing professionals services. Demonstrable capability to participate in a collaborative BIM-enabled project delivery process is a pre-requisite for engaging the CPSPs. Further, after the preferred project professionals have been selected, they will be required to commit to providing the EIR as specified by the client. Service level agreements would, therefore, be modified to include the EIR.

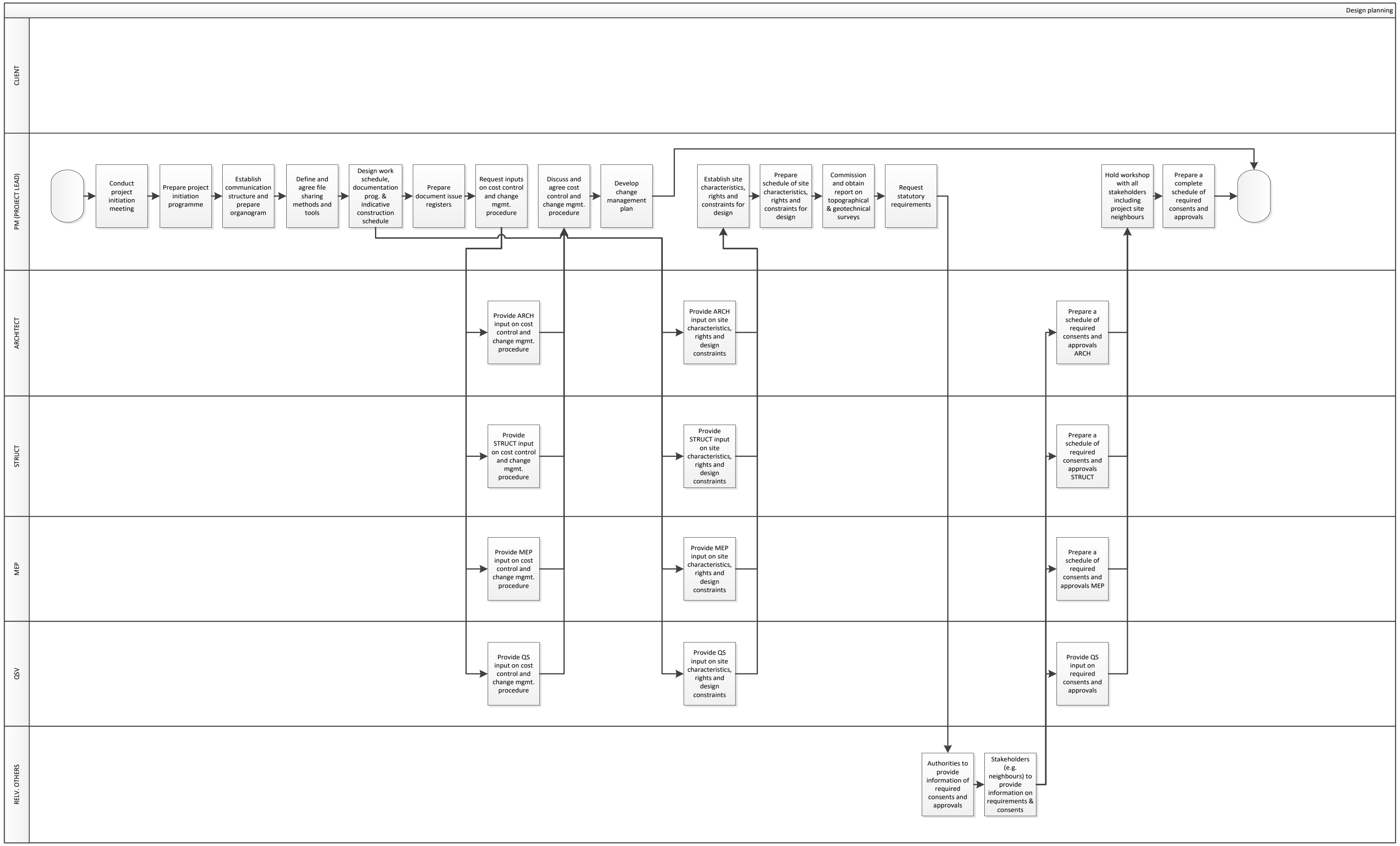


Figure 7.6: Design planning workflow (pre-BIM)

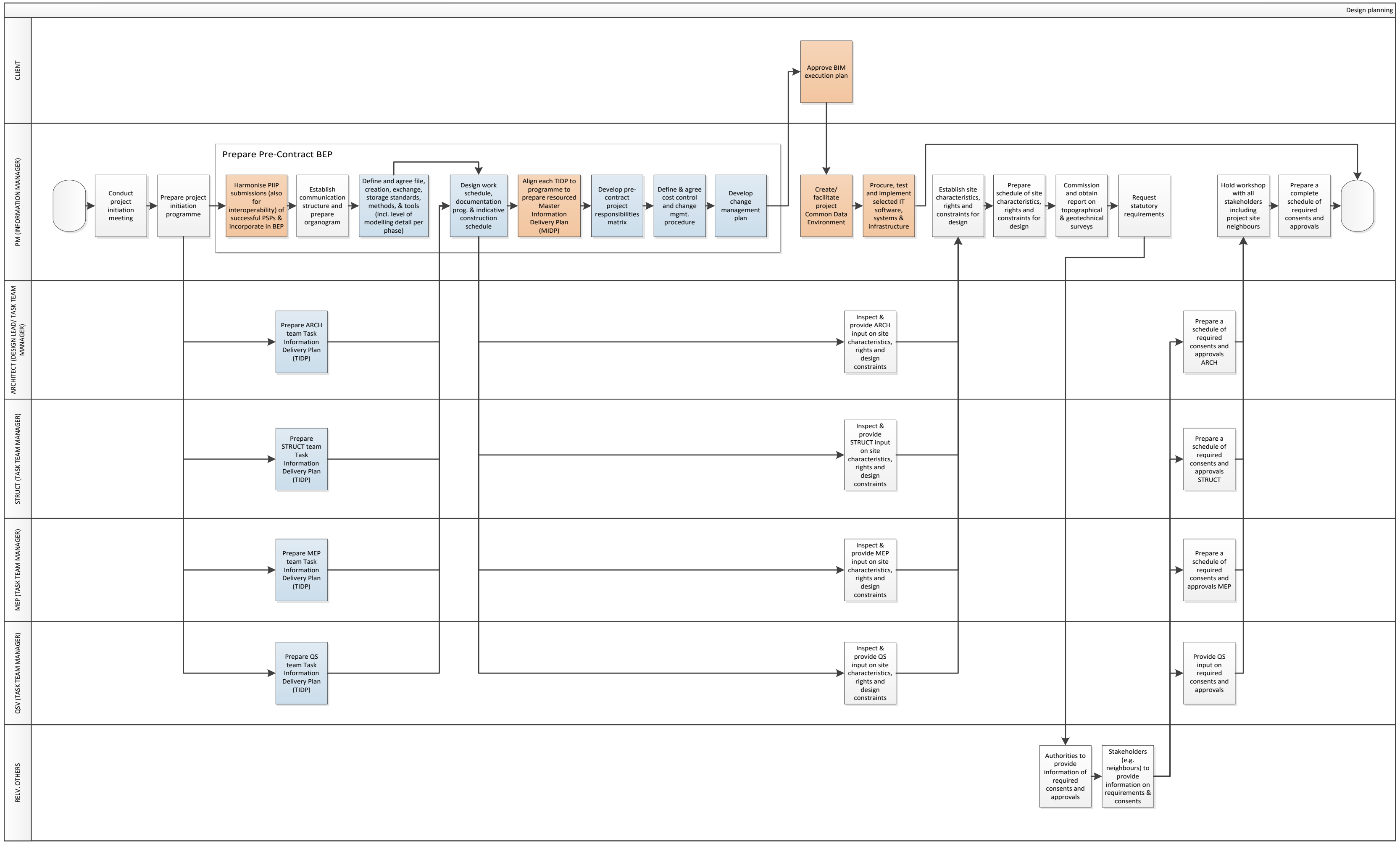


Figure 7.7: Design planning workflow (BIM)

7.6.3 Design planning phase

In this phase (depicted in *Figure 7.6* and *Figure 7.7*), there are several new important steps to take as well as a modification of existing ones to facilitate the execution of a BIM-enabled project. Since different CPSPs would have submitted diverse proposals for information creation, sharing and management, there would be a need for harmonising the different proposals into specifics of IT systems, data exchange methodologies and standards all with a focus on achieving interoperability. This is an important step because non-interoperability of tools and processes would defeat the purpose of taking a structured approach to implementing BIM on projects.

Further, as part of the preparation of a pre-contract BIM execution plan by the PM/Information Manager, there is also need to document the definition and agreement to the file creation exchange, storage and management standards methods and tools. This record would include levels of modelling detail specification for each project element/component and at every project phase. This would be followed by the design of a work schedule and documentation programme inclusive of an indicative construction schedule. It should be noted though that this is not are not new requirements for projects but they take different forms for BIM-enabled projects. Similarly, each CPSP produces resourced task team information delivery plans (TIDP) for their team/organisation. Based on these, the PM/Information Manager prepares a resourced master information delivery plan (MIDP) (to include persons responsible for carrying out tasks). This is an alignment of all TIDPs to resources and also to the indicative project programme.

Next is the need for developing the pre-contract project responsibilities matrix, the definition of cost control and design change management procedures and development of a change management plan all of which are not new requirements for projects but take on different forms or are done differently for BIM-enabled projects. They are nonetheless essential components of a BIM project execution plan. The pre-contract BEP also required approval by the client for assurance of the plans capability to ensure the fulfilment of the EIR.

Further, the PM/Information Manager (his/her organisation) is assigned the responsibility to create and maintain a common project data environment (CDE) upon which all project communications will take place. The CDE is one of the most important requirements for a BIM-enabled project. Some projects would employ the use of cloud storage applications for sharing project data, but the CDE offers much more than just a platform where project files can be accessed and downloaded. It should provide essential capabilities for document/knowledge management. The CDE should provide an avenue for controlled access to sharing and download/reference project information depending on the project team member role. Essentially, the CDE is central to achieving BIM-enabled project objectives. IT is an IT platform controlled by the PM/Information Manager. Its key functions are to aid a central location for all project information with regulated/controlled access for adding and retrieval of project information by participants.

The CDE would typically consist of a Work-In-Progress (WIP) section in which on-going and unapproved team member/organisational work are stored. However, consultants' Work-In-Progress section is differentiated from the contractors' WIP section of the CDE. The CDE also has a SHARED section where all information approved by the PM/Information Manager is stored and shared for access by other team members other than the team member from which the information originates. From the SHARED section, information is made available for reference, integration with other team members' model or information and design review by the Architect/Lead Designer. Approval of information into this section of the CDE platform requires shared information to pass model suitability, technical content and data completeness checks by the PM/Information Manager. The design of this framework was made to allow each originator of approved information the responsibility to move/upload them into the SHARED section of the CDE by themselves so that responsibility for data integrity may still largely rest with the originator.

The PUBLISHED section of the CDE is where all information models are issued to after, integration, clash detection, and clash resolution have been carried out by the Lead Designer. This section holds information that has been reviewed and approved as suitable for communication to the client, construction and archival on the ARCHIVE section of the CDE. All published and archived information/project information models are such that they can be transferred to operations and maintenance as-built asset information. In addition to the procurement, operation and maintenance of the CDE, the PM/Information Manager also procures tests and implements all selected IT software systems and tools as required.

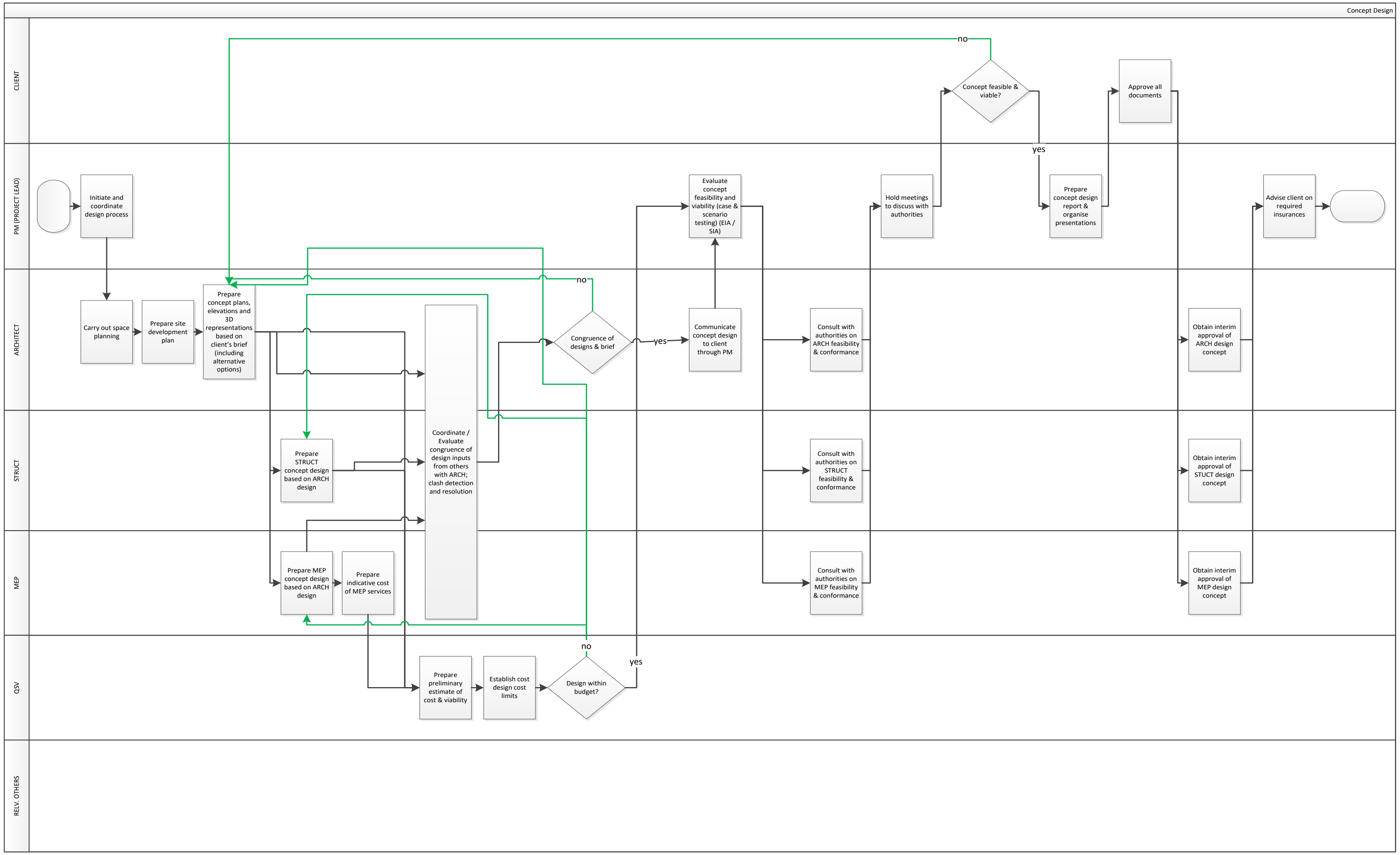


Figure 7.8: Concept design workflow (pre-BIM)

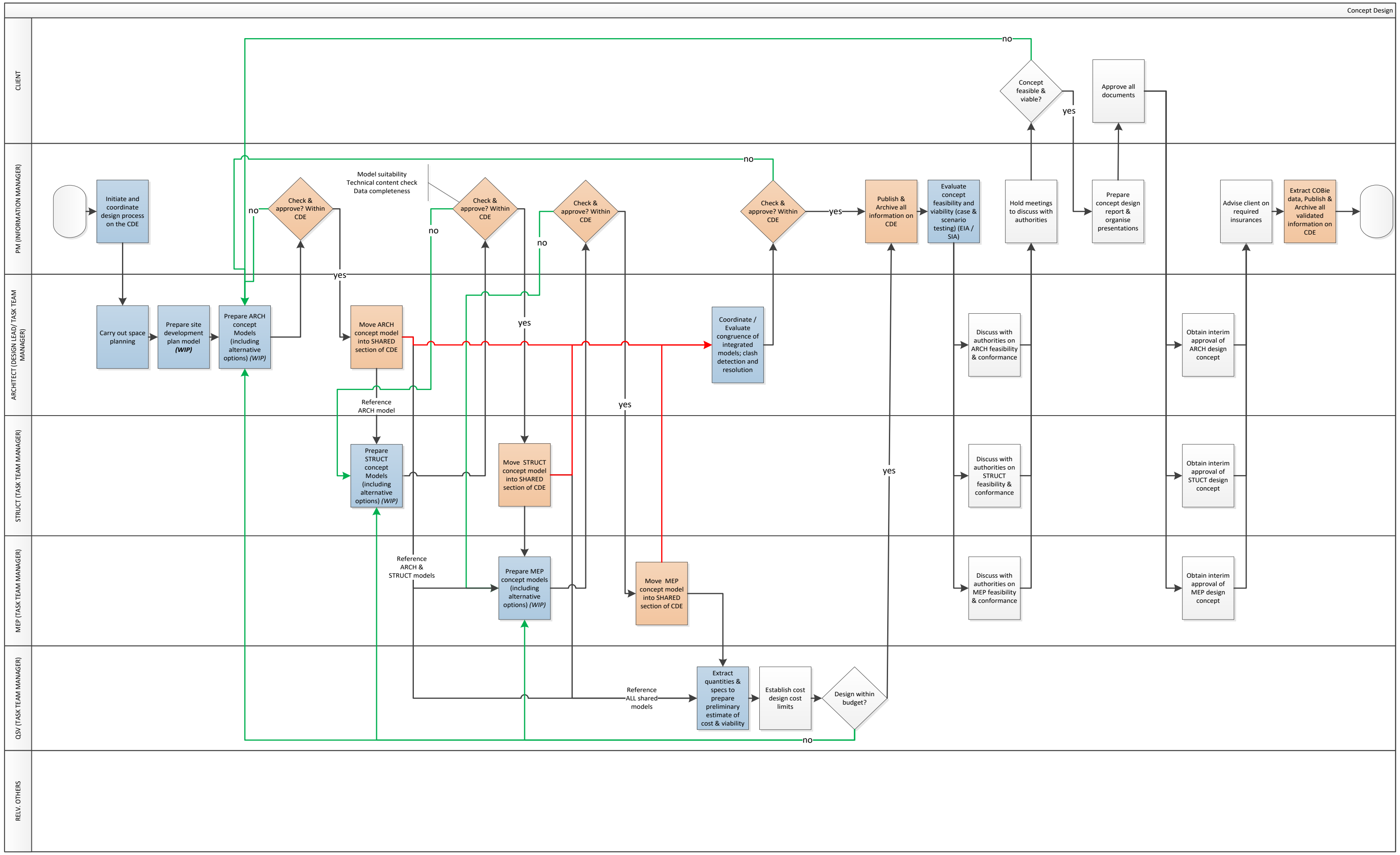


Figure 7.9: Concept design workflow (BIM)

7.6.4 Concept design phase

Design workflows (depicted in *Figure 7.8* and *Figure 7.9*) are the aspect of project delivery with the highest impact from implementing BIM on projects. The modelling methodology or approach to design implies in the first instance that the first three steps in the framework above are carried out differently from the conventional way since only 3D data-rich models are employed rather than 2D designs. The development of the design concept, therefore, follows the workflow described for the operation of the CDE. In addition, the framework provides for the Quantity Surveyor to reference shared information from designers to extract quantities and specifications, prepare preliminary estimates of cost and viability. This information created by the Quantity Surveyor is thereafter shared and published with controlled access on the CDE by the PM/Information Manager.

All design review and coordination are led by the Architect/Lead Designer. This may also necessitate the collocation of all project team members to resolve specific challenges as would be required for conventional project delivery workflow. An important advantage of the BIM modelling methodology is that more design scenarios and options may be simulated and tested for feasibility early on before the design concept is developed into full detailed designs. At the culmination of this phase, all information/data are verified, extracted into COBie data (all graphical and non-graphical data) and thereafter, published and archived on the CDE.

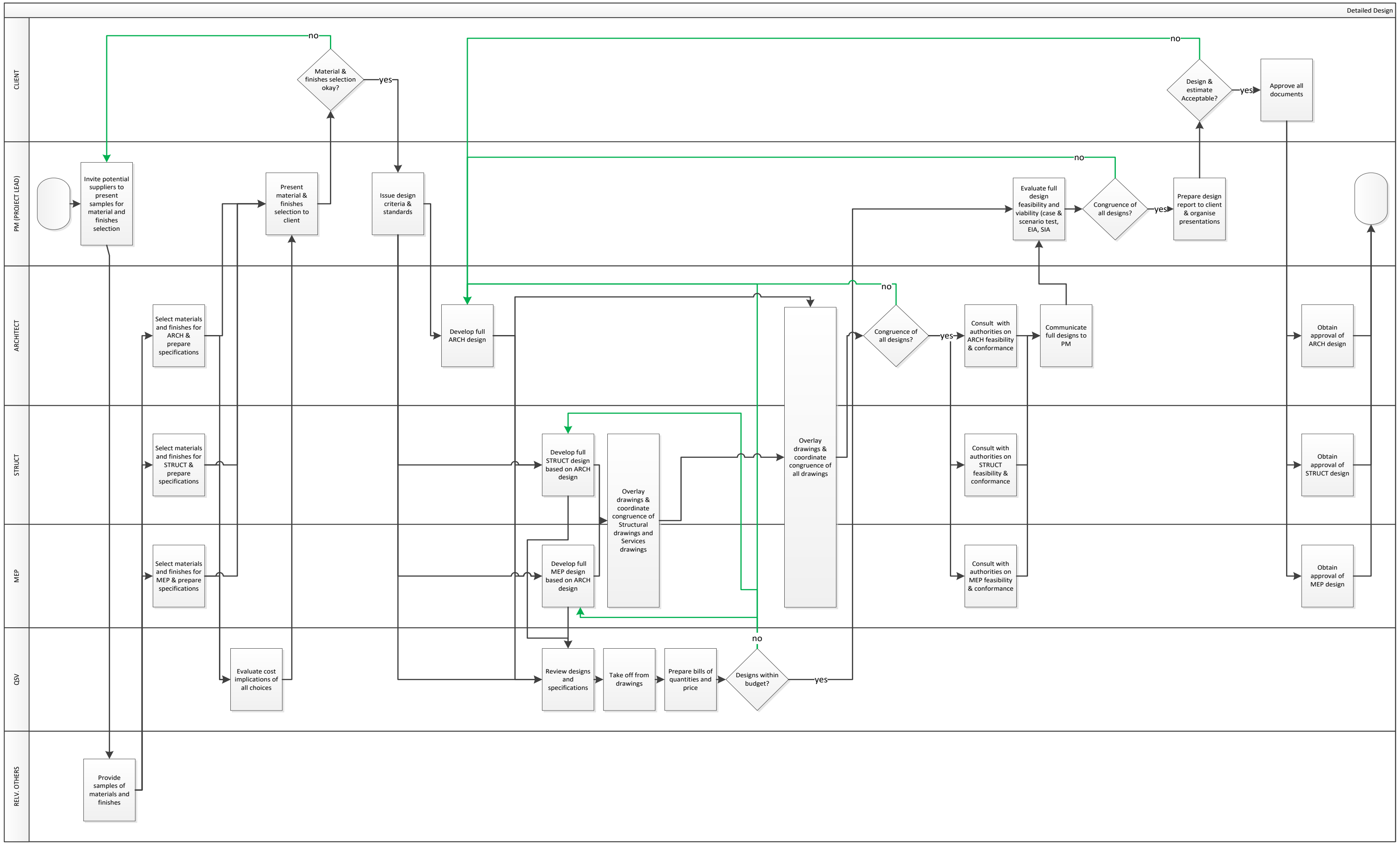


Figure 7.10: Detailed design workflow (pre-BIM)

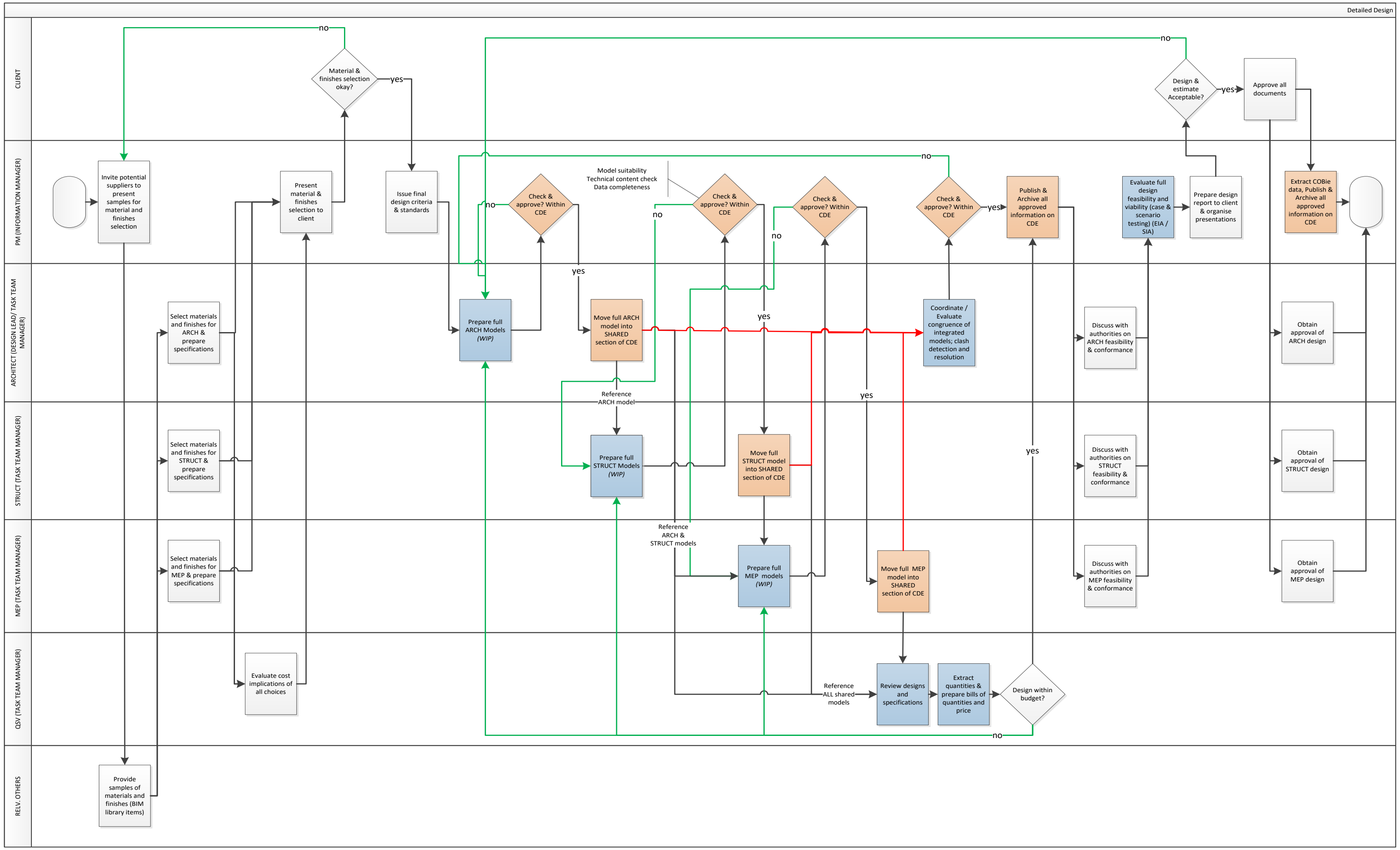


Figure 7.11: Detailed design workflow (BIM)

7.6.5 Detailed design phase

The detailed design stage BIM workflow (depicted in *Figure 7.10* and *Figure 7.11*) is quite similar to the concept design stage workflow. Essential components of the concept and design workflow are the new requirements for checking and approval of shared models. These checks are mainly for model suitability, technical correctness and data completeness. They are carried out by the PM/Information Manager who then approves for uploading into the shared section of the CDE for reference and use by others. As a result, these checks are decision points or workflow gates which could either mean work progresses unto the next step if it meets set standards of quality or otherwise needs to be reworked by the PM/Information Manager. It may be surmised therefore that the modelling process as described does not necessarily eliminate all rework in the process due to unidentified and unresolved design clashes which might have even been carried on into the construction phase of the delivery process. At the culmination of this phase also all information/data are verified, extracted into COBie data formats (including all graphical and non-graphical data) and thereafter, published and archived on the CDE.

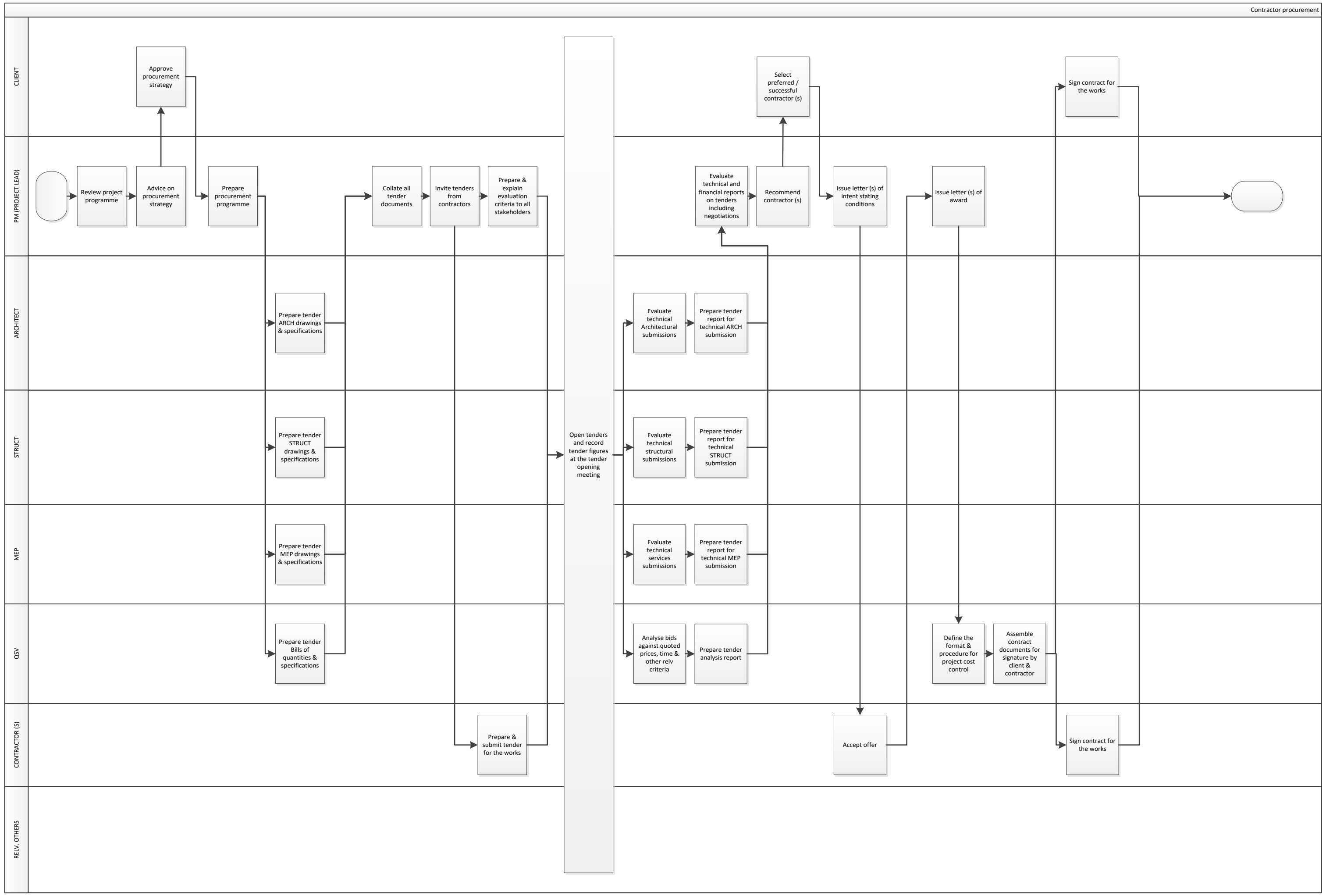


Figure 7.12: Contractor procurement workflow (pre-BIM)

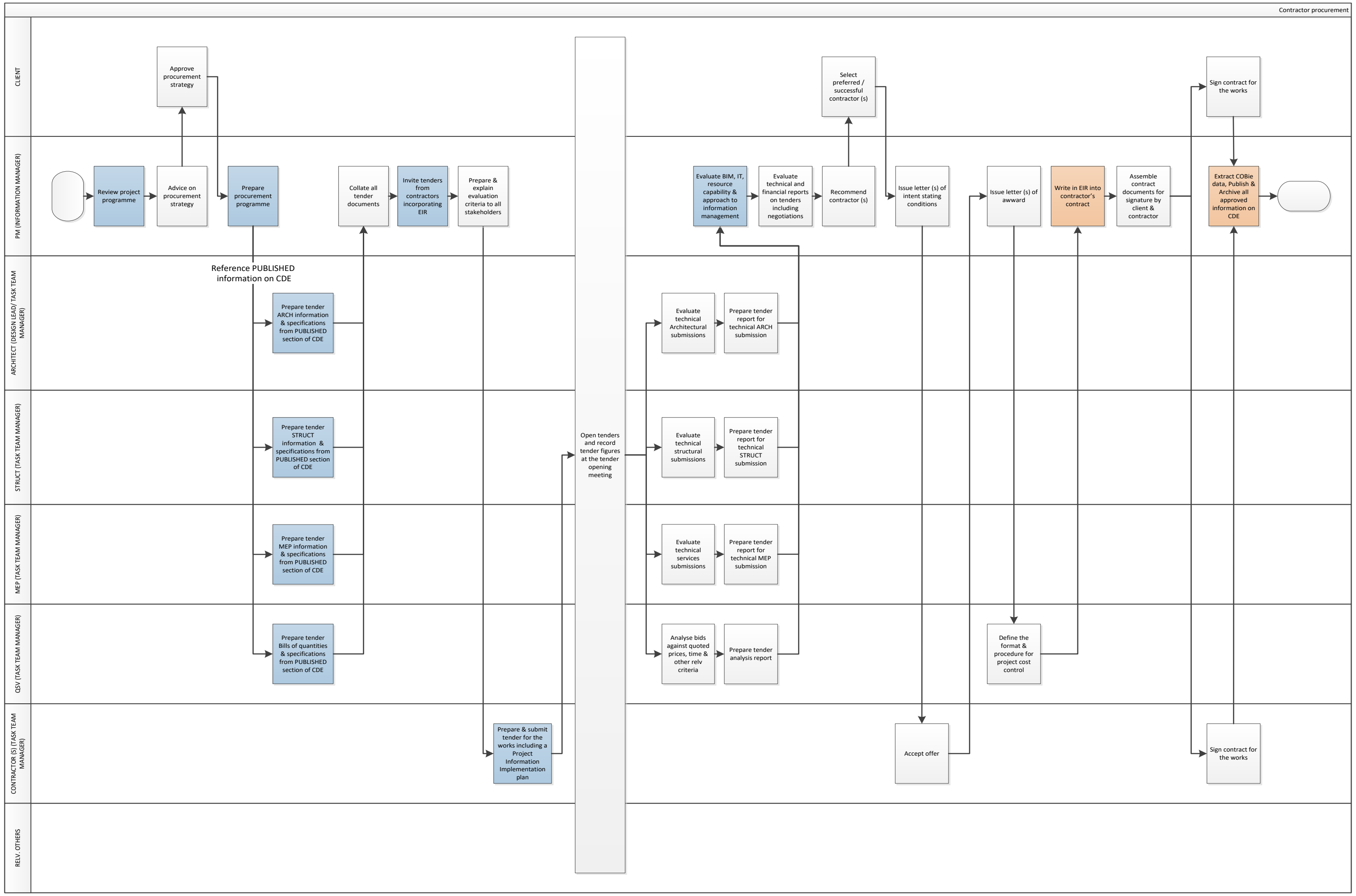


Figure 7.13: Contractor procurement workflow (BIM)

7.6.6 Contractor Procurement phase

The key impact of implementing BIM at this stage as described in this framework (*Figure 7.12* and *Figure 7.13*) include that all tender documents are prepared from only the PUBLISHED section (vetted and approved by the PM/Information Manager and Architect/Design lead) of the common data exchange platform. Tender documents for procuring contractors' services are prepared to incorporate the EIR just as it was done for CPSP procurement. This would offer the PM/Information Manager the opportunity to assess the contractors' capability in terms of resource persons' IT, BIM capability as well as the contractors' approach to information management. This step is crucial as the failure to appoint competent contractors with requisite BIM knowledge and proficiency could be detrimental to the success of the project. It is essential that all project team members are able to collaborate with BIM at the same level. Without this non-interoperability of tools and business processes are inevitable. Further, the EIR is written into the contractors' contract to ensure that it is committed to. Finally, all procurement information would then be verified extracted into COBie data formats and published by the PM/Information Manager in the PUBLISHED section of the CDE and archived, all with controlled access.

7.6.7 Summary

Using swimlane modelling, BIM implementation requirements drawn from the PAS1192:2 guidance document, CIC BIM Protocol, and the CIC Outline Scope of Services for the Services of the Information Manager have been aligned to the pre-BIM workflows. Since the DSM/MDM modelling methodology was argued as an alternative but more analytical approach, in the next section, the results of the analysis of the same data presented as swimlane models are presented using MDM analysis of the workflow structure.

7.7 MDM modelling and analysis of the Pre-BIM and BIM-enabled pre-construction workflows

The MDM modelling methodology as has been argued previously enabling concise and adaptable representation of information. Its use here is complementary to the swimlane process models presented in the preceding section although it can stand-alone on its own. The MDM has the advantage in its ability to represent more information concisely, and in a relatively smaller space while providing an avenue for far more in-depth analysis than is possible with swimlane process modelling methodology. The MDM methodology (using LOOMEO software) was therefore explored to assist in modelling the pre-construction stage workflows in more detail and also provide further insight into the differences in structural characteristics of the pre-BIM and BIM-enabled workflows as in the next section.

7.7.1 General description of the structural characteristics of the pre-BIM and BIM-enabled project delivery workflows

Figure 7.14 and *Figure 7.15* show the LOOMEO screenshots of the pre-BIM and BIM-enabled MDM models each consisting of 3 DSM models (shown in the diagonal matrices) and 2 DMM models. These are the Task-Task DSM, People-People DSM, Information/Documents-Information/Documents DSM, Task-People DMM and Task-Information/Documents DMM respectively.

Two types of information were modelled; two binary DSMs, (Task-Task, and Information/Document-Information/Documents relationship DSMs) and one ternary DSM (People-People DSM) showing intra-team interfaces/interactions. A complete schedule of MDM models showing all tasks, roles and information/documents modelled can be found in *APPENDIX 2*.

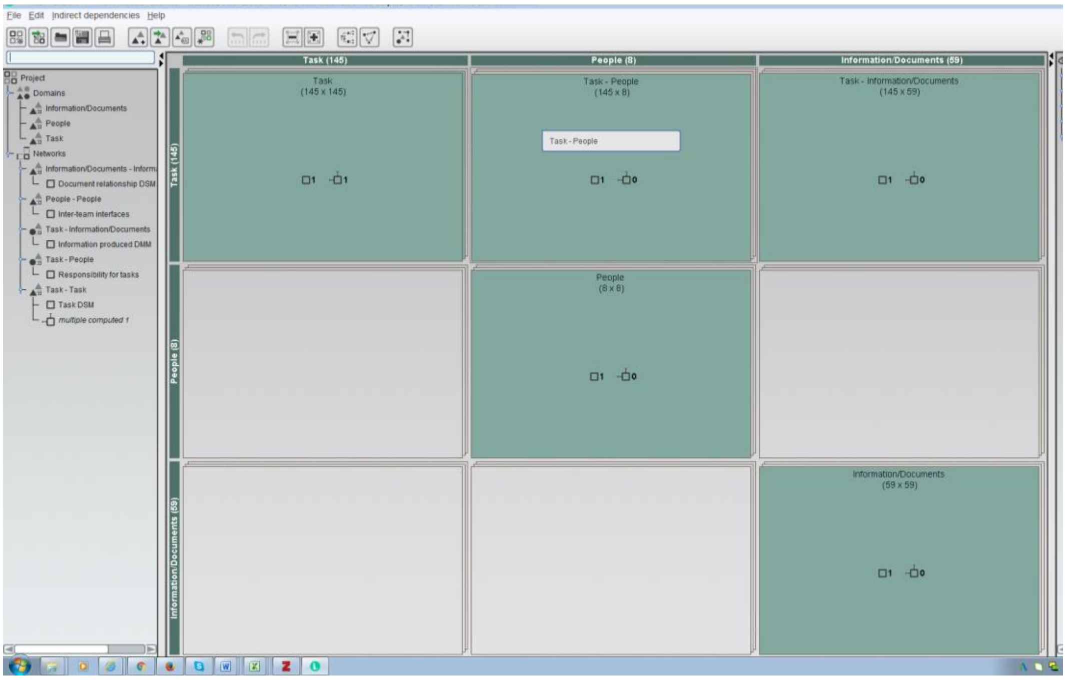


Figure 7.14: MDM model of the pre-BIM pre-construction workflow

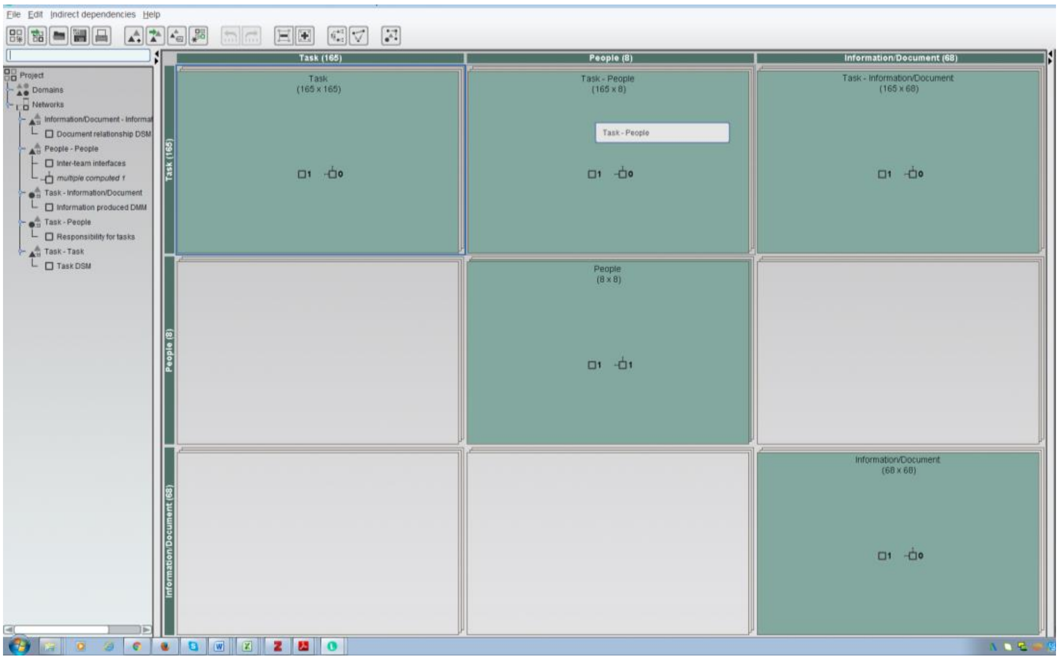


Figure 7.15: MDM model of the BIM-enabled pre-construction workflow

As is evident from visual inspection, the BIM-enabled workflow DSM contains more tasks compared to the pre-BIM workflows while more information is also produced therefrom. These include the new requirements for extracting and storing graphic and non-graphic building information in the COBie data formats.

The MDM models, therefore, helped to comparatively analyse differences between the pre-BIM and BIM-enabled project delivery workflows as in *Table 7.2* for each phase of the pre-construction stage of work.

Table 7.2: General differences between the Pre-BIM and BIM-enabled project workflows by phase

PHASE	No. of Tasks	No. of edges (interfaces)	No. of intra-team interfaces	No. of documents produced
Planning MDM (pre-BIM)	11	12	5	5
Planning MDM (BIM)	12	13	4	6
CPSP procurement MDM (pre-BIM)	18	21	14	10
CPSP procurement MDM (BIM)	20	23	19	10
Design planning MDM (pre-BIM)	29	37	25	10
Design planning MDM (BIM)	33	42	27	17
Concept design MDM (pre-BIM)	25	40	25	7
Concept design MDM (BIM)	31	49	38	10
Detailed design MDM (pre-BIM)	31	52	40	9
Detailed design MDM (BIM)	35	56	45	10
Contractor procurement MDM (pre-BIM)	31	37	68	14
Contractor procurement MDM (BIM)	34	40	79	15

It is evident from *Table 7.2* that the modelled tasks are more in number for the BIM-enabled project workflows than for the pre-BIM workflows (this analysis has taken the few redundant activity steps not required for a BIM-enabled project delivery process into account). The extra tasks in some cases ensure that all shared information between team members have been verified and approved.

In terms of other metrics based on which the comparisons are being made, there is a general increase in the number of edges (interfaces), inter-team interfaces, and the number of information/documents produced from the BIM-enabled project workflow as modelled. It is pertinent therefore to note, in terms of rework, that it is impossible to model the exact number of feedback associated rework as there are endless possibilities and scenarios in practice. The important question, however, is whether the increases mean that the BIM-enabled project delivery process is more or less efficient or collaborative. Apart from its ability to enable analytical inferences to be made from visualisation, the LOOMEO software also helped to perform and model certain important metrics that can provide answers to this question.

Managers of projects often contend with problems as may be created during implementation of innovative methods that have effects on several other components of complex systems (Lindemann et al. 2009). In their text on managing complex systems, Lindemann et al. (2009) presented a set of objective criteria (summarised in *Table 7.3*) through which insight and understanding of the structure of a complex system may be gained.

Table 7.3: Analysis criteria for structural characterisation of nodes and edges in a system

ANALYSIS CRITERION	DESCRIPTION	EXPLANATION
Active sum	Quantity of outgoing edges	Element with high active sum provides impacts to further elements
Passive sum	Quantity of incoming edges	Elements with high passive sum receive numerous impact from further elements
Activity	Division of active sum by passive sum	The activity shows an element's degree of active participation in change impacts
Criticality	Multiplication of active sum and passive sum	The criticality shows an element's degree of integration to change impacts in the system
Strongly connected parts	All nodes can be mutually reached by an edge path	Every element possesses a direct or indirect influence or change impact potential to any other node in the subset

Source: Adapted from Lindemann et al. (2009)

The following therefore highlights the differences in the structures of the Pre-BIM to the BIM-enabled project workflow MDMs combining visual and objective analysis.

7.7.2 Examining the differences in the structural characteristics of the pre-BIM and BIM-enabled workflows

7.7.2.1 Examining the Information/Documents DSM interrelationships

The Information/Documents DSM structures for the pre-BIM and BIM-enabled project delivery workflows share certain characteristics but are also different in significant ways.

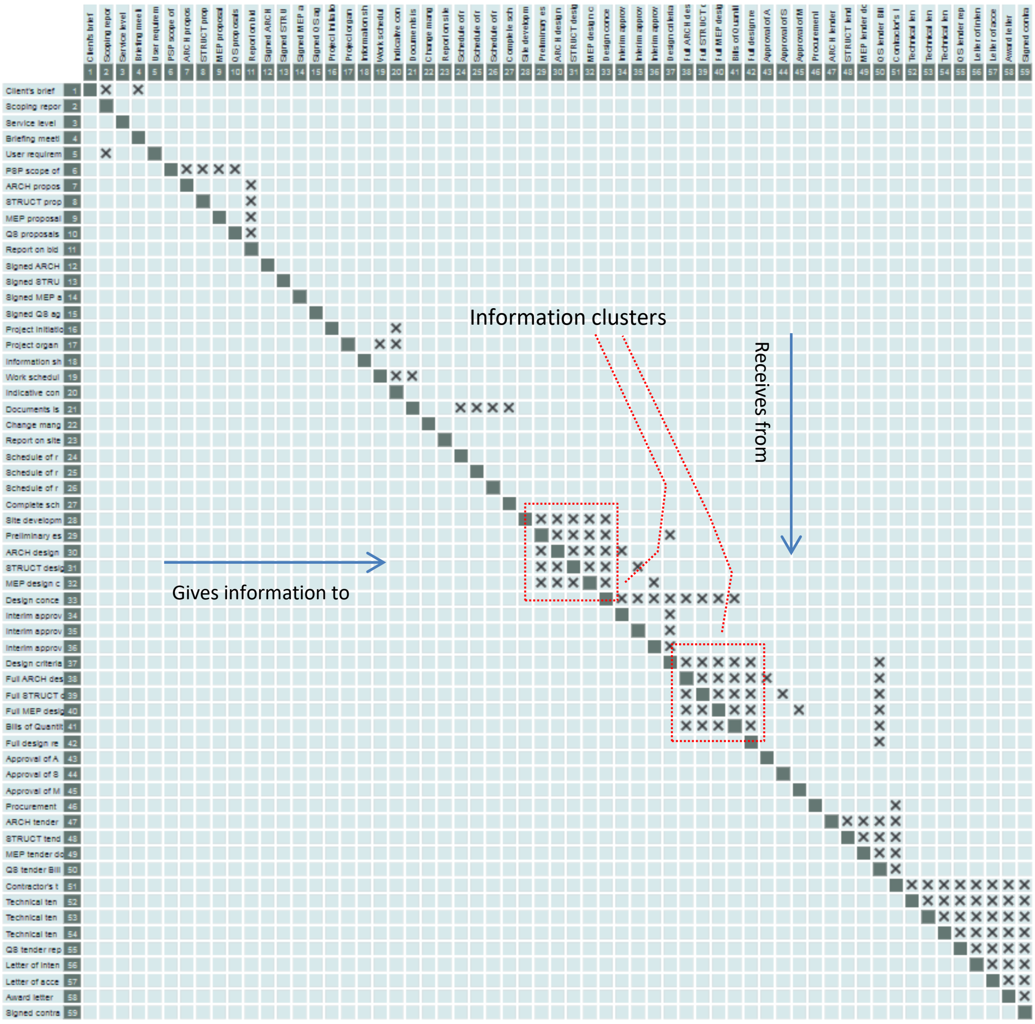


Figure 7.16: Structure of pre-BIM workflow Information-Information DSM

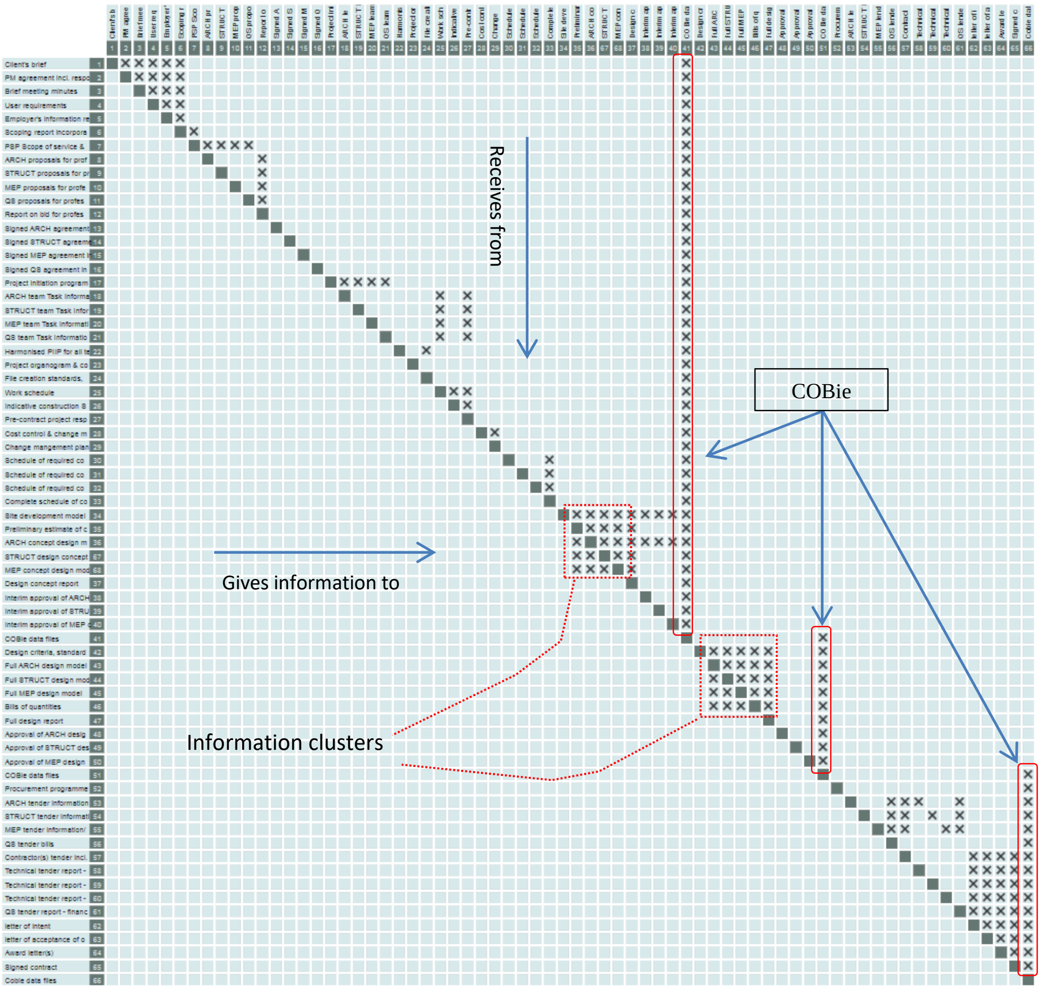


Figure 7.17: Structure of BIM-enabled workflow Information-Information DSM

The information produced from design development related tasks are typically highly connected and clustered as can be seen in *Figure 7.16* and *Figure 7.17*. This remains so for the BIM-enabled workflow information matrix. However, when compared further the key difference in the structure are first, the requirement for new information to be created and modification of existing information as outlined in the analysis of BIM guidance documents in *Table 11.3* of the Appendix. Second, the relationships between all information generated and the COBie data extracted at the three defined points. That is, at the culmination of the concept design, detailed design and contractor selection phases of the pre-construction stage. Furthermore, it is important to note the relationship between the COBie information collected and archived at the different phases which shows its incremental nature.

7.7.2.2 Examining the Responsibilities DSM structure

Figure 7.18 (a) and (b) show the level of interaction between project participants for the pre-BIM and BIM-enabled project delivery workflows respectively using graph models. These models depict for comparison, the connectedness of the participant and the criticality of each team member in the delivery workflow. Both structures show similar characteristics on visual inspection alone but clearly also show the BIM-enabled project team to be more connected and more integrated compared to the pre-BIM project workflow.

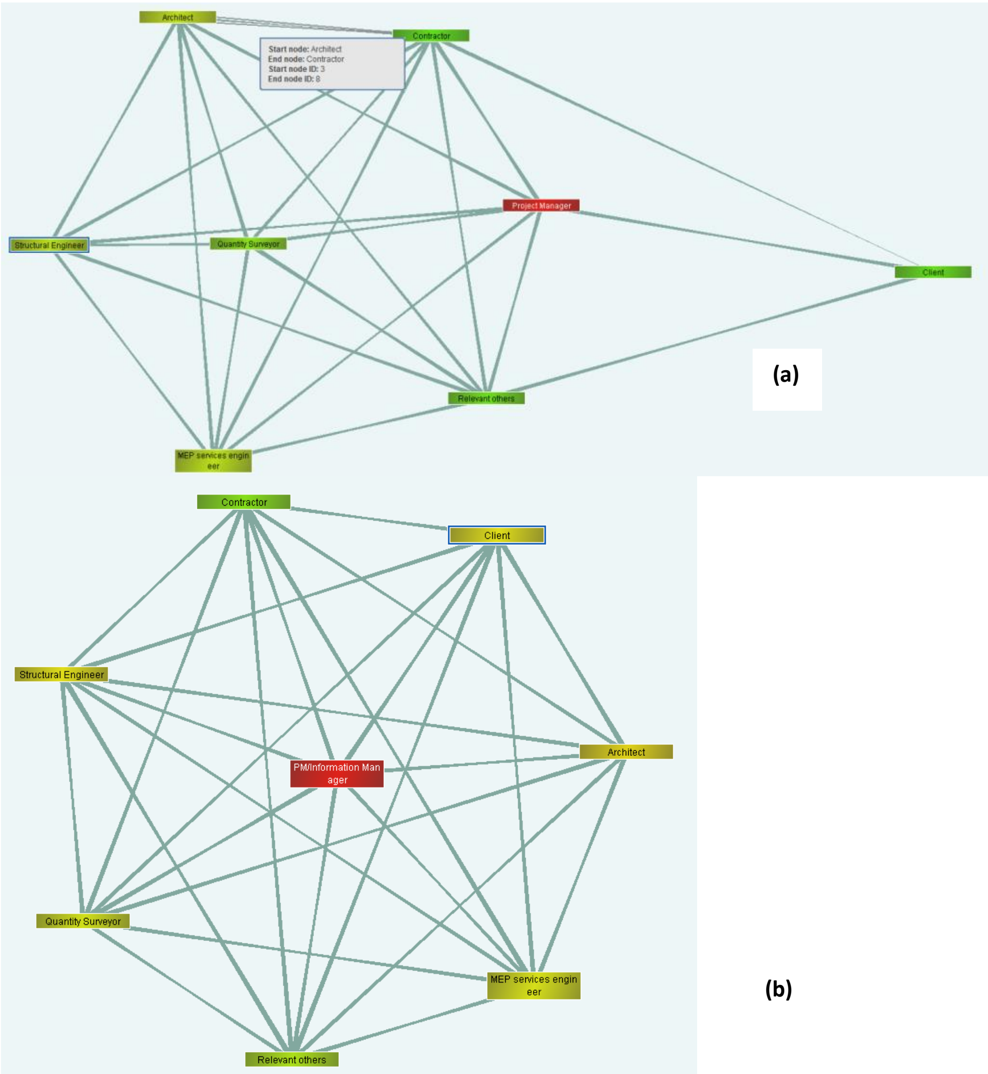


Figure 7.18: People-People interaction DSM (unweighted) (a) pre-BIM (b) BIM-enabled
Team member node colours denote their criticality ranging from Red (highest) to Green (least)

Furthermore, in terms of criticality of their individual participation in the delivery process, the Project Manager remains the most critical although more so in the BIM-enabled project process since the Project Manager also assumes the role of Information Manager.

(a)

		Client	Projec	Archit	Struct	MEP s	Quant	Contr	Relev
		1	2	3	4	5	6	8	7
Client	1		8						2
Project Manager	2	8		7	7	7	8	3	3
Architect	3		12		7	7	3	1	1
Structural Engineer	4		9	5		8	3	1	1
MEP services engineer	5		9	5	5		3	1	1
Quantity Surveyor	6		8	2	2	2		1	2
Contractor	8	1	2	1	1	1	1		1
Relevant others	7	1	2	3	3	3	3	1	

(b)

		Client	PM/Inf	Archit	Struct	MEP	Quant	Contr	Relev
		1	2	3	4	5	6	8	7
Client	1		12	5	3	3	1	1	1
PM/Information Manager	2	11		14	12	11	7	2	4
Architect	3	1	16		3	3	3	1	1
Structural Engineer	4	1	14	3		3	3	1	1
MEP services engineer	5	1	12	3	3		3	1	1
Quantity Surveyor	6	1	11	3	3	3		1	1
Contractor	8	1	3	1	1	1	1		1
Relevant others	7	1	2	3	3	3	3	1	

Figure 7.19: People-People interaction DSM (weighted (showing edge values) (a) pre-B (b) BIM-enabled
Team member node colours denote their criticality ranging from Red (highest) to Green (least)

The edge values showing the actual number of outgoing (used in computing active degree/sum) and incoming (used in computing passive degree) interfaces can be seen in *Figure 7.19* (a) and (b). It is evident from the edge values and colouring that relatively, the Project Manager, as Information Manager, gains a more critical role within the project team as can be seen in *Figure 7.19* (b).

7.7.3 Summary

The MDM methodology offered the opportunity to model the same information presented with swimlane workflow models and more. It enabled the concise modelling of interrelationships between tasks performed; information/documents produced from them and the team member responsibilities for them. In this section, an objective analysis of the MDM structure focussing mainly on the areas of significant differences between the pre-BIM and BIM-enabled project delivery workflows have been presented. These show the BIM-enabled project delivery workflow to be more collaborative. The MDM outputs showing the Task-Task DSMs, Information/Documents-People DMMs, and Information/Documents-People DMMs presented concisely in *Figure 7.14* and *Figure 7.15*. Details of these have been placed in *APPENDIX 2*.

8 CONCLUSIONS AND RECOMMENDATIONS

8.1 Introduction

This study began with the aim of developing an understanding of how organisational and project team work practices co-evolve with the implementation of new technology, i.e. Building Information Modelling, from a theoretical and practical standpoint. The research question posed was:

How do organisational and project team work practices coevolve with the implementation of new technology (BIM)? The sub-questions included:

1. What is the impact of implementing BIM on existing organisational and project team work practices?
2. What is the structure of pre-BIM project team delivery workflows?
3. How can the workflows of project teams be reorganised for collaboratively implementing BIM on projects?
4. What are the differences between pre-BIM project team delivery workflows and BIM-enabled project delivery workflows?

In the following sections, answers to the questions posed are provided along with their implications, research contribution and recommendations.

8.2 Significant research findings from the review of literature

Several important findings were elicited from the review of the literature on BIM and relevant theory. These include:

- The construction industry contends with fragmentation that is intrinsic in its structure and a product of the separation of design and construction functions;
- Solutions to the construction industry's challenges are being sought through changing processes and procedures as well as the application of the right type of technology such as Building Information Modelling among other things;

- The South African construction industry currently contends with several challenges, as are other countries, which the right application of technology is capable of alleviating;
- Implementing BIM does not produce guaranteed results. Importantly, it is claimed in literature that implementing BIM requires and induces changes in many aspects of organisations, projects and construction industry processes; and
- Activity theory as a base theory, along with institutional theory and perspectives from similar theories are suitable for developing an understanding of changing construction professional work practices induced by implementing BIM.

These formed the theoretical foundation for the empirical work conducted using a multimethod qualitative study.

8.3 Findings from descriptive analysis of key informant interview data

The findings from the descriptive analysis of cases of organisations that have implemented BIM within them and on multidisciplinary construction projects are as follows:

8.3.1 Organisational level constraints and changes induced by implementing BIM

- Through the analysis of both negative and positive cases of BIM implementation, the findings suggest that relative level of success at implementing BIM within the organisational context is linked to the organisations' disposition towards BIM as a way of delivering on the organisations' objectives, their adoption and implementation strategy, the nature of their experiences with the implementation and the challenge coping methods employed by them; and
- Implementing BIM induces both procedural and socio-cultural changes in professional work practices within organisations and project teams. Significant procedural changes that occurred include changed design workflows and a restructuring of organisations' processes around BIM

implementation requirements. Socio-cultural changes attributed to the implementation of BIM include the creation of new BIM roles for the management of information, changed organisation structure, and changed leadership & authority structure

8.3.2 Project team level constraints and changes induced by implementing BIM

- Organisational level challenges greatly influence project team level challenges. These include varying levels of BIM proficiency and experiential knowledge by participants which is strongly connected to non-interoperability of business processes on BIM-enabled projects;
- The challenge with the most far-reaching effects in South Africa is the lack of uniform BIM standards that could guide BIM information creation, use, re-use, transfer and storage. This at present is at the organisational and national levels;
- BIM change impacts within multidisciplinary project teams included changed workflows (changed sequence of tasks), and change in contextual design in terms of how designs fit with the environment using augmented reality and virtual reality applications; and
- Socio-cultural impacts of implementing BIM include the creation of new BIM roles within multidisciplinary projects for BIM management and attendant changes in project leadership and authority structures.

8.3.3 BIM enablement within organisations and on multidisciplinary project teams

Although BIM benefits are not fundamental to this study's arguments, conceptually, other than constraints (as posited in activity theory), change in work practices can also be accounted for in the enabling attributes of BIM. The following significant BIM experienced by within the organisations studied and accounts of experiences given:

- Organisations that have failed at implementing BIM and who also had critical or pessimistic attitudes towards BIM as a way of working reported minimal experiences of benefits, and;
- Experienced benefits include, *inter alia*, improvements in the areas of productivity, error reduction, rework reduction, integration and coordination.

8.4 Findings from interpretive analysis of data

An important objective of this study was to provide theoretical explanations of how implementing BIM propagates change in professional work practices. In this regard, the findings show that:

- The needs prompting the creation of new BIM roles are BIM knowledge deficiency and a perception of BIM authoring tools and processes as complex by core professionals (architects and engineers, among others);
- Core professionals' roles are not clearly demarcated from those of new BIM role takers;
- There is no clear evidence of role conflict on account of the poor demarcation of the new BIM role takers from those of core professionals, thereby affirming the acceptance of the new BIM role takers into the existing cultural framework of practice; and
- New BIM role takers derive legitimacy and authority to act and influence the actions of others due to their knowledge resource advantage over core professionals.

Therefore, with an increase in knowledge and capabilities of the core professionals, new BIM role takers would become less relevant and unsustainable. Hence, it is concluded that new BIM roles are transitory social objects that would lose relevance and acceptance once the purpose for which they were created no longer exists.

Furthermore, activity theory was used to theoretically re-describe and explain changing patterns of professional work practices upon the introduction of BIM. Depictions of the changes were conceptualised stepwise based on the data collected to show how a change in one element of organisational or project level activity systems causes a change in other elements of the activity system as well.

8.5 Findings from objective analysis of pre-BIM and BIM-enabled project delivery workflows

Along with findings from the interpretive analyses, the study also provided an objective appraisal of BIM implementation impacts on multidisciplinary construction project team workflows using multi-domain mapping matrices. The findings show that:

- BIM impacts project team workflows significantly, particularly the design development stages;
- When compared to pre-BIM workflows across all the project delivery stages, BIM-enabled project workflows do not indicate a reduction in the total number of tasks but show a significant increase in the number of tasks for the Project Manager since they take up the Information Management role. Therefore the Project Manager, as Information Manager, gains a more critical role within the project team;
- In terms of criticality of their individual participation in the delivery process, the Project Manager remains the most critical although more so in the BIM-enabled project process since the Project Manager assumes the role of Information Manager
- Both structures for the pre-BIM and BIM-enabled project delivery workflows show similar characteristics on visual inspection but clearly show the BIM-enabled project team to be more connected and integrated compared to the pre-BIM project workflow when analysed further; and
- The information produced from design development related tasks are typically highly connected and clustered. Nevertheless, the key differences in structure (between the pre-BIM and BIM workflows) are the requirements for new information to be created and the modification of existing information as outlined in the analysis of BIM guidance documents. Furthermore, the modelled relationship between the COBie

information collected and archived at the different phases shows its incremental nature.

8.6 Conclusions

The rationale for implementing new innovative technology in construction is its ability to alleviate the perennial challenges of the industry such as the sub-optimal performance and productivity. However, with little practical and objective evidence on return on investment, the use of BIM is claimed in literature as capable of alleviating these challenges, albeit without guarantees of results. A critical review of research on BIM related issues and its impacts on professional work practices revealed that objective explanations of BIM implementation impacts on existing professional work practices fell short of clarity and objectivity, as the case may be.

More so, in BIM literature, several claims are made about BIM's impact. These include that BIM drives a different approach to work (Gu and London 2010), requires adaptation to fit with existing project delivery workflows (Gheisari and Irizzary 2016), necessitates new workflows, practices and procedural changes (Rogers et al. 2015), requires a new digital workflow (Aibinu and Venkatesh 2014) and is changing the old way of delivering projects (Ambrose 2012). However, these are construed to be claims without much critical and theoretical substantiation, as Fox (2014) critically argued. The pertinent questions that informed this study were about how such change in professional work patterns are propagated, and how? Authors like Rekola et al. (2010), Tsai et al. (2014), Porwal and Hewage (2013) and Poirier et al. (2015) have attempted to evaluate such BIM impacts objectively, and this study adds to that body of literature.

BIM literature was found to be lacking in the widespread application of psychosocial theory despite having proliferated in the last decade and many of the pertinent issues being related to socio-cultural aspects of its implementation. Therefore, while acknowledging the importance of theoretical grounding in research, a theoretical and conceptual framework for clarifying the nature of the problem and research direction was developed around these ideas. This also formed a basis for explaining the changes in patterns of professional work practices upon the implementation of new/innovative technology. With this, the grounds for theoretical contributions were laid. These ideas also laid the foundation for the application of the MDM methodology for modelling and analysing the project delivery process as a complex system of interacting elements.

In the fourth chapter, a review of prominent research methodology/methods texts revealed the difficulty in choosing mutually exclusive research strategies. An eclectic approach was therefore taken in the choices made of research strategies and methods in a way that could best help to achieve the aim of this study, these combined constructivist and post-positivist (objective) methodologies. The rationale is that while the researcher holds constructivist/relativist ideologies about knowledge, there is nevertheless a difference between epistemic and judgemental relativism. Therefore the philosophy that informed the research methodology was that it is not enough to develop relativist understandings the phenomenon of interest. It was also important to develop objective understandings from a perspective that removes the researcher from the research situation to answer objective what and how questions. The methods employed were largely driven by theory and practicality. A summary of methods applied for the whole study is given and elaborated in the analysis chapters thereafter. Basically, this was a multi-staged and multi-method study that employed in-depth and structured interviewing for primary data collection.

The fifth chapter presented findings from cases of BIM implementation by organisations within and on multidisciplinary construction projects. The findings show that success at implementing BIM on multi-disciplinary projects depends greatly on the participating organisations' proficiency, readiness and commitment to collaborating in a new way for delivering projects. In turn, these are determined by organisations' appraisal and understanding of immediate and long-term implications of making a shift in how they provide their services. Although many of the challenges brought about by implementing BIM within an organisation are not peculiar to BIM as a new technology or innovative way of working, a number of its challenges are unique. Furthermore, it is clear that organisational level challenges need to be understood and mitigated as a pre-requisite to reaping returns from the high investment costs in organisations' technology infrastructure and their people. It can be argued further that organisational challenges and issues around BIM implementation perhaps deserve more attention, or at least, equal attention as team level challenges.

South Africa is in a peculiar situation as there is no central drive from the government or the private sector for adoption in the industry. This can be both advantageous and detrimental. It is disadvantageous in that individual organisations create and employ several different sets of adapted (from other countries) sets of standards and guidelines for implementing BIM. The consequences of this are myriad. Ultimately, it could lead to non-interoperability of the technical aspects of BIM implementation as well as of business processes across collaborating team members on multi-disciplinary projects. However, and debatably so, a lack of rigid guidelines to which organisations must conform allows them to adopt and implement in stages at their own pace. The research results are instructive in pointing out that success at implementing BIM for organisations requires considerable effort. It requires great planning, structural alignment, rethought processes, organisational level R&D, knowledge management, knowledge sharing, training and education. Experiences of constraints at the organisational level are transferred to the project team context where they become detrimental to the efficiency of projects regardless of BIM use. Team level experiences included varying levels of proficiency among project team members, diverse implementation methodologies due to a lack of standards and technological non-interoperability.

First, from an institutional theory perspective of legitimacy, the finding that new roles are being created within organisations and project teams in response to constraints was explored in-depth. Based on the theoretical argument from the works of Nelson (1994), Tolbert and Zucker (1996), and Johnson et al. (2006), legitimating new roles and role takers within the existing cultural framework of practice in the industry requires that the situation of demand for which the roles emerged should continue to subsist. It was argued further with grounding in empirical data that since new roles and role takers are only legitimated to act and direct others to act based on the perception of BIM complexity and lack of proficiency by existing core professionals, therefore, the new roles may not be sustainable. They would ebb away just as core professionals gain the requisite knowledge and self-efficacy. Second, activity theory analysis of changing patterns of professionals work practices showed the path through which organisational and project work practices evolve through constraints created within organisational and project team activity systems. These leant on works of Engestrom (1999, 2000), Kaptelinin and Nardi (2006) and Yamagata-Lynch (2010).

To provide an objective answer to the question of what changes in project team work processes may be expected from implementing BIM, Pre-BIM swimlane and multi-domain mapping matrices were produced. This was followed by a juxtaposition of requirements for change derived from the first stage study of cases of BIM implementers and BIM guidance documents on the pre-BIM way of working. Finally, a changed project team delivery workflow is presented to represent how BIM-enabled project work should or may be done. Through this, implications of implementing BIM on the old ways of working at a medium-level of abstraction of work processes were provided.

8.7 Weighing the research propositions against the evidence

The first research proposition originated from the theoretical argument that the introduction of new tools (and associated processes) into organisational and project team activity systems prompts dysfunctions in the systems, which in turn create demands for change in the systems' elements. The resolutions of the systems' dysfunctions are the drivers for change and development (Engestrom 2000; Kaptelinin and Nardi 2006). The second research proposition posits that aligning construction professionals' work practices to BIM implementation requirements can increase the likelihood of the implementation's success.

The findings reported in *Chapters 5* and 6 support both propositions, from where they were argued and established from a practical and theoretical standpoint (see

Section 5.8 and *Table 5.10* and see also *Sections 6.1* and *6.2*). Furthermore, having supported both propositions using cases of organisations that have implemented BIM, in *Chapter 7*, the swimlane and DSM/MDM modelling methods were used to demonstrate the alignment of BIM implementation requirements drawn from BIM implementation standards for the delivery phase of construction projects. A juxtaposition of BIM requirements to pre-BIM project workflows thereby provided a further practical understanding of BIM implementation implications.

8.8 Achievement of the research objectives

Objective one, which was to evaluate, using an interpretive research methodology, the impact of implementing BIM on organisational and project team work practices, has been achieved through the analysis of key informant interview data within eight cases of BIM implementation within professional organisations in South Africa (*Chapters 5* and *6*). A summary of significant findings that provide answers to the questions asked can be found in *Sections 8.3* and *8.4*.

Objective two was to elicit and model the structure of pre-BIM project team delivery workflows using structured interview data. This was achieved in C*hapter 7* and is the basis upon which BIM-enabled project workflows were modelled.

Objectives three and four entailed the modelling of a collaborative (collective work) project delivery framework by juxtaposing the modelled pre-BIM workflows against BIM implementation requirements drawn from findings obtained from objective one and a detailed content analysis of BIM standards documents. This objective was achieved in *Chapter 7*. Particularly, ***Objective four*** sought to determine the differences evident in pre-BIM and BIM-enabled workflows. Answers to this can be found in *Section 7.7* and *Section 7.7.1*.

8.9 Research contributions

This study claims both theoretical and practical contributions. First, the study offers theoretical explanations of evolutionary patterns of change in professional work practices upon being impacted by new technology (and associated processes) mainly from an activity theory perspective. The application of activity theory in this way is new in BIM research. The ability of the theory to aid the engagement of a system as it emerges was leant on. Activity theory assumptions, propositions and arguments as a base theory were combined with perspectives from institutional theory and role theory. From these, ideas emerged for the conceptual model in *Figure 8.1*. This study thus provides a theoretical and practical understanding of how BIM propagates changes through dysfunctions in existing professional work practices for organisations and for project teams in the South African construction industry.

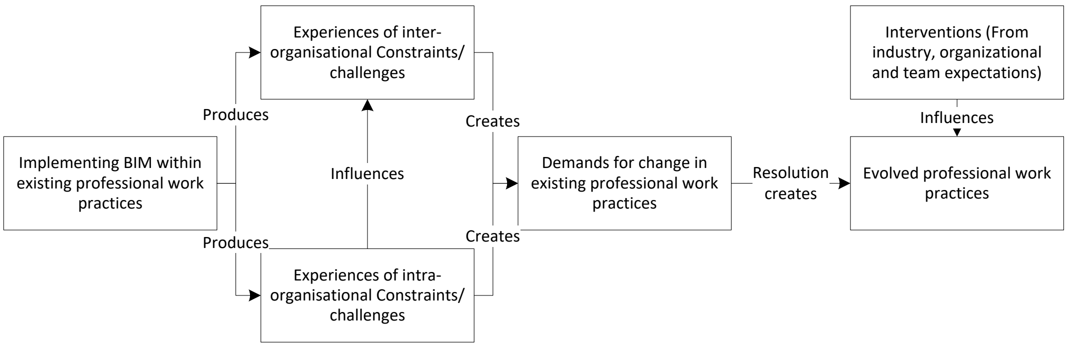


Figure 8.1: Conceptual model
Source: adapted from Akintola et al. (2015)

Second, this study provides theoretical explanations of the legitimation of newly-created roles within organisations and project teams. This is not a new theory, but an extension of the existing theory to provide explanations for new concepts and is grounded in empirical data. A deep conceptualisation and new theoretical insight were developed on the phenomenon of new role creation and legitimation. This establishes that new BIM role takers are legitimated to exercise authority within project teams and organisations mainly by leveraging on superior knowledge as a strategic resource. By implication, they will remain legitimate only as long as the constraint prompting their creation subsists, i.e. core professionals' BIM knowledge deficiencies, thereby affirming that the new BIM roles are transitory and unsustainable (See *Figure 8.3*).

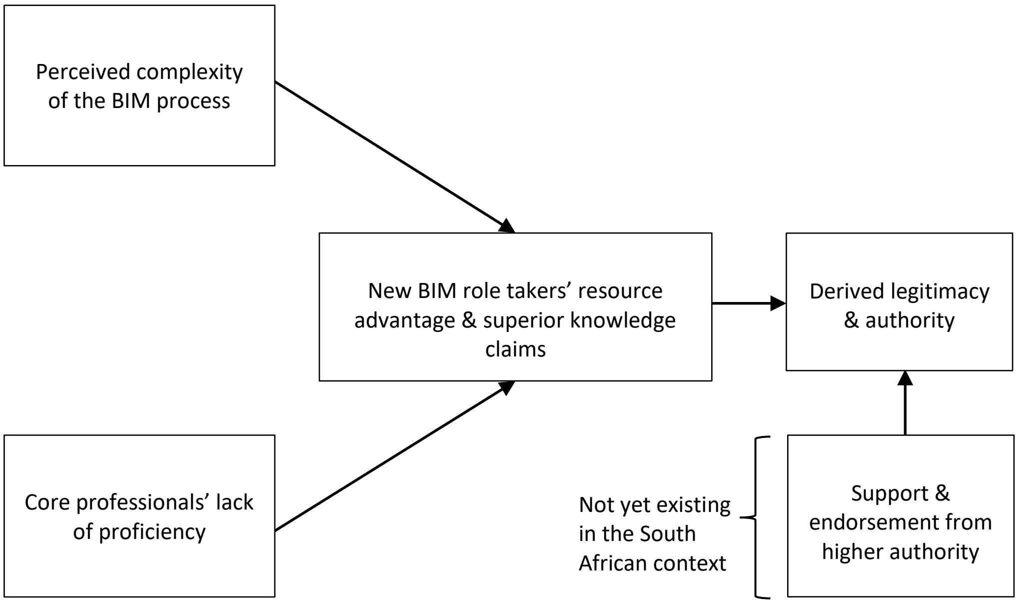


Figure 8.2: Conceptualisation of new BIM role takers' derivation of legitimacy and authority
Source: Akintola et al. (2017)

Third, this study describes construction professional work activity as it evolves from a pre-BIM implementation state to show how the dynamics of change within collaborating organisations' different contexts can bring about the evolution of project context activity (see *Figure 8.3*). The analysis employs an existing theory in explaining empirical findings on the impact of implementing new technology (BIM) on professional work practices while providing theoretical explanations of their evolution into a newer form using a historical and analytical method. As in the work of Engestrom and Escanlante (1996), the article presented how activity systems analysis can be used in describing collaborative activity between construction project stakeholders, while conceptually highlighting the links between the organisational context activity system and project context activity system. In addition, it also theoretically and conceptually demonstrates the influence of organisational evolution due to new technology (BIM) on project team activity or the work practices upon which it is based.

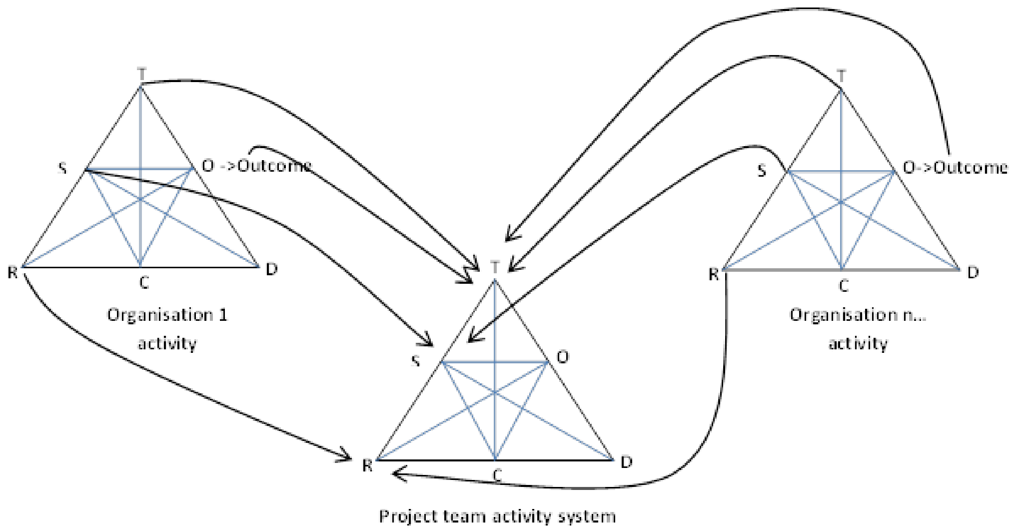


Figure 8.3: Influence of organisational activities on project team activity

In effect, activity theory was used to describe the path and pattern of change in work practices using a cultural-historical perspective. In so doing, conceptualisations of pre-BIM organisational and project team activity contexts were developed and presented as in *Section 6.2*.

Fourth, the findings of this study are useful practically to implementers of BIM. They provide an understanding of what to expect in terms of constraints and changes at the organisational level and project team level. The swimlane and DSM/MDM representations of pre-BIM and BIM-enabled project workflows are unique in that they represent a project workflow enabled by implementing BIM rather than a 'BIM project' workflow. This distinction is essential if a practical understanding of BIM implementation on project team workflows is to be provided to implementers. This is clearly different from existing approaches used in literature (Kaner et al. 2008; Poirier et al. 2015; Porwal and Hewage 2012; Rekola et al. 2010; Tsai et al. 2014).

Lastly, this study presents advancements methodologically. It employs a uniquely crafted multi-stage method toolbox that uses structured elicitation interviews for tacitly-held knowledge, analysis of elicited knowledge and a combination of ideas from activity theory, swimlane modelling and DSM/MDM modelling methodologies to good effect. The study also benefited from the use of complex structure analysis software LOOMEO which provided valuable insight into the structural characteristics of project delivery workflows.

8.10 Limitations of the study

Selecting a large number of organisational cases was impracticable as is typical of qualitative research designs, therefore the aim was to generalise to theory rather than to a population. To achieve this, the interpretive analysis of data was done to enable theoretical explanations and re-description of data collected from the cases studied. This is supported by the works of Yamagata-Lynch (2010), Fletcher (2017) and Patton (2015).

Second, the BIM-enabled project delivery workflow models produced in this study could benefit from real-life case testing and refinement. This could help to deepen the understanding of change in the workflows and also allow the analysis to be carried further to a lower level of abstraction.

Third, though all multidisciplinary projects are collaborative, the modelled workflows are based on only the design bid and build method of delivery. Further insight into BIM's impact on other delivery frameworks would be essential.

8.11 Recommendations

8.11.1 Recommendations for future work

BIM technology is evolving; therefore, as its acceptance and adoption grow, it would be necessary to continue to map the path through which it induces evolution of professional work practices. Furthermore, it would be interesting to investigate the power dynamics on collaborative construction projects further, as is the need to investigate the legal implications of changes that are taking place. The second stage of this study only captured project team workflows for objective analysis of change. Future work could also objectively investigate the changing work processes within organisations while taking their peculiarities into account.

8.11.2 Recommendations for public sector authorities

It is essential for construction-related government organisations (at all levels) to invest in skills development both on core professional competencies and on innovative technology and processes. BIM implementation requires a top-down strategical drive to ensure widespread implementation at high maturity. A drive should be provided in part by government bodies, even though the South African construction industry is not ripe for a BIM mandate at the moment. Presently, the industry would benefit greatly from incentives and motivations for adoption and implementation from public sector organisations and clients.

8.11.3 Recommendations for CIDB and CBE

Since the responsibility for registering, guiding and regulating construction industry businesses rests with the CIDB and the CBE. It is important for these and related organisations also to improve internal capacity for innovative service delivery so that in developing standards and guidance documents, current innovations in the construction industry may also be considered.

The CIDB and CBE can be important drivers of processes that could help to adapt and adopt (as the case may be) appropriate BIM standards and guidelines for the South African context. A working group may be created by them to include all relevant stakeholders as a nexus for BIM development in South Africa, just as Western countries have been doing for some time with significant successes, for example in the UK.

8.11.4 Recommendations for private sector organisations

It is clear that understanding BIM implementation implications from the outset, that is at the time decisions to adopt and implement BIM are made, is of paramount importance. While implementing BIM offers several potential benefits, it is still possible for organisations to completely fail at it. It is, therefore, necessary for organisations intending to implement BIM to establish and document formal strategies, objectives and measurable expectations. Implementation fortunes at the organisational level typically influence project team implementation outcomes. Efforts should hence be made into developing implementation best practices.

There is a need for organisational learning and knowledge management around BIM, and this cannot be overemphasised. Through learning and development, all that seems novel presently will eventually become the norm. Further, the BIM-enabled project workflows that were developed in this study could provide organisations and project teams with a practical understanding of what collaborating with BIM on a multidisciplinary project might entail.

9 RESEARCH OUTPUTS

The following papers are the direct outputs of this thesis. They include published work, work under review and working papers.

9.1 Published work

Published works include:

Akintola, A., Venkatachalam, S., and Root, D. (2017). "New BIM Roles' Legitimacy, and Changing Power Dynamics on BIM-Enabled Projects." *Journal of Construction Engineering and Management*, 143(9), 1–11.

Akintola, A., Douman, D., Kleynhans, M., and Maneli, S. (2016). "The Impact of Implementing BIM on AEC Organisational Workflows." *Emerging Trends in Construction Organisational Practices and Project Management Knowledge Areas*, 9th Postgraduate Research Conference. Department of Construction Economics and Management, University of Cape Town, Cape Town, 506–516.

Akintola, Y., Senthilkumar, V., and Root, D. S. (2015). "Identification of process, team and tool dependencies in building information modelling (BIM) implementation using multi-domain mapping (MDM) - A theoretical framework." *Modeling and Managing Complex Systems,* 17th International Design Structure Modelling Conference. Hanser, Texas, 65–74.

Akintola, A., Root, D., and Venkatachalam, S. (2017). "Key Constraints to Optimal and Widespread Implementation of BIM in the South African Construction Industry." In: Chan, P W and Neilson, C J (Eds) Proceeding of the 33rd Annual ARCOM Conference, 4-6 September 2017, Cambridge, UK, Association of Researchers in Construction Management, 15-24.

9.2 Working papers

Akintola, A., Venkatachalam, S., and Root, D. (2017). "Understanding BIM Induced Change on Professional Work Practices Using Activity Theory as a Lens." *Intended for a journal publication.*

Akintola, A., Venkatachalam, S., and Root, D. (2017). "Modelling the impacts of Implementing BIM using DSM/MDM methodology." *Intended for a journal publication.*

Akintola, A., Venkatachalam, S., and Root, D. (2017). "Organisations' Work Practice Change Agency through BIM Implementation." *Intended for a journal publication.*

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11 APPENDIX 1

Table 11.1: Theoretical perspectives employed in the BIM literature

AUTHOR	TITLE	THEORY / THEORETICAL PERSPECTIVE
Wu *et al.* (2016)	An Integrated BIM and cost estimating blended learning model – acceptance differences between experts and novice	The Technology Acceptance Model 3 (TAM3) theory was used to compare the expert and novice students' acceptance of a blended learning model
Xu *et al.* (2014)	Users-orientated evaluation of building information model in the Chinese construction industry	The model drew on technology acceptance model and innovation diffusion theory and was validated using survey data from the construction industry in China.
De Lima *et al.* (2011)	A complex view from the design process	Complexity theory
Doloi *et al.* (2015)	Drivers And Impediments Of Building Information Modelling From A Social Network Perspective	Social network theory was used to investigate the impediments associated with the BIM functionalities within the project. The theory was said to have been applied in identifying the relative stakes of actors and various functional units in the study of organisational dynamics and similar management issues.
Forgues *et al.* (2012)	A Framework for an Integrated and Evolutionary Body of Knowledge	This paper proposes a model for a framework combining Integrated Design Process and Building Information Modelling for sustainable built environment. It draws from studies in social learning including those in activity theory and situated action theories. It leans on the positions of these theories in that learning and knowledge generation occur mainly within a social process, defined as an activity
Ghosh (2012)	Virtual Construction + Collaboration Lab: Setting a new paradigm for BIM education	Social Development Theory Zone of Proximal Development (ZPD)
Ghosh *et al.* (2011)	Impact of Sustainability on Integration and Interoperability between BIM and ERP – A Governance Framework	Study draws from the theory of reflexive governance for sustainable development
Isaac *et al.* (2013)	Analyzing building information using graph theory	The study attempts to propose an outline for the synthesis of BIM and graph theory
Ganah and John (2015)	Integrating Building Information Modeling and Health and Safety for Onsite Construction	Communication theories with particular references to H&S on construction sites were used
Ambrose (2009)	BIM and comprehensive design studio education	Design theory
Krystallis *et al.* (2014)	Supporting future-proof healthcare design by narrowing the design space of solutions using building information modelling	Decision theory was used while it also draws from human-computer interaction theoretical positions

AUTHOR	TITLE	THEORY / THEORETICAL PERSPECTIVE
Li *et al.* (2009)	Design with space syntax analysis based on building information model	Space syntax theory
Liu *et al.* (2014)	Research on the Concept and Framework of Building Information Modeling Ecosystem	Theory of ecology was used. BIM was considered to be a comprehensive system interacting closely with surrounding environment rather than a linear and mechanical progression
Love *et al.* (2011a)	Bad apple theory of human error and building information modelling: a systemic model for BIM implementation	Bad apple theory of human error
Lu *et al.* (2013b)	Generic model for measuring benefits of BIM as a learning tool in construction tasks	The learning curve theory was used to empirically measure the benefits of BIM as a learning tool in real-life construction tasks
Lu *et al.* (2013c)	BIM collaboration: a conceptual model and its characteristics	A key theoretical foundation for collaboration research is the relationship management literature
Aranda-Mena and Wakefield (2006)	Interoperability of building information: myth or reality?	Diffusion of Innovations
Mäki and Kerosuo (2014)	Site managers' uses of building information modeling on construction sites	Activity theory was used to explain the construction management activity as interconnected to other activities such as the activity of designers
Merschbrock and Munkvold (2014)	Succeeding with Building Information Modeling: A Case Study of BIM Diffusion in a Healthcare Construction Project	Diffusion of Innovations theory informed the analysis of factors leading to collaboration
Merschbrock and Wahid (2013)	Actors' Freedom of Enactment in a Loosely Coupled System: The Use of Building Information Modelling in Construction Projects	Employs freedom of enactment as the degree of flexibility an actor possesses to perform actions in a given structure or to create new structure
Arnett and Quadrato (2012)	Building Information Modeling: Design Instruction by Integration into an Undergraduate Curriculum	Learning theories (these are normally drawn from a range of psycho-social theories of learning prominent among which are positions put forward by the likes of Vygotsky in child development research)
Nach and Lejeune (2015)	The Role of Identity in adopting building information modeling: a comparative study	Employs identity theory to gain an understanding of how identity accounts for acts of resistance and adoption of BIM in AEC industry
Raisbeck *et al.* (2010)	Assessing integrated project delivery: a comparative analysis of IPD and alliance contracting procurement routes	Alliance contracting theory (it is doubtful that this has a 'formal' body of knowledge, however)
Sacks *et al.* (2011)	KanBIM Workflow Management System: Prototype implementation and field testing	The linguistic action theory
Setterfield *et al.* (2010)	Simulating the collaborative design process through a multidisciplinary capstone project	As a result, a goal was to explore the use of technology and pedagogical theory to help guide the capstone effort.

AUTHOR	TITLE	THEORY / THEORETICAL PERSPECTIVE
Shibeika (2014)	Diffusion of digital innovation in a project-based firm: case study of a UK engineering firm	Draws from diffusion of innovations theory to answer the question of how digital innovation diffuses in the firm?
Son *et al.* (2014)	The Adoption of Building Information Modeling in the Design Organization: An Empirical Study of Architects in Korean Design Firms	This study suggests an extended TAM to examine the factors that influence the behavioural intention of architects in the adoption of the BIM
Al Hattab and Hamzeh (2015)	Using social network theory and simulation to compare traditional versus BIM–lean practice for design error management	Employs social network theory and simulation to compare traditional versus BIM-lean practice for design error management
Brewer and Gajendran (2012)	Attitudes, behaviours and the transmission of cultural traits Impacts on ICT/BIM use in a project team	The theory of planned behaviour
Cao *et al.* (2014)	Impacts of Isomorphic Pressures on BIM Adoption in Construction Projects	Draws on institutional theory to examine how three types of isomorphic pressures, coercive, mimetic, and normative pressures impact building information modelling (BIM) adoption on construction projects.
Davies and Harty (2013a)	Measurement and exploration of individual beliefs about the consequences of building information modelling use	TAM and other streams of technology acceptance research and associated theoretical models brought together and synthesised into a version of TAM referred to as unified technology acceptance and use theory
Diao *et al.* (2010)	Development of an optimal design aid system based on building information modeling	Optimization theory
Ding *et al.* (2015)	Key factors for the BIM adoption by architects: a China study	Study attempts to develop a model explaining mechanism of BIM adoption based on the theory of reasoned action
Enegbuma *et al.* (2015)	Effects of perceptions on BIM adoption in Malaysian construction industry	Unified technology acceptance and use theory (UTAUT) fused into technology acceptance models (TAM)
Olatunji (2015)	Constructing Dispute Scenarios in Building Information Modeling	Uses chaos theory to explain the nature of interdependencies in building information modelling (BIM)
Forsythe *et al.* (2015)	How far can BIM reduce information asymmetry in the Australian construction context?	Principal-agency theory
Fox (2014)	Getting real about BIM: Critical realist descriptions as an alternative to the naive framing and multiple fallacies of hype	Critical realism perspectives drove the purpose of this study
Gajendran *et al.* (2013)	Internationalisation of Construction Business and E-commerce: Innovation, Dynamic Capabilities	Competitive advantage theory
Gledson (2016)	Hybrid project delivery processes observed in constructor BIM innovation adoption	Innovation diffusion theory and organisational change theory

AUTHOR	TITLE	THEORY / THEORETICAL PERSPECTIVE
Godwin (2014)	Preliminary building information modelling adoption model in Malaysia: A strategic information technology perspective	Builds up from previous technology acceptance models such as Theory of Reasoned Action, TAM, Theory of Planned Behaviour, Innovation Diffusion Theory, Decomposed Theory of Planned Behaviour, Extension of Technology Acceptance Model (TAM2) and Unified Theory of Acceptance and Use of Technology
Hartmann (2014)	Semiotic User Interface Analysis of Building Information Model Systems	Computer semiotic theory
Hosseini *et al.* (2015)	Adopting global virtual engineering teams in AEC Projects: A qualitative meta-analysis of innovation diffusion studies	Innovation diffusion
Irizarry *et al.* (2013)	Human-Computer Interaction Modes for Construction Education Applications: Experimenting with Small Format Interactive Displays	Constructivism theory, holistic learning theory, action learning theory, reinforcement theory, and sensory stimulation theory were alluded to
Jeong and Ban (2011)	Computational algorithms to evaluate design solutions using Space Syntax	Space Syntax theory
Chasey *et al.* (2012)	Evolution of the New Construction Classroom	Zone of Proximal Development (ZPD)
Kerosuo *et al.* (2015)	Challenges of the expansive use of Building Information Modelling (BIM) in construction projects	Cultural-historical activity theory (activity theory)
Kim *et al.* (2016)	Assessment of BIM Acceptance Degree of Korean AEC Participants	Innovation Diffusion Theory
Korpela *et al.* (2015)	The challenges and potentials of utilizing building information modelling in facility management: the case of the Centre for Properties and Facilities of the University of Helsinki	Cultural-historical activity theory
Lee *et al.* (2012)	A BIM- and sensor-based tower crane navigation system for blind lifts	The system quality was evaluated regarding ease of use and usefulness based on the Technology Acceptance Model (TAM) theory
Lee *et al.* (2015)	Quantitative analysis of warnings in building information modelling (BIM)	Learning curve theory
Lee and Yu (2016)	Comparative Study of BIM Acceptance between Korea and the United States	Technology Acceptance Model (TAM) and related theories are mentioned
Chen and Pan (2015)	A BIM-integrated fuzzy multi-criteria decision-making model for selecting low-carbon building measures	Fuzzy set theory

AUTHOR	TITLE	THEORY / THEORETICAL PERSPECTIVE
Mäki and Kerosuo (2015)	Site managers' daily work and the uses of building information modelling in construction site management	The study was claimed to be ethnographic in part and therefore employs activity-theoretical perspectives in observing the research participants. The activity-theoretical analysis focused on how the tools were used and how BIM served the activities on the construction site. The disturbances in the activity and the flaws and errors in the models were also analysed
Miettinen and Paavola (2014)	Beyond the BIM utopia: Approaches to the development and implementation of building information modelling	The authors suggested the combination of cultural-historical activity theory and evolutionary perspectives that draw from cultural-historical psychology and sociological and organisational studies of technology implementation
Shibeika and Harty (2015)	Diffusion of digital innovation in construction: a case study of a UK engineering firm	Diffusion of innovations theory was used to examine how new ideas move through a social system.
Singh and Holmstrom (2015)	Needs and technology adoption: observation from BIM experience	The paper investigates Building Information Modeling (BIM) adoption from the viewpoint of Maslow's motivational theory on hierarchy of needs. The study is claimed to have established the congruence between Maslow's motivational theory of needs and Roger's theory of technology adoption and innovation diffusion
Son *et al.* (2015)	What drives the adoption of building information modelling in design organizations? An empirical investigation of the antecedents affecting architects' behavioural intentions	Technology acceptance model
Sun and Wang (2015)	The interaction between BIM's promotion and interest game under information asymmetry	The research analysed the interaction between BIM's promotion and project owner-contractor interest game by combining Asymmetric Information theory and game theory.

Table 11.2: Contrasting defining features of five qualitative strategies

CHARACTERISTICS	NARRATIVE RESEARCH	PHENOMENOLOGY	GROUNDED THEORY	ETHNOGRAPHY	CASE STUDY
Focus	▪ Explores the present or historical life of an individual	▪ Its focus is on understanding the nature of the experience of a phenomenon of interest	▪ Developing a theory grounded in field data	▪ Describing and interpreting the practices of a culture-sharing group	▪ Developing an in-depth description and analysis of a bounded case or cases
Type of problem best suited to the strategy or approach	▪ It is based on the need to tell stories of individual experiences of life or aspects of life	▪ It is based on the need to chronicle the nature of an experienced or lived phenomenon by individuals	▪ It is based on the need to develop explanations for previously unexplained actions or processes and grounded in the views of participants	▪ Describing and interpreting and interpreting the shared patterns practices of a culture-sharing group	▪ Providing an in-depth understanding of cases of interest
Discipline background	▪ Origins are from humanities; anthropology, literature, history, psychology and sociology	▪ Origins are from philosophy, psychology and education	▪ Origins are from sociology	▪ Origins are from anthropology and sociology	▪ Origins are from psychology, law, political science, and medicine
Unit of analysis	▪ One or more individuals	▪ Several individuals who have shared the experience of phenomena or interest	▪ Processes, actions or interactions involving many individuals	▪ Studying a group that shares the same culture	▪ Studying and event, programme, process, person, activity etc.
Data collection methods	▪ Mainly interviews and documentary evidence	▪ Mainly interviews with individuals but may include observations documents, and artefacts	▪ Mainly interviews with about 20-60 persons	▪ Mainly observations and interviews but may also include other data sources	▪ Several sources of evidence including interviews, observations, documents and artefacts

CHARACTERISTICS	NARRATIVE RESEARCH	PHENOMENOLOGY	GROUNDED THEORY	ETHNOGRAPHY	CASE STUDY
Data analysis strategies	▪ Analysing data for told stories, and developing themes in the other of time	▪ Analysing data for significant statements, meanings, textual and structural description, and description of the nature (of the phenomenon of interest)	▪ Analysing data through a structured method involving open coding, axial coding, and selective coding	▪ Analysing data through descriptions of the culture sharing group and themes about the group	▪ Analysing data through description of the case and themes of the case as well as cross-case themes
Reporting style	▪ Developing a narrative about the stories of an individual's life story	▪ Describing the nature of the experience	▪ Developing a graphically conceptualised theory	▪ Describing how culture-sharing group function	▪ Developing a detailed analysis of one or more cases

Source: adapted from Creswell (2013)

Table 11.3: Content analysis of BIM level 2 guidance documents

ITEM	REQUIREMENT/ CLAUSE/ CONDITION/ DEMAND	ENVISAGED IMPACTS ON PRE-BIM WORKFLOWS													ANALYSIS	PHASE OF THE WORKFLOWS IN WHICH IT WAS INCLUDED
		PROCESS/TASKS				PEOPLE		TOOLS			DOCUMENT/INFORMATION					
		SS	SC	RDD	TM	R	FR	CP	RDD	RNT	RDD	RND	RSC	RSF		
	SOURCE: PAS 1192-2:2013															
1	Other documents Under development to support BIM implementation: CIC Scope of Services for the Role of Information Management, First Edition, 2013, Early adopters learning report, Institutional plans of work, CIC BIM Protocol, First Edition, 2013, Employers Information Requirements, Government Soft Landings										X	X	X		There is a need to develop similar documents here in South Africa. This will require restructuring of existing documents like the Infrastructure Delivery Management System (IDMS) guidelines and the requirement for new documents that fit the SA context. Perhaps also a redundancy of some existing documents that guide project delivery	
2	Documents for information management shall be prepared by CPI and referred to as the Construction Project Information Xchange (CPIx): a) the **Project Implementation Plan (PIP)** which is submitted pre-contract-award convey each potential supplier's capability related to information management; b) the **Task Information Delivery Plan (TIDP)** which is submitted by each task team working on the project to set out each team's responsibility for delivering information; c) the **Responsibility Matrix** which sets out the relationship between disciplines and production of information or models; d) the **Master Information Delivery Plan (MIDP)** which collates all the TIDPs against the construction programme; and e) the **BIM Execution Plan (BEP)** which is submitted firstly pre-contract to address the issues raised in the EIR and then with more detail post-contract- award to explain the supplier's methodology for delivering the project using BIM.	X	X			X			X			X	X	X	6 new types of documents/information are required here. In turn, their contents will also impinge on contractual arrangements (and documents) between project participants. There is also the question of who takes on the responsibility of preparing these documents and also what influence their contents will have on existing project team responsibilities. As a direct consequence also, since responsibilities are associated with tasks, it is necessary to consider the effects of the foregoing on task sequence and task composition	These have been reflected in the BIM workflows for Professional Service Provider Procurement and Design Planning stages. See Figure 7.5 and Figure 7.7

ITEM	REQUIREMENT/ CLAUSE/ CONDITION/ DEMAND	ENVISAGED IMPACTS ON PRE-BIM WORKFLOWS													ANALYSIS	PHASE OF THE WORKFLOWS IN WHICH IT WAS INCLUDED
		PROCESS/TASKS				PEOPLE		TOOLS			DOCUMENT/INFORMATION					
		SS	SC	RDD	TM	R	FR	CP	RDD	RNT	RDD	RND	RSC	RSF		
3	All project information, whether in BIM environments or in conventional data formats should be shared using a single collaborative data environment (CDE).	X	X		X	X	X	X		X			X	X	First, this implies the need for new tools (technological infrastructure) and perhaps redundancy of existing ones. Next, impacts on existing documentation (contractual etc.) existing tools (compatibility) and roles (person responsible for the CDE & impact on existing roles), project task sequence and composition need to be considered	This has been reflected in the BIM workflows for the Design Planning stage. Figure 7.7
4	The EIR (Employers' Information Requirement) shall be incorporated into the tender documentation, to enable suppliers to produce their initial BIM execution plan (BEP) upon which their proposed approach, capability and capacity can be evaluated. (5.1.4)	X	X			X							X	X	This requires altering the structure/content of existing documents. Next, the implications on existing roles, tasks composition and sequence are necessary. Also the question of who incorporates the information or who takes responsibility for coordinating inputs or information from various sources.	This has been reflected in the Planning & CPSP procurement BIM workflows (Figure 7.5)
5	The employer, or the employer's representative, shall be responsible for ensuring that information requirements are included in project contracts in such a way as to avoid duplication of responsibilities (5.1.5)	X	X			X						X	X	X	This is related to the previous requirement. See item 4 above	
6	EIRs are produced as part of a wider set of documentation for use during project procurement and shall typically be issued as part of the employer's requirements or tender documentation. The development of the EIR shall start either with the assessment of an existing asset, leading to the development of the employer's need, or directly with the employer's need if no existing asset or asset information model is to be considered (5.2.1.)	X	X			X							X	X	As before, tender documentation and contractual arrangements may need to be altered or redrafted to accommodate this changes. Responsibility for making the change(s) and implications on tasks and task sequence are pertinent considerations	The responsibility for information management has been assigned to the Project Manager as explained earlier
7	a schedule of the standards and guidance documents used to define the BIM processes and protocols to be		X	X								X	X	X		

ITEM	REQUIREMENT/ CLAUSE/ CONDITION/ DEMAND	ENVISAGED IMPACTS ON PRE-BIM WORKFLOWS													ANALYSIS	PHASE OF THE WORKFLOWS IN WHICH IT WAS INCLUDED
		PROCESS/TASKS				PEOPLE		TOOLS			DOCUMENT/INFORMATION					
		SS	SC	RDD	TM	R	FR	CP	RDD	RNT	RDD	RND	RSC	RSF		
	used on the project															
8	provision of a clear definition of the employer's information requirements (EIR)											X	X			
9	Key decision points are to form part of the contract possibly through adoption of the CIC BIM Protocol												X		Has implications on the structure/content of contractual documents	
10	Need for provision of a single environment to store shared asset data and information, accessible to all individuals who are required to produce, use and maintain it	X	X			X	X			X		X	X		The CDE has implications on contracts, documents, people roles and interaction, tasks and task sequence as well as requirement for new tools and compatibility issues	The idea of the CDE formed the basis of the information flow modelled in the design stages
11	This PAS formalizes and makes explicit many of the existing information management practices seen in UK construction projects. It is the UK government's express objective that BIM Level 2 has minimal impact on existing contracting methods.											X	X		It is interesting that the objective of the UK government in developing the PAS 1192 is to have minimal impact on existing contracting methods. However, this may not be feasible.	
12	Information exchange and collaborative working requirements are described in the EIRs, which form part of the employer's requirements and will, in turn, be incorporated by a supplier into their Project Execution Plan. The contents of the EIRs are aligned to employer decision points which in turn will coincide with project stages. The EIRs shall be consistent with other appointment and contract documents in use on the project, which in turn should be aligned with industry standards such as the RIBA Plan of Work or APM Project Stages. Information requirements set out in the EIRs shall only provide enough information to answer the "Plain Language Questions" required at a particular stage, at an appropriate level of detail					X						X	X		These basically have implications for project documentation and responsibility for the tasks	The requirement for producing the EIR has been included in the Planning and CPSP Procurement BIM workflows (Figure 7.5)

ITEM	REQUIREMENT/ CLAUSE/ CONDITION/ DEMAND	ENVISAGED IMPACTS ON PRE-BIM WORKFLOWS													ANALYSIS	PHASE OF THE WORKFLOWS IN WHICH IT WAS INCLUDED
		PROCESS/TASKS				PEOPLE		TOOLS			DOCUMENT/INFORMATION					
		SS	SC	RDD	TM	R	FR	CP	RDD	RNT	RDD	RND	RSC	RSF		
13	This document describes the generic methods for contract management and design information production management. The detailed methods of design management and the specifics of the procurement strategy and documentation will need to be referenced in detail for actual delivery. These will be described in the project implementation plan (PIP) and contract documents	X	X									X	X		Clearly, this implies that the PAS describes only in generic terms. Therefore, specific workflows will have to be defined for each project team	
14	Employers are strongly advised to assign the role of project delivery manager to one or more individuals as early as possible to develop these requirements. Under the CIC BIM Protocol (2013) the employer is obliged to appoint a party to undertake the role of Information Manager					X						X	X		Here a new role of 'Project delivery manager' is prescribed. However, it is not clear who takes this responsibility and the job scope. Further, how does it tie into the roles of project manager and prime consultant? (Role conflict)	The responsibility for information management has been assigned to the Project Manager as explained earlier
15	The EIR shall include the following contents, as a minimum: a) information management: 1) levels of detail – e.g. requirements for information submissions at defined project stages. This is needed to populate the Model Production and Delivery Table required under the Protocol; 2) training requirements – not likely to be mandatory; 3) planning of work and data segregation – requirements for bidders' proposals for the management of the modelling process (e.g. model management, naming conventions, etc.); 4) co-ordination and clash detection – requirements for bidders' proposals for the management of the co-ordination process; 5) collaboration process – requirements for bidders' proposals for the management of the collaboration process; 6) HSE/CDM – requirements for bidders' proposals for BIM/CDE-supported H&S/CDM management;	X	X	X		X						X	X		This has implications for contracts, documents, people roles and interaction, tasks and task sequence as well as requirement for new tools and compatibility issues	The inclusion of the EIR in the contracts of client's agents was reflected in the Planning and CPSP procurement workflow (Figure 7.5).

ITEM	REQUIREMENT/ CLAUSE/ CONDITION/ DEMAND	ENVISAGED IMPACTS ON PRE-BIM WORKFLOWS													ANALYSIS	PHASE OF THE WORKFLOWS IN WHICH IT WAS INCLUDED
		PROCESS/TASKS				PEOPLE		TOOLS			DOCUMENT/INFORMATIO N					
		SS	SC	RDD	TM	R	FR	CP	RD D	RN T	RD D	RND	RS C	RSF		
16	7) a schedule of any security and integrity requirements for the project; 8) a schedule of any specific information to be either excluded or included from information models; 9) a schedule of any particular constraints set by the employer on the size of model files, the size of extranet uploads or emails, or the fi le formats that can define the size of a volume; In addition to the generic contents listed above, the EIR may also include project specific items such as pre-construction surveys or a requirement for the employer to receive information models describing newly-generated products and assemblies	X	X	X		X						X	X		This has implications for contracts, documents, people roles and interaction, tasks and task sequence as well as requirement for new tools and compatibility issues	The inclusion of the EIR in the contracts of client's agents was reflected in the Planning and CPSP procurement workflow (Figure 7.5).
17	Compliance plan – requirements for bidders' proposals for the management of the co-ordination process					X						X	X		This requires new documents and modifications of contractual documents. Raises also the question of who prepares the document and the impact of the contents on existing tasks and task sequence	
18	A definition of any co-ordinate origin/system (3 dimensions) that the employer requires to be used to place graphical models, for example Ordnance Survey locators, geospatial and location with respect to an agreed origin	X	X			X						X	X		This relates to the specifics of the design coordination processes.	This could not be modelled at the level of abstraction of the workflows
19	b) commercial management: 1) exchange of information – alignment of information exchanges, work stages, purpose and required formats; 2) client's strategic purposes – details of the expected purposes for information provided in models (See Figure 7 at 6.1.5); 3) a schedule of any software formats, including version numbers, that shall be used by the supply chain to deliver the project							X	X	X		X	X			
20	A schedule of any changes to the standard roles, responsibilities, authorities and competences set out in					X						X	X		This is required to be documented. The responsibility	This is reflected in the Design Planning BIM

ITEM	REQUIREMENT/ CLAUSE/ CONDITION/ DEMAND	ENVISAGED IMPACTS ON PRE-BIM WORKFLOWS													ANALYSIS	PHASE OF THE WORKFLOWS IN WHICH IT WAS INCLUDED
		PROCESS/TASKS				PEOPLE		TOOLS			DOCUMENT/INFORMATION					
		SS	SC	RDD	TM	R	FR	CP	RDD	RNT	RDD	RND	RSC	RSF		
	the contract														for carrying this out also needs to be considered	workflow (Figure 7.7)
21	This BEP (BIM Execution plan) shall be submitted by the supplier to the employer on behalf of the whole supply chain and shall include a summary of their capabilities and responsibilities (6.1.4)	X	X			X							X			This has been reflected in the Design Planning BIM workflow (Figure 7.7)
22	6.2 Production of the pre-contract BIM execution plan (BEP) The contents of the pre-contract BEP shall consist of everything requested in the EIR plus the following information: a) the project implementation plan (PIP) – see 6.3; b) project goals for collaboration and information modelling; c) major project milestones consistent with the project programme; and d) project information model (PIM) deliverable strategy (for example the CIC Schedule).	X	X									X	X		The requirement for new information/documents and restructuring of existing ones.	This has been reflected in the Planning and CPSP procurement and Design Planning BIM workflows (Figure 7.5 and Figure 7.7)
23	Project implementation plan (PIP) The PIP shall be submitted, as part of the initial BEP, by each organization bidding for a project (6.3.1). The PIP is one of the documents used by an employer to assess the capability, competence and experience of potential suppliers bidding for a project, along with quality documentation.	X	X			X						X	X		The requirement for new information/documents and restructuring of existing ones.	This has been reflected in the Planning and CPSP procurement and Design Planning BIM workflows (Figure 7.5 and Figure 7.7)
24	The PIP shall include the supply chain capability summary form, incorporating: a) the supplier building information management assessment form(s); b) the supplier information technology assessment form(s); and c) the supplier resource assessment form(s). (6.3.2)	X	X			X						X	X		Considerations: Need for modifying existing and creating new information/documents; persons responsible for creating the documents; tasks; task sequence	This has been reflected as a responsibility for potential service providers to include this in their Bids through the PIP/PIIP (Figure 7.5)

ITEM	REQUIREMENT/ CLAUSE/ CONDITION/ DEMAND	ENVISAGED IMPACTS ON PRE-BIM WORKFLOWS													ANALYSIS	PHASE OF THE WORKFLOWS IN WHICH IT WAS INCLUDED
		PROCESS/TASKS				PEOPLE		TOOLS			DOCUMENT/INFORMATION					
		SS	SC	RDD	TM	R	FR	CP	RDD	RNT	RDD	RND	RSC	RSF		
25	Supplier BIM assessment form A supplier BIM assessment form shall be completed by all appropriate organizations within the supply chain, so as to demonstrate their competence in and understanding of BIM and provide a comparable document by which to assess their capability (6.4.1).	X	X			X						X	X		Considerations: Need for modifying existing and creating new documents; persons responsible for creating the documents; tasks; task sequence	This has been reflected in the Design Planning BIM workflow (Figure 7.7) as part of the Task Information Delivery Plan
26	Supplier information technology (IT) assessment form Completed by all appropriate organizations within the supply chain, usually in conjunction with the organization's IT department, the supplier IT assessment form shall enable organizations to demonstrate their information exchange capability and IT maturity, and provide a meaningful method of assessing differences and similarities with the project IT systems (6.5.1).	X	X					X		X		X	X		Considerations: Need for modifying existing and creating new documents; persons responsible for creating the documents; tasks; task sequence	This has been reflected in the Design Planning BIM workflow (Figure 7.7) as part of the Task Information Delivery Plan
27	Supplier resource assessment form: The supplier resource assessment form shall be used to assess an organization's current resource capability and capacity. The form shall be completed by all appropriate organizations within the delivery team as part of the sub-contract procurement process.	X	X			X						X	X		Considerations: Need for modifying existing and creating new documents; persons responsible for creating the documents; tasks; task sequence	This has been reflected in the Design Planning BIM workflow (Figure 7.7) as part of the Task Information Delivery Plan
28	Supply chain capability summary form The supply chain capability summary form shall be used to facilitate rapid comparison of the information within the team IT and resource assessment forms provided by each organization (an extract from a template is shown in CPIx Online). The form shall be completed by all appropriate organizations within the Delivery Team as part of the sub-contract procurement process	X	X			X						X	X		Considerations: Need for modifying existing and creating new documents; persons responsible for creating the documents; tasks; task sequence	This has been reflected in the Design Planning BIM workflow (Figure 7.7) as part of the Task Information Delivery Plan
29	The MIDP shall be used by the PDM to manage the delivery of information during the project (7.3.2)	X	X			X						X	X		See Item 2	This has been reflected in the Design Planning BIM workflow (Figure 7.7) and responsibility for the PM/Project

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		PROCESS/TASKS				PEOPLE		TOOLS			DOCUMENT/INFORMATION					
		SS	SC	RDD	TM	R	FR	CP	RDD	RNT	RDD	RND	RSC	RSF		
																Lead/Information Manager
30	The MIDP shall list the information deliverables for the project, including but not limited to models, drawings or renditions, specifications, equipment schedules, room data sheets, and shall be managed via change control (7.3.3)					X						X	X		See Item 2	This has been reflected in the Design Planning BIM workflow (Figure 7.7) and responsibility for the PM/Project Lead/Information Manager
31	Task information delivery plan (TIDP) Each task team manager shall compile their own TIDP, with its milestones. These shall be used to convey the responsibility for delivery of each supplier's information	X	X									X	X		See Item 2	This has been reflected in the Design Planning BIM workflow (Figure 7.7) and responsibility of each Project Team member and compiled by the PM/Information manager
32	Roles should be embedded into contracts, either through a specific schedule of services or more general obligations. Information management roles are likely to be embedded into more extensive project roles – design team leader, principal contractor, etc.					X						X	X		This is natural as every modification or decision about roles would have contractual implications	This is expected to be done at the Planning and CPSP procurement stage.
33	On projects led with the CIC BIM Protocol (2013), a key role is the information manager. The information manager has a role in facilitating the management of the federated model and the production of project outputs. The information manager is also responsible for managing the operation, standards and culture of the common data environment. The information manager is not a stand- alone role and is expected to shift from design team to contractor prior to start on site. Under the BIM Protocol, a client is obliged to appoint an information manager at all project stages.					X						X	X		The new role of information manager is identified here. This needs to be considered for identification of possible role conflicts with other project team members (e.g. Project manager)	This role is not a standalone role and has been assigned to the Project manager and design model integration and coordination to the Architect.

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		SS	SC	RDD	TM	R	FR	CP	RDD	RNT	RDD	RND	RSC	RSF		
34	At the induction meeting as many of the information management roles shall be identified and confirmed as possible. (7.5.1.1) This may be done through a stage-based deliverables matrix and this should be revisited during successive project stages as specialists and supply chain members join the delivery team	X	X			X						X	X		This is an additional task to be performed. It also expands the roles of the team member that takes up the responsibility. Further, as in the previous items, it impinges on existing documents and contracts	This is reflected in the Design Planning BIM workflow (Figure 7.7)
35	Data delivery shall include some all of the following data entities: native (product-proprietary) fi le formats, COBie-UK-2012 and read-only PDF; to enable a complete Level 2 project (9.1.4)	X	X				X	X		X		X	X		Here data interoperability issues need to be considered	These are specifics of data formats that could not be modelled at the level of abstraction adopted.
36	The ARCHIVE section of the CDE shall be used to record all progress as each project milestone is met and shall hold a record of all transaction and change orders to provide an audit trail in the event of a dispute (9.2.2.7)	X	X			X						X	X		See the previous discussion on CDE	This is reflected in the Concept Design and Detailed design BIM workflows (Figure 7.9 and Figure 7.11)
37	There shall be a “change of ownership” procedure for the information and objects that specialist sub-contractors introduce to replace the original designers’ intent such that the resulting graphical models can be used for fabrication, manufacture and installation (9.2.2.10).	X	X			X						X	X		Change of ownership of information will need to be incorporated into contract documents. Person(s) responsible for effecting this change also needs to be considered. Tasks and task sequence may also be affected	The workflows cover only the pre-construction phase. Therefore, this was not modelled.
38	Any additional fi le types required for a particular project shall be defined and agreed at the start of the project and registered in the EIR and BEP (9.3.2.3)	X	X			X		X				X	X		The task needs to be incorporated into the workflow and Responsibility for this definition needs to be clarified	See previous analysis on EIR and BEP

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		SS	SC	RDD	TM	R	FR	CP	RD D	RN T	RD D	RND	RS C	RSF		
39	Publication of information The employer or the employer's representative (who may be the lead designer or the supplier) shall sign-off the information and request publication (9.5.1). NOTE It is recognized that some contract forms make this process difficult. In these cases it must be made clear to the employer who within the delivery team is responsible for undertaking these processes. This should be documented in the EIR and BEP	X	X				X						X		Contract documents will have to be reviewed to accommodate the requirement	This is reflected in the Concept Design and Detailed design BIM workflows (Figure 7.9 and Figure 7.11). However, contractual issues are not within the scope of this study.
40	Information shall be issued according to the process above in a digital format. This will be defined in the EIR (5.3) (9.5.3).	X	X			X				X			X			
41	Levels of model definition shall conform to: a) the EIR; b) the scope of work set out by the CIC Scope of Services, for example, related to the project stages; and c) the Uniclass classification tables regarding the relationship of systems, products and elements with the specification and the cost plan. (9.8.4)							X					X			The LOD definitions were not modelled at the level of abstraction adopted.
42	Handover and close-out At the handover and close-out stage all necessary information about the product shall be included in the handover document and attached to the commissioning and handover documentation. The as-constructed model shall represent the as-constructed project in content and dimensional accuracy (9.9.6).	X	X			X							X		Considerations: Need for modifying existing and creating new information/documents; persons responsible for creating the documents; tasks; task sequence	
43	Classification Models, documents, project information, cost information and specifications shall all be organized using a classification system to allow external processes such as cost planning to take place (9.10).	X	X			X				X		X	X			

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		SS	SC	RDD	TM	R	FR	CP	RD D	RN T	RD D	RND	RS C	RSF		
44	General – Information delivery – Asset information model (AIM) maintenance Guidance on the use and maintenance of the AIM is to be documented in PAS 1192-3. It is expected that the data generated during the delivery phase's described above together with the commissioning information will form the majority of the information to be handed over at completion. COBie-UK-2012 is the recommended format for information exchange. If extra information such as proprietary geometric models (2D or 3D) or extra data attributes are required employers and project delivery teams should document these alternative formats in the EIR at project commencement.	X	X									X	X		There may be additional documentation outside of what the COBie.UK-2012 stipulates	
45	Handover process between CAPEX and OPEX The effective transfer of structured information between the asset lifecycle stages delivers significant value. To effectively enable this, formal handover processes shall be documented in the EIR. The document shall define the structure, process and content of information to be exchanged. This document shall form the basis for the operational contract documentation. (10.2.1)	X	X			X							X			The scope of the workflows cover only the pre-construction phase
46	This approach does not require more work, as this information has always been required to be produced											X			This is a strange assertion. Despite that, this document was intended to have minimal impact on existing workflows; this is hardly true as evidenced by the analysis in this document (table). Nevertheless, it is also true that most of the information requirements are not new but only being produced in new ways and with new tools	
47	Provision of a clear definition of the employer's information requirements (EIR)											X	X		The requirement for restructuring existing documents	

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		SS	SC	RDD	TM	R	FR	CP	RDD	RNT	RDD	RND	RSC	RSF		
															(contracts), and need for new documents (EIR document). See previous analysis on EIR	
48	A BIM execution plan (BEP) shall be developed by the supplier containing: 1) assigned roles, responsibilities and authorities; 2) standards, methods and procedures; and 3) a resourced master information delivery index, aligned with the project programme;	X	X	X	X	X						X			Considerations: Need for modifying existing and creating new documents/information; persons responsible for creating the documents; tasks; task sequence	This has been reflected in the Design Planning BIM workflow (Figure 7.7)
49	c) competence assessment: 1) details of the competence assessment which bidders must respond to; 2) changes to associated tender documentation (e.g. PQQ, PEP, tender questionnaire, tender evaluation plan); 3) BIM tender assessment details.	X	X									X	X		Considerations: Need for modifying existing and creating new documents/information; persons responsible for creating the documents; tasks; task sequence	This has been reflected in the Design Planning BIM workflow (Figure 7.7)
50	The PUBLISHED DOCUMENTATION section of the CDE shall be used to hold published information. (9.2.2.6)	X	X			X						X				This is reflected in the Concept Design and Detailed design BIM workflows (Figure 7.9 and Figure 7.11).
51	An additional WIP section of the CDE shall be used to hold unapproved information for the specialist contractors and designers. It shall also conclude with the Approved Gate ("4" in Figure 15 (9.2.1)) which represents the transition to SHARED where the information is checked, reviewed and approved by the main contractor and the designers who have responsibility for ensuring compliance to the design, using the same approval checks as Gate 1. (9.2.2.9)	X	X			X						X			This describes in fair detail the workflow for approving drawings on the CDE platform.	This is reflected in the Concept Design and Detailed design BIM workflows (Figure 7.9 and Figure 7.11).

ITEM	REQUIREMENT/ CLAUSE/ CONDITION/ DEMAND	ENVISAGED IMPACTS ON PRE-BIM WORKFLOWS: PROCESS/TASKS SS	SC	RDD	TM	PEOPLE R	FR	TOOLS CP	RDD	RNT	DOCUMENT/INFORMATION RDD	RND	RSC	RSF	ANALYSIS	PHASE OF THE WORKFLOWS IN WHICH IT WAS INCLUDED
52	Levels of model definition The minimum level of detail needed by the team or the employer for each model's purpose shall be defined. The level of model definition required in a model at an information exchange shall be defined in the EIR and the CIC BIM Protocol (2013). The level of graphical information and data to be delivered at each information exchange will be defined with reference to industry standard (9.8.1-2)	X	X			X						X			Responsibility for this task needs to be defined along with where it fits in the workflow and existing documents (e.g. contractual)	This was not modelled at the level of abstraction adopted.
53	The levels of model definition shall be articulated in the BEP and need to be fully understood by all relevant members of the project team (9.8.3)	X	X			X						X				
54	Originators produce definition information in models which they control, sourcing information from other models where required by way of reference, federation or direct information exchange	X	X			X	X	X		X						This is reflected in the Concept Design and Detailed design BIM workflows (Figure 7.9 and Figure 7.11).
55	Following contract award, the project delivery manager (PDM) shall initiate a project induction meeting to confirm resource availability and capability in relation to the responsibility matrix issued as part of the EIR; identify training and education needs, and; collaborate to develop the MIDP with reference to the team members' TIDPs (7.3.1)					X	X								The role of Project delivery manager is highlighted here, whether or not this will conflict with other team members' roles is worthy of investigation	This is reflected in the Design Planning BIM workflows (Figure 7.7)
56	Data within a CDE is finely granulated and structured to ease its re-use. It provides the ability to produce traditional drawings or documents as views of multi-authored data within the CDE. It also gives greater control over the revisions and versions of that data	X	X			X	X	X		X					This role is expected to be taken by the information manager whom the CIC describes as likely to be performed by either by the Design Lead or the Project Lead, which could be a consultant or contractor at different stages of the project. It constitutes an expansion of roles for the team member. Compatibility of tools and the requirement for new tools are essential considerations here among others.	

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		SS	SC	RDD	TM	R	FR	CP	RD D	RN T	RD D	RND	RS C	RSF		
57	If a clash is detected which cannot be resolved by the task team interface manager then the lead designer shall be involved in the discussion to reach agreement and make the necessary changes to the models (9.4.3)	X	X			X	X								This is similar to the route (and roles) taken to resolve conflicts on traditional delivery projects but may necessitate considerations for tasks and task sequencing also	The responsibility for this should rest with the Lead Designer
58	Evaluation of the proposed approach, capability and capacity of each supplier, and their supply chain, to deliver the required information, prior to contract award is to be carried out					X									This is construed as an expansion of the roles of the team member that is assigned to this task	The responsibility for this and the tasks have been reflected in the Design Planning BIM workflow (Figure 7.7)
59	Definition of the information exchange and collaborative working requirements shall be undertaken in parallel with other procurement and project definition activities (5.1.2).	X	X			X									Apart from considerations for where it fits in the workflow, the responsibility for the task needs to be considered	This responsibility rests with the PM/Information manager
60	Responsibility for the delivery of information in principle rests with the employer who discharges accountability to the design or construction team as appropriate. **<u>Allocation of these responsibilities shall be project specific and documented in the contract</u>**. For further information on generic roles, refer to the various Scopes of Services such as those published by CIC					X							X		This suggests that these responsibilities may be different for specific projects	The documentation of this requirements have been reflected in the Planning and CPSP procurement workflows (Figure 7.5)
61	A schedule of any software formats, including version numbers, that shall be used by the supply chain to deliver the project; NOTE Public sector employers may not wish to or be able or specify software packages to be used by their suppliers, but may instead specify the formats of any outputs. Private sector employers may choose to specify software packages and/or output formats.					X		X				X	X		Persons responsible for drawing up this specification needs to be decided while issues of interoperability of new tools and formats need to be considered	The lack of treatment of interoperability issues is acknowledged in the PAS document. Indeed, the document wasn't intended to deal with the technical aspects of BIM implementation
62	An initial responsibility matrix setting out any discipline responsibilities for model or information production in line with the defined project stages needs to set out at the start					X									The responsibility for this task and its implications on project team roles requires consideration	This is reflected in the Design Planning BIM workflow (Figure 7.7) although it is not a new requirement for projects

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		SS	SC	RDD	TM	R	FR	CP	RDD	RNT	RDD	RND	RSC	RSF		
63	As part of the main contract selection process, the employer shall request in the EIRs that bidders shall submit details of their approach to project information management, sufficient to demonstrate the supplier's proposed approach, capability, capacity and competence to meet the EIR (6.1.1). (The purpose of the pre-contract BEP is to demonstrate the supplier's proposed approach, capability, capacity and competence to meet the EIR. It is likely that the BEP will be developed in two phases, pre- and post-contract award)	X	X			X									This task has to be worked into project workflows. It also expands project team responsibilities	This is reflected in the Planning and CPSP procurement BIM workflows (Figure 7.5)
64	Post contract award, the BEP shall be re-submitted by the supplier to the employer confirming the supply chain's capabilities and the master information delivery plan (MIDP) and that all relevant parties have agreed and committed to the BEP (6.1.3)	X	X			X									This task has to be worked into project workflows. It also expands project team responsibilities	The scope of the workflows does not cover Construction phase workflows
65	Milestones within each TIDP shall be aligned with the design and construction programmes to produce the MIDP (7.4.2).	X	X			X									This needs to be worked into project workflows	This is reflected as the responsibility of the PM/Information Manager in the Design Planning BIM workflow (Figure 7.7)
66	For each deliverable, the TIDPs shall be used to indicate the team member responsible or to note that such responsibility has yet to be allocated (7.4.3).	X	X			X									This task has to be worked into project workflows. It also impinges on team member responsibilities	This is reflected as the responsibility of the PM/Information Manager in the Design Planning BIM workflow (Figure 7.7)
67	The TIDPs shall be used to take account of the required sequence of model preparation for any work packages used in the project (7.4.5)	X	X			X									This task has to be worked into project workflows. It also impinges on team member responsibilities	This is reflected as the responsibility of the PM/Information Manager in the Design Planning BIM workflow (Figure 7.7)
68	The roles and responsibilities of individual team members shall be defined, as shall the schedule of responsibilities for deliverables of the overall team, bearing in mind that one person may deliver multiple					X										This is reflected as the responsibility of the PM/Information Manager in the Design

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		SS	SC	RDD	TM	R	FR	CP	RDD	RNT	RDD	RND	RSC	RSF		
	roles (7.5.1.2)															Planning BIM workflow (Figure 7.7)
69	The selected software, IT systems and infrastructure, including the CDE, shall be procured, implemented and tested (8.2)	X	X			X		X	X	X					The responsibility for this task, and its implications for project team roles and tools requires consideration	This is reflected as the responsibility of the PM/Information Manager in the Design Planning BIM workflow (Figure 7.7)
70	One element not defined in BS 1192:2007 or in this document is a solution to the problem of interoperability between the different CAD and BIM solutions used within a project. Generally the guidance would state that whenever possible data/information should be made in the native format of the solutions being used. In addition, the project teams should agree on the number of data renditions required, and check these renditions to ensure their interoperability or to understand the limitations of the solutions they relate to					X		X							This highlights the need to consider tool compatibility (interoperability). This is important and was considered in modelling the workflows in the next chapter.	
71	The PIM shall be progressively developed and delivered to the employer through a series of information exchanges as defined within, for example, the CIC Scope of Services, at key points to coincide with the employer's decision-making processes as defined by the EIRs and the CIC BIM Protocol (2013) (9.1.1).	X	X			X									Model development workflows need to be fitted into existing workflows while also considering the impacts it might have on current project team responsibilities	This is reflected in the Concept Design and Detailed design BIM workflows (Figure 7.9 and Figure 7.11).
72	The WIP section of the CDE shall be used to hold unapproved information for each organizational role (9.2.2.1). (The WIP section concludes with the Approval Gate ("1" in Figure 15 (9.2.1)) which represents the transition to SHARED, where the information is checked, reviewed and approved by the lead designer).	X	X			X										This is reflected in the Concept Design and Detailed design BIM workflows (Figure 7.9 and Figure 7.11).

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		SS	SC	RDD	TM	R	FR	CP	RD D	RN T	RD D	RND	RS C	RSF		
73	To pass through the Approval Gate (Gate 1) a check, review and approval process shall be carried out before issue to the SHARED area. The checks shall include: a) model suitability check; b) SMP check; c) technical content check; d) COBie completeness check; e) drawings extract checks along with any additional documentation that is shared as a co-ordinated package of information; and f) approval by the task team manager. (9.2.2.2)	X	X			X									While these tasks simply describe a design approval workflow, they are a different set of tasks compared with existing design approval tasks. Expanding or new roles also need to be given attention.	This is reflected in the Concept Design and Detailed design BIM workflows (Figure 7.9 and Figure 7.11).
74	The SHARED section of the CDE shall be used to hold Information which has been approved for sharing with other organizations to use as reference material for their own design development. When all design has been completed, the information shall be placed for authorization in the Client Shared Area (9.2.2.3)	X	X			X		X		X					This describes a BIM information sharing workflow that may impact on existing tasks and task sequencing	This is reflected in the Concept Design and Detailed design BIM workflows (Figure 7.9 and Figure 7.11).
75	To pass through the Authorized Gate ("2" in Figure 15 (9.2.1)) the information in the Client Shared Area shall be authorized by the employer or the employer's representative (9.2.2.4)	X	X			X									This describes a BIM information sharing workflow that may impact on existing tasks and task sequencing	This is reflected in the Concept Design and Detailed design BIM workflows (Figure 7.9 and Figure 7.11).
76	In addition, as-constructed information shall be checked and verified in the PUBLISHED section to allow transition through the Verified Gate to the ARCHIVE section (9.2.2.8).	X	X			X									This describes a BIM information sharing workflow that may impact on existing tasks and task sequencing	This is reflected in the Concept Design and Detailed design BIM workflows (Figure 7.9 and Figure 7.11).
77	In the PIM only the objects representing those elements or products that are to be actually constructed by the specialist sub-contractors shall be included. The objects representing design intent shall not appear unless they are also the items to be built (9.2.2.11)	X	X			X									This describes a BIM information sharing workflow that may impact on existing tasks and task sequencing	

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		SS	SC	RDD	TM	R	FR	CP	RDD	RNT	RDD	RND	RSC	RSF		
78	9.2.2.12 The Accepted Gate ("5" in Figure 15 (9.2.1)) shall be used for information to be verified (Information Exchanges 1, 2 & 3 in Figure 15 (9.2.1)) and validated (Information Exchange 6 in Figure 15 (9.2.1)) when it is delivered as an AIM for use in operation of the facility (This process will be iterative if the sign-off process finds that the requirements for the information exchange have not been met).	X	X			X									Describes a BIM design and design review workflow that may need to be incorporated into existing team workflows	The scope of the workflows does not extend beyond the pre-construction stage
79	NOTE 2 Status codes are provided by information originators to define how information may be used during different phases of the CDE. The SHARED suitability codes are stated as "Issued for…" but this does not infer any contractual or insurable purpose. Their purpose is to limit the reuse of the information at that stage. See also BS 1192 and Building Information Modelling – A Standard Framework and Guide to BS 1192, Richards, 2010.	X	X			X										This is reflected in the Concept Design and Detailed design BIM workflows (Figure 7.9 and Figure 7.11).
80	Each task team shall take ownership of their own WIP information and model(s) and check and review these with their task team manager before issuing the information and model(s) to the SHARED part of the CDE (9.4.2)	X	X			X									Describes a BIM design and design review workflow that may need to be incorporated into existing team workflows	
81	Once the lead designer is satisfied that clashes have been resolved, the CAD and technical checks have been completed and the COBie-UK-2012 files and drawings in PDF have been extracted then all information shall be SHARED (9.4.4)	X	X			X									Describes a BIM design and design review workflow that may need to be incorporated into existing team workflows	This is reflected in the Concept Design and Detailed design BIM workflows (Figure 7.9 and Figure 7.11).
82	Each task team manager shall change the status of their team's signed-off information, update the revision and issue the information and model(s) to the PUBLISHED part of the CDE (9.5.2)	X	X			X									Describes a BIM design and design review workflow that may need to be incorporated into existing team workflows	In the Design workflows, the sole responsibility for issuing PUBLISHED information rests with the PM who validates the PIM first
83	The clash renditions, drawings and COBie data shall be created from the native files to ensure consistency (9.5.4)	X	X			X		X							Describes a BIM design and design review workflow that may need to be incorporated into existing team workflows	Clash renditions are the responsibility of the Architect as in the Concept Design and

ITEM	REQUIREMENT/ CLAUSE/ CONDITION/ DEMAND	ENVISAGED IMPACTS ON PRE-BIM WORKFLOWS													ANALYSIS	PHASE OF THE WORKFLOWS IN WHICH IT WAS INCLUDED
		PROCESS/TASKS				PEOPLE		TOOLS			DOCUMENT/INFORMATION					
		SS	SC	RDD	TM	R	FR	CP	RDD	RNT	RDD	RND	RSC	RSF		
																Detailed design BIM workflows (Figure 7.9 and Figure 7.11)
84	The use of library systems to store, manage and share pre-defined assemblies or sub-assemblies is a key productivity-enhancing feature of most BIM tools. They are also a useful location to store lessons learnt for future projects. Libraries may be managed by the employer or their representative with specific controls which will be documented or referenced by the EIR.	X	X			X				X			X			These were not modelled at the level of abstraction adopted.
85	The handover process and detailed operational processes are documented in PAS 55; the data requirements for these and associated activities are to be documented in PAS 1192-3.	X	X			X										The scope of the workflows does not extend beyond the pre-construction stage
86	Based on responses from the supply chain, methods of information sharing shall be reviewed and resolved by the principal supplier. Agreed solutions shall be documented by the final BEP submitted to the employer (6.5.3)	X	X			X									Here it is evident that even the principal supplier (main contractor) is to have an expanded role. Seemingly above or just at par with clients representatives	This is reflected in the Design Planning BIM workflow (Figure 7.7)
87	If separate COBie-UK-2012 files have been produced by each task team then these shall be co- ordinated prior to forwarding to the employer. See also 6.5.3.	X	X			X									The responsibility for this task and how it fits into the project workflow needs to be considered	In the workflows, only one set of COBie files would be produced by the PM/Information manager
88	Clash avoidance/checking shall be carried out during specialist design and development of the virtual construction model, with particular focus on soft clashes (for example, positioning of insulation around ductwork and pipework) and proximity checks (for example, the placement of oxygen and other gases or flammable substances in hospitals) (9.4.7).	X	X												This is quite similar to conventional clash detection workflows but requires consideration still	The overall responsibility for clash avoidance has been modelled to rest with the Lead Designer/Architect
89	Clash avoidance/checking shall continue during the construction process as the models are updated with as-constructed information and checked against the construction tolerances specified in the contract (9.4.8)	X	X												This is quite similar to conventional clash detection workflows but requires consideration still	

ITEM	REQUIREMENT/ CLAUSE/ CONDITION/ DEMAND	ENVISAGED IMPACTS ON PRE-BIM WORKFLOWS													ANALYSIS	PHASE OF THE WORKFLOWS IN WHICH IT WAS INCLUDED
		PROCESS/TASKS				PEOPLE		TOOLS			DOCUMENT/INFORMATION					
		SS	SC	RDD	TM	R	FR	CP	RDD	RNT	RDD	RND	RSC	RSF		
90	The individual SHARED models may be combined for design review by the lead designer. Design decisions or clashes that cannot be resolved by the interface managers can then be reviewed and resolved	X	X					X							Interoperability is a concern here	This is reflected in the Concept Design and Detailed design BIM workflows (Figure 7.9 and Figure 7.11)
91	The information delivery cycle and the project stages described in this PAS shall begin at “CAPEX start” and end at Handover (5.1.1)	X	X													The scope of the workflows does not extend beyond the pre-construction phase
92	Definition of the information exchange and collaborative working requirements shall be undertaken in parallel with other procurement and project definition activities (5.1.2).	X	X		X	X										
93	The WIP section of the CDE shall be used to hold unapproved information for each organizational role. The WIP section concludes with the Approval Gate (“1” in Figure 15 (9.2.1)) which represents the transition to SHARED, where the information is checked, reviewed and approved by the lead designer (9.2.2.1)	X	X			X										This is reflected in the Concept Design and Detailed design BIM workflows (Figure 7.9 and Figure 7.11)
94	Information models to be developed using one of the following combinations of enabling tools: 1) discipline-based software, with individual proprietary databases, that have limited interoperability between them or with associated design analysis software; 2) discipline-based software, with individual proprietary databases, that are fully interoperable, but with limited interoperability with associated design analysis software; 3) discipline-based software, with individual proprietary databases, and associated design analysis software that is fully interoperable; or							X		X					This may require new tools other than those used pre-BIM.	

ITEM	REQUIREMENT/ CLAUSE/ CONDITION/ DEMAND	ENVISAGED IMPACTS ON PRE-BIM WORKFLOWS													ANALYSIS	PHASE OF THE WORKFLOWS IN WHICH IT WAS INCLUDED
		PROCESS/TASKS				PEOPLE		TOOLS			DOCUMENT/INFORMATION					
		SS	SC	RDD	TM	R	FR	CP	RDD	RNT	RDD	RND	RSC	RSF		
95	**<u>Contents of the EIR:</u>** 7) a schedule of any security and integrity requirements for the project; 8) a schedule of any specific information to be either excluded or included from information models; 9) a schedule of any particular constraints set by the employer on the size of model files, the size of extranet uploads or emails, or the fi le formats that can define the size of a volume; In addition to the generic contents listed above, the EIR may also include project specific items such as pre-construction surveys or a requirement for the employer to receive information models describing newly-generated products and assemblies.	X				X		X		X		X	X			This is reflected in the Section following the Planning and CPSP Procurement BIM workflow
96	9.4.10 To achieve spatial co-ordination when the software solutions of the individual teams are incapable of a reasonable level of interoperability then clash renditions shall be used. The clash renditions shall be made in the format of the viewing tool that has been chosen for the project. The clash rendition for each model for each discipline shall be issued to the SHARED area along with all other deliverables							X		X						This is reflected in the Concept Design and Detailed design BIM workflows (Figure 7.9 and Figure 7.11)
	SOURCE: CIC PROTOCOL, 2013															
97	All parties involved in the use, production or delivery of Models on the Project (the "Project Team Members") are required to have a BIM Protocol appended to their contracts.					X							X		As with most of the content of the CIC protocol, this relates to contractual documentation issues and roles or project participants	
98	The Protocol is intended to be expressly incorporated into all direct contracts between the Employer and the Project Team Members												X		This relates to contractual documentation issues and roles or project participants	

ITEM	REQUIREMENT/ CLAUSE/ CONDITION/ DEMAND	ENVISAGED IMPACTS ON PRE-BIM WORKFLOWS													ANALYSIS	PHASE OF THE WORKFLOWS IN WHICH IT WAS INCLUDED
		PROCESS/TASKS				**PEOPLE**		**TOOLS**			**DOCUMENT/INFORMATIO N**					
		SS	SC	RDD	TM	R	FR	CP	RD D	RN T	RD D	RND	RS C	RSF		
99	Project Team Members should arrange for the Protocol to be incorporated into subcontracts which concern the use, production or delivery of Models to the extent required to ensure that the Project Team Member complies with the Protocol. This will also ensure the sub-contractors have the benefit of and are subject to the licences in clause 6.					X							X		This relates to contractual documentation issues and roles or project participants	
100	The Employer is granted a licence in respect of the Material (the electronic information contained in the Models produced by the Project Team Member) for the Permitted Purpose and clauses 6.6 and 6.7 grant a licence and sub-licence from the Employer to the Project Team Member in respect of other information contained in Models (including material provided by the Employer or on his behalf for inclusion in the Project Team Member's Models) for the **Permitted Purpose**. This means that a Project Team Member will be granted a licence, via the Employer, to use the Models produced by an Other Project Team Member, subject to the terms of clause 6 and vice versa											X	X		This calls for a new document much like the CIC protocol to be developed, while also implying a need to incorporate necessary clauses in existing documents	
101	The Scope of Services for the Role of Information Management will need to be defined in the Appointment of the party undertaking the Information Management Role. Details of the scope of services of the Information Manager have been prepared by the CIC. There are two versions: a detailed version compatible with the CIC scope of services, and another simpler version suitable for incorporation with any appointment, these are published separately on the BIM Task Group website, www:bimtaskgroup.org.	X	X			X							X			

ITEM	REQUIREMENT/ CLAUSE/ CONDITION/ DEMAND	ENVISAGED IMPACTS ON PRE-BIM WORKFLOWS													ANALYSIS	PHASE OF THE WORKFLOWS IN WHICH IT WAS INCLUDED
		PROCESS/TASKS				PEOPLE		TOOLS			DOCUMENT/INFORMATIO N					
		SS	SC	RDD	TM	R	FR	CP	RD D	RN T	RD D	RND	RS C	RSF		
102	The principal responsibilities of the Information Manager can be summarised as: • Managing the processes and procedures for information exchange on projects; • Initiating and implementing the Project Information Plan and Asset Information Plan; • Assisting in the preparation of Project Outputs, such as data drops; and • Implementation of the BIM Protocol, including the updating of the MPDT	X	X			X							X		As discussed earlier with the reference made about this in the PAS 1192, This role may likely overlap that of the project manager or lead supplier (consultant)	These have been reflected in the BIM workflows. These are some of the same requirements contained in the PAS1192 document
103	The initial responsibility for the appointment of the Information Manager lies with the Employer, who must ensure that there is an Information Manager appointed (whether by the Employer or another party) at all times until completion of the Project, save to the extent that this is the responsibility of the relevant Project Team Member	X	X			X							X			This is reflected in the Planning and CPSP procurement BIM workflows (Figure 7.5)
104	The Information Requirements should be adapted to suit the needs of the Project. Once prepared, the IR will be appended to the Protocol attached to all Project Team Agreements. It is likely to be an evolving document and will be subject to the change control procedure under the Agreement	X	X			X						X	X			See analysis above for the PAS1192
105	The Model Production and Delivery Table (MPDT) is a key document as it both allocates responsibility for preparation of the Models and identifies the Level of Detail (LOD) that Models need to meet at the project stages or data drops stated in the table.											X	X		This is an important document as stated. It will describe in fair detail, responsibilities for project team members for model production	See analysis above for the PAS1192
106	Parties should consider whether any amendments are required to the scope of services of the members of the Project Team in addition to the Protocol to reflect the fact that BIM is being used					X							X		Possible requirement for altering existing documents is highlighted here.	
107	Information Requirements means the document attached to this Protocol at Appendix 2 setting out the way in which Models shall be produced, delivered and used on the Project, including any processes, protocols and procedures referred to therein.											X	X		Note	

ITEM	REQUIREMENT/ CLAUSE/ CONDITION/ DEMAND	ENVISAGED IMPACTS ON PRE-BIM WORKFLOWS													ANALYSIS	PHASE OF THE WORKFLOWS IN WHICH IT WAS INCLUDED
		PROCESS/TASKS				PEOPLE		TOOLS			DOCUMENT/INFORMATIO N					
		SS	SC	RDD	TM	R	FR	CP	RD D	RN T	RD D	RND	RS C	RSF		
108	Model Production and Delivery Table means the table attached to this Protocol at Appendix 1 specifying the subject matter of each Model, the person who is to produce and deliver each Model (described in the table as "Model Originator") at each Stage and the Level of Detail for each Model at each Stage.					X						X	X		Note	
109	This Protocol forms part of the Agreement. In the event of a conflict or inconsistency between the terms of this Protocol and any other documents contained in and/or forming part of the Agreement, except where the Protocol states otherwise, the terms of this Protocol shall prevail												X			
110	The primary objective of the Protocol is to enable the production of Building Information Models at defined stages of a project. The Protocol is aligned with Government BIM Strategy and incorporates provisions which support the production of deliverables for 'data drops' at defined project stages. The Protocol also provides for the appointment of an 'Information Manager'					X									Note	
111	The responsibility for ensuring that Protocols are in place is with the Employer named in each agreement					X									This once more emphasised the increased responsibility for the Employer	
112	Models which are scheduled in Appendix 1, the Model Production and Delivery Table (MPDT), are subject to the Protocol. Models which are not listed in the MPDT do not benefit from the provisions of the Protocol					X						X			The way the MPDT is described portrays it as a schedule of deliverables rather than of planned actions	
113	The Protocol requires the Employer to appoint a party to undertake the Information Management Role. This is expected to form part of a wider set of duties under an existing appointment and is likely to be performed either by the Design Lead or the Project Lead, which could be a consultant or contractor at different stages of the project. In some circumstances, the Employer may appoint a standalone Information Manager					X									See the previous discussion on the Information Manager's role	See analysis above for the PAS1192

ITEM	REQUIREMENT/ CLAUSE/ CONDITION/ DEMAND	ENVISAGED IMPACTS ON PRE-BIM WORKFLOWS													ANALYSIS	PHASE OF THE WORKFLOWS IN WHICH IT WAS INCLUDED
		PROCESS/TASKS				PEOPLE		TOOLS			DOCUMENT/INFORMATIO N					
		SS	SC	RDD	TM	R	FR	CP	RD D	RN T	RD D	RND	RS C	RSF		
114	The Information Manager has no design related duties. Clash detection and model coordination activities associated with a 'BIM Coordinator' remain the responsibility of the design lead.					X									This clarifies the role of the Information Manager in more detail	See analysis above for the PAS1192
115	It is the responsibility of the Information Manager to agree and issue the IR, which should be prepared before the Agreements are concluded, as otherwise, the parties will have to rely on the other contractual arrangements, which may not address the items covered by the IR.	X	X			X										See analysis above for the PAS1192
116	Information Management Role means a role in connection with the Project which includes, inter alia, the establishment and management of the processes, protocols and procedures set out in the Information Requirements.					X									Still clarifying the role of the Information Manager	See analysis above for the PAS1192
117	Information Manager means the person appointed, initially by the Employer, to perform the Information Management Role.					X										See analysis above for the PAS1192
118	The Employer shall: arrange for a protocol in substantially the same terms as this Protocol and for the obligations set out herein to be incorporated into all Project Agreements; and save to the extent that such obligations are within the scope of the Project Team Member's obligations under any other part of the Agreement: a ensure that until the end of the Project the Information Requirements and the Model Production and Delivery Table are reviewed and updated at each Stage; and ensure that the appointment of the Information Manager shall be changed or renewed as necessary to ensure that there is at all times until the end of the Project a person performing the Information Management Role.					X									Clarifies the role of the Employer	See analysis above for the PAS1192

ITEM	REQUIREMENT/ CLAUSE/ CONDITION/ DEMAND	ENVISAGED IMPACTS ON PRE-BIM WORKFLOWS													ANALYSIS	PHASE OF THE WORKFLOWS IN WHICH IT WAS INCLUDED
		PROCESS/TASKS				PEOPLE		TOOLS			DOCUMENT/INFORMATIO N					
		SS	SC	RDD	TM	R	FR	CP	RD D	RN T	RD D	RND	RS C	RSF		
119	The Project Team Member shall: produce the Specified Models (excluding any material forming part of the same which is provided to the Project Team Member by or on behalf of the Employer) to the Level of Detail specified in the Model Production and Delivery Table using the level of skill and care required under the Agreement; and subject to events outside its reasonable control, (including the acts or omissions of the Employer, Other Project Team Members and any third party but excluding the Project Team Member’s sub-contractors), use reasonable endeavours to: a deliver the Specified Models at the Level of Detail specified in the Model Production and Delivery Table at the Stage specified therein and in accordance with the Information Requirements; b use the Project Team Models in accordance with any procedures therefor in the Information Requirements; and c comply with the Information Requirements; and 4.1.3 arrange for this Protocol to be incorporated into any sub-contracts that it enters into in relation to the Project to the extent required to enable the Project Team Member to comply with this Protocol.	X	X			X									Clarifies the roles of a Project Team member	See analysis above for the PAS1192

12 APPENDIX 2

12.1 MDM models presented phase by phase

	Depends on →	1	2	3	4	5	6	7	8	9	10	11	A	B	C	D	E	F	G	A	B	C	D	E
1	Initiate project process by by inviting the services of a PM	■											X									X		
2	Provide a brief of intent	X	■										X							X			X	
3	Dicussions to identify requirements and scope		X	■										X										
4	Sign a service level agreement with client			X	■									X										
5	Provide input on specific needs of users			X		■													X					X
6	Identify specific needs client needs to fill				X	X	■							X										
7	Discuss client's proposals & think up possiblities						X	■						X										
8	Visit proposed project site							X	■					X										
9	Identify likely general project constraints								X	■				X										
10	Establish client's requirements in a scoping report									X	■	X		X							X			
11	Approve scoping report										X	■		X										
A	CLT												■	1										
B	PM												2	■					1					
C	ARCH														■									
D	STRUCT															■								
E	MEP																■							
F	QSV																	■						
G	RELV. OTHRS													1					■					
A	Client's brief																			■				
B	Scoping report																			X	■			X
C	PM agreement																					■		
D	Brief meeting minutes																			X			■	
E	User requirments																							■

Figure 12.1: Planning MDM (Pre-BIM)

	Depends on	1	2	3	4	5	6	7	8	9	10	11	12	A	B	C	D	E	F	G	A	B	C	D	E	F
1	Initiate project by inviting the services of a PM & Information manager	■												X												
2	Provide a brief of intent	X	■											X							X					
3	Discussions to identify requirments & scope		X	■											X											
4	Provide input on specific needs by users			X	■															X				X		
5	Sign service level agreement with client			X		■									X							X	X			
6	Identify specific needs client needs to fill				X	X	■								X											
7	Discuss client's proposals & think up possibilities						X	■							X											
8	Visit project site							X	■						X											
9	Identify likely general project constraints								X	■					X											
10	Define & document EIR									X	■				X										X	
11	Establish client's requirements in a scoping report incorporating EIR										X	■	X		X											X
12	Approve scoping report											X	■	X												
A	CLT													■	1											
B	PM/Information Manager													2	■					1						
C	ARCH															■										
D	STRUCT																■									
E	MEP																	■								
F	QSV																		■							
G	RELV. OTHRS														1					■						
A	Client's brief																				■					
B	PM agreement incl. responsibility for information management																				X	■				
C	Brief meeting minutes																				X	X	■			
D	User requirements																				X	X	X	■		
E	Employer's information requirements (EIR)																				X	X	X		■	
F	Scoping report incorporating EIR																				X	X	X	X	X	■

Figure 12.2: Planning MDM (BIM)

	Depends on	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	A	B	C	D	E	F	G	A	B	C	D	E	F	G	H	J	K
1	Evaluate client's capacity for risk assumption																				X															
2	Evaluate risks & advise on appropriate procurement strategy	X																			X															
3	Define PSP scope of services & prepare responsibilities matrix		X																		X						X									
4	Request for proposals for professional services			X									X								X															
5	Submit proposals for professional ARCH services				X																							X								
6	Submit proposals for professional STRUCT services				X																								X							
7	Submit proposals for professional MEP services				X																									X						
8	Submit proposals for professional QS services				X																										X					
9	Evaluate submissions on behalf of the client & prepare report					X	X	X	X												X											X				
10	Evaluate report on PSP proposals									X										X																
11	Negotiate with prospective PSPs										X									X																
12	Make judgement on satisfaction with selection											X								X																
13	Select preferred PSP												X							X																
14	Facilitate signing of service level agreement for other PSPs													X							X															
15	Sign ARCH service agreement														X							X											X			
16	Sign STRUCT service agreement														X								X											X		
17	Sign MEP service agreement														X									X											X	
18	Sign QS service agreement														X										X											X
A	CLT																																			
B	PM																			2		1	1	1	1											
C	ARCH																				2															
D	STRUCT																				2															
E	MEP																				2															
F	QSV																				2															
G	RELV. OTHRS																																			
A	PSP Scope of service & responsibilities matrix																																			
B	ARCH proposals for professional services																										X									
C	STRUCT proposals for professional services																										X									
D	MEP proposals for professional services																										X									
E	QS proposals for professional services																										X									
F	Report on bid for professional services																											X	X	X	X					
G	Signed ARCH agreement																																			
H	Signed STRUCT agreement																																			
J	Signed MEP agreement																																			
K	Signed QS agreement																																			

Figure 12.3: CPSP procurement MDM (Pre-BIM)

	Depends on	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	A	B	C	D	E	F	G	A	B	C	D	E	F	G	H	J	K
1	Evaluate client's capacity for risk assumption	■																					x															
2	Evaluate risks & advise on appropriate procurement strategy	x	■																				x															
3	Define generic PSP scope of services & prepare responsibilities matri		x	■																			x						x									
4	Request for proposals for professional services incorporating EIR			x	■									x									x															
5	Submit proposals for ARCH services including PIIP				x	■																		x						x								
6	Submit proposals for STRUCT services including PIIP				x		■																		x						x							
7	Submit proposals for MEP services including PIIP				x			■																		x						x						
8	Submit proposals for QS services including PIIP				x				■																		x						x					
9	Evaluate BIM, IT & resource capability & approach to information management					x	x	x	x	■													x															
10	Evaluate proposals on behalf of client & prepare report									x	■												x											x				
11	Evaluate report on PSP proposals										x	■										x																
12	Negotiate with prospective PSPs											x	■									x																
13	Assess satissfaction with selection												x	■								x																
14	Select PSPs													x	■							x																
15	Write EIR into PSPs contracts														x	■							x															
16	Facilitate signing of service level agreement for other PSPs															x	■						x															
17	Sign ARCH service level agreement & commit to EIR																x	■						x											x			
18	Sign STRUCT service level agreement & commit to EIR																x		■						x											x		
19	Sign MEP service level agreement & commit to EIR																x			■						x											x	
20	Sign QS service level agreement & commit to EIR																x				■						x											x
A	CLT																					■	1															
B	PM/Information Manager																					2	■	2	2	2	2											
C	ARCH																						2	■														
D	STRUCT																						2		■													
E	MEP																						2			■												
F	QSV																						2				■											
G	RELV. OTHRS																											■										
A	PSP Scope of service & responsibilities matrix for info. production																												■									
B	ARCH proposals for professional services incl. PIIP																												x	■								
C	STRUCT proposals for professional services incl. PIIP																												x		■							
D	MEP proposals for professional services incl. PIIP																												x			■						
E	QS proposals for professional services incl. PIIP																												x				■					
F	Report on bid for professional services																													x	x	x	x	■				
G	Signed ARCH agreement incorporating EIR																																		■			
H	Signed STRUCT agreement incorporating EIR																																			■		
J	Signed MEP agreement incorporating EIR																																				■	
K	Signed QS agreement incorporating EIR																																					■

Figure 12.4: CPSP procurement MDM (BIM)

	Depends on	1	2	3	4	5	6	7	8	9	#	11	#	#	#	#	#	#	#	#	#	#	#	#	#	#	#	#	#	#	A	B	C	D	E	F	G	A	B	C	D	E	F	G	H	J	K	L	N
1	Conduct project initiation meeting	■																														x																	
2	Prepare project initiation programme	x	■																													x						x											
3	Establish comm structure & prep organogram		x	■																												x							x										
4	Define & agree file sharing method & tools			x	■																											x								x									
5	Design work schedule, documentation programme & indicative construction schedule				x	■																										x									x	x	x						
6	Prepare document issue register					x	■																									x																	
7	Request inputs on cost control & change mgmt. procedure						x	■																								x																	
8	Provide ARCH input on cost control & chang mgmt procedure							x	■																								x																
9	Provide STRUCT input on cost control & chang mgmt procedure							x		■																								x															
#	Provide MEP input on cost control & chang mgmt procedure							x			■																								x														
11	Provide QS input on cost control & chang mgmt procedure							x				■																								x													
#	Discuss & agree cost control & change mgmt plan								x	x	x	x	■																			x												x					
#	Develop change mgmt plan												x	■																		x																	
#	Provide ARCH input on site charateristics, rights & design constraints					x									■																		x																
#	Provide STRUCT input on site charateristics, rights & design constraints					x										■																		x															
#	Provide MEP input on site charateristics, rights & design constraints					x											■																		x														
#	Provide QS input on site charateristics, rights & design constraints					x												■																		x													
#	Establish site characteristics, rights and design constraints														x	x	x	x	■													x																	
#	Prepare schedule of site characteristics, rights & constraints																		x	■												x																	
#	Commission & obtain Topo & Geo surveys																			x	■											x													x				
#	Request statutory requirements																				x	■										x																	
#	Authorities to provide information on required consents & approvals																					x	■																										
#	Stakeholders to provide information on requirements & consents																						x	■																									
#	Provide QS input on Required consents & approvals																							x	■											x													
#	Provide MEP input on Required consents & approvals																							x		■									x													x	
#	Provide STRUCT input on Required consents & approvals																							x			■							x													x		
#	Provide ARCH input on Required consents & approvals																							x				■					x													x			
#	Hold workshop with all stakeholders including site neighbours																								x	x	x	x	■			x																	
#	Prepare a complete schedule of required consents & approvals																												x	■		x																	x
A	CLT																														■																		
B	PM																															■	3	3	3	3													
C	ARCH																															2	■				1												
D	STRUCT																															2		■			1												
E	MEP																															2			■		1												
F	QSV																															2				■	1												
G	RELV. OTHRS																															1					■												
A	Project initiation programme																																					■											
B	Project organogram/ comm structure																																						■										
C	Information sharing methods and tools																																							■									
D	Work schedule																																						x		■								
E	Indicative construction schedule																																					x	x		x	■							
F	Documents issue register																																								x		■						
G	Change management procedure/plan																																											■					
H	Report on site surveys																																												■				
J	Schedule of required consents & approvals ARCH																																										x			■			
K	Schedule of required consents & approvals STRUCT																																										x				■		
L	Schedule of required consents & approvals MEP																																										x					■	
N	Complete schedule of required consents & approvals																																										x						■

Figure 12.5: Design planning MDM (Pre-BIM)

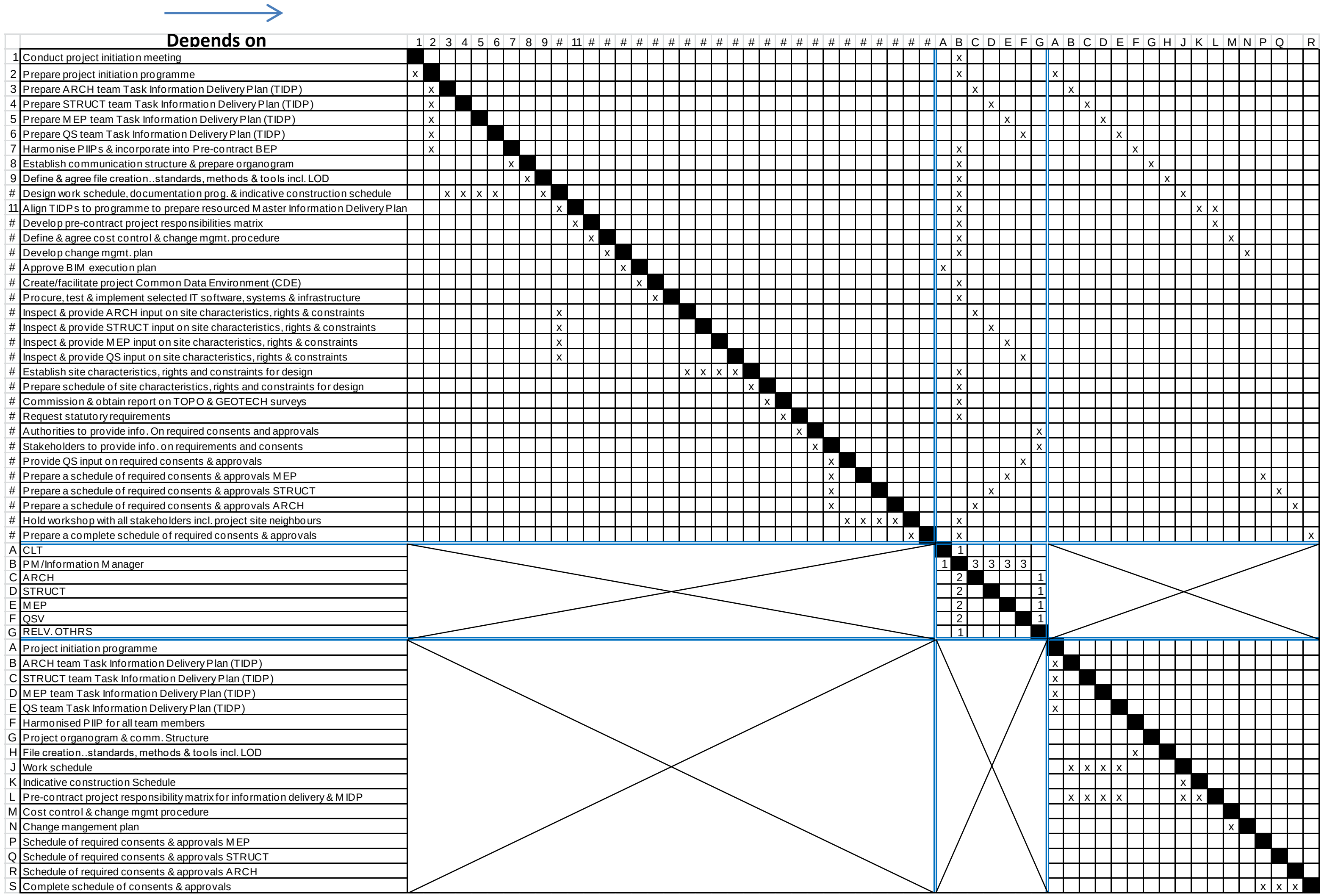

Figure 12.6: Design planning MDM (BIM)

	Depends on	1	2	3	4	5	6	7	8	9	#	11	#	#	#	#	#	#	#	#	#	#	#	#	#	#	A	B	C	D	E	F	G	A	B	C	D	E	F	G
1	Initiate & coordinate design process	■																										x												
2	Carry out space planning	x	■																										x											
3	Prepare site development plan		x	■																									x						x					
4	Prepare concept plans & 3D representations			x	■						x		x							x									x											
5	Prepare STRUCT concept design				x	■					x		x																	x										
6	Prepare MEP concept design				x		■				x		x																		x									
7	Prepare indicative cost of MEP services							■																							x	x								
8	Prepare preliminary estimate of cost & viability					x	x	x	■																							x			x					
9	Estabilsh design cost limits								x	■																						x								
#	Assess fit of design with budget									x	■																													
11	Coordinate/evaluate congruence of design inputs from others incl. clash detection and resolu				x	x	x	x				■																	x	x	x									
#	Evaluate congruence of all designs & with brief											x	■																x											
#	Communicate concept design to client through PM										x		x	■														x								x				
#	Evaluate concept feasibility & viability (scenario testing)														■														x											
#	Consult with Authorities on feasibility & conformance of ARCH concept													x	x	■													x											
#	Consult with Authorities on feasibility & conformance of STRUCT concept													x			■													x										
#	Consult with Authorities on feasibility & conformance of MEP concept													x				■													x									
#	Hold meeting with Authorities															x	x	x	■									x												
#	Decide on concept feasibility & viability																		x	■							x													
#	Prepare concept design report & organise presentations																			x	■						x	x									x			
#	Approve all documents																				x	■																		
#	Obtain interim approval of ARCH design concept																					x	■						x									x		
#	Obtain interim approval of STRUCT design concept																					x		■						x									x	
#	Obtain interim approval of MEP design concept																					x			■						x									x
#	Advise client on required insurances																						x	x	x	■		x												
A	CLT																										■	2												
B	PM																										1	■	3	2	2									
C	ARCH																												■	2	2									
D	STRUCT																												2	■	2									
E	MEP																												2	2	■									
F	QSV																												1	1	1	■								
G	RELV. OTHRS																																■							
A	Site development plan																																	■						
B	Preliminary estimate of cost & viability																																		■	x				
C	Design concept																																	x	x	■				
D	Design concept report																																	x	x	x	■			
E	Interim approval of ARCH concept design																																			x		■		
F	Interim approval of STRUCT concept design																																			x			■	
G	Interim approval of STRUCT concept design																																			x				■

Figure 12.7: Concept design MDM (Pre-BIM)

	Depends on	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	A	B	C	D	E	F	G	A	B	C	D	E	F	G	H	J	K
1	Initiate & coordinate desing process on the CDE	■	x																															x															
2	Carry out space planning		■	x																															x														
3	Prepare site development plan model *(WIP)*			■	x																														x					x									
4	Prepare ARCH concept model incl. alternative options *(WIP)*				■	x																													x														
5	Check & approve ARCH concept models for upload into *SHARED*				x	■	x																											x															
6	Move ARCH concept model into SHARED section of CDE						■	x			x			x			x																		x														
7	Prepare STRUCT concept model (WIP)							■	x																											x							x						
8	Check & approve STRUCT concept models for upload into *SHARED*							x	■	x																								x															
9	Move STRUCT concept model into SHARED section of CDE									■	x			x			x																			x													
10	Prepare MEP concept model (WIP)										■	x																									x							x					
11	Check & approve MEP concept models for upload into *SHARED*										x	■	x				x																	x															
12	Move MEP concept model into SHARED section of CDE												■	x			x																				x												
13	Extract quantities & specs to prepare preliminary estimate of cost & viability													■	x																							x			x								
14	Establish design cost limits														■	x																						x											
15	Assess fit of design with budget				x			x			x					■			x																			x											
16	Coordinate/Evaluate congruence of integrated models; clash detection & resolution																■	x																	x														
17	Check & approve coordinated concept models for upload into *SHARED*				x													■	x															x															
18	PUBLISH & ARCHIVE all approved information on CDE																		■	x														x															
19	Evaluate concept feasibility and viability (case scenario testing)																			■	x	x	x											x								x							
20	Discuss with authorities on ARCH feasibility & conformance																				■			x											x														
21	Discuss with authorities on STRUCT feasibility & conformance																					■		x												x													
22	Discuss with authorities on MEP feasibility & conformance																						■	x													x												
23	Hold meetings to discuss with authorities																							■	x									x															
24	Assess feasibility & viability of design concept				x																				■	x																							
25	Prepare concept design report & organise presentation																									■	x						x	x											x				
26	Approve all documents																										■	x	x	x			x																
27	Obtain interim approval of ARCH design concept																											■			x				x												x		
28	Obtain interim approval of STRUCT design concept																												■		x					x												x	
29	Obtain interim approval of MEP design concept																													■	x						x												x
30	Advise client on required insurances																														■	x		x															
31	Extract COBie data, PUBLISH & ARCHIVE all approved information on CDE																															■		x															x
A	CLT																																■	1	2	1	1												
B	PM/Information Manager																																2	■	4	3	3												
C	ARCH																																	4	■	1	1	1											
D	STRUCT																																	3	1	■	1	1											
E	MEP																																	1	1	1	■	1											
F	QSV																																	1	1	1	1	■											
G	RELV. OTHRS																																						■										
A	Site development model																																							■	x	x			x	x	x	x	x
B	Preliminary estimate of cost & viability																																								■	x			x				x
C	ARCH Design concept model																																									■	x	x	x	x	x	x	x
D	STRUCT Design concept model																																										■	x	x				x
E	MEP Design concept model																																											■	x				x
F	Design concept report																																												■				x
G	Interim approval of ARCH concept design																																													■			x
H	Interim approval of STRUCT concept design																																														■		x
J	Interim approval of MEP concept design																																															■	x
K	COBie data files																																																■

Figure 12.8: Concept design MDM (BIM)

	Depends on	1	2	3	4	5	6	7	8	9	#	11	#	#	#	#	#	#	#	#	#	#	#	#	#	#	#	#	#	#	#	#	A	B	C	D	E	F	G	A	B	C	D	E	F	G	H	J
1	Invite potential suppliers to present samples for material and finishes selection	■							X																									X															
2	Provide samples of materials and finishes	X	■																																													
3	Select materials & finshes for ARCH & prepare specifications		X	■																															X														
4	Select materials & finshes for STRUCT & prepare specifications		X		■																															X													
5	Select materials & finshes for MEP & prepare specifications		X			■																															X												
6	Evaluate cost implications of all choices (finishes & specs)			X	X	X	■																															X											
7	Present materials & finishes selection to client			X	X	X	X	■																										X															
8	Decide on appopriateness of selected materials							X	■																								X																
9	Issue design criteria & standards								X	■																								X						X								
#	Develop full ARCH design									X	■						X									X		X							X						X							
11	Develop full STRUCT design									X	X	■					X																			X						X						
#	Develop ful MEP design									X	X	X	■				X																				X						X					
#	Review designs & specifications									X	X	X	X	■																								X										
#	Take-off from drawings												X	■																								X										
#	Prepare bills of quantities & price													X	■																							X						X				
#	Assess fit of designs with budget														X	■																						X										
#	Overlay drawings & coordinate congruence of STRUCT & MEP designs incl. clash detection & resolution											X	X					■																		X	X											
#	Overlay drawings & coordinate congruence of all designs incl. clash detection & resolution										X							X	■																X	X	X											
#	Evaluate congruence of all designs																		X	■															X													
#	Discuss ARCH design feasibility & conformance with authorities																			X	■														X													
#	Discuss STRUCT design feasibility & conformance with authorities																			X		■														X												
#	Discuss MEP design feasibility & conformance with authorities																			X			■														X											
#	Communicate full designs to PM																				X	X	X	■											X													
#	Evaluate full design feasibility and viability																X							X	■									X														
#	Evaluate congruence of all full designs																								X	■								X														
#	Prepare design report to client & organise presentations																									X	■							X												X			
#	Evaluate design and estimate cost acceptability																										X	■					X															
#	Approve all documents																											X	■				X															
#	Obtain approval of full ARCH design																												X	■					X											X		
#	Obtain approval of full STRUCT design																												X		■					X											X	
#	Obtain approval of full MEP design																												X			■					X											X
A	CLT																																■	2														
B	PM																																	■	2			1										
C	ARCH																																	1	■	2	2	1	1									
D	STRUCT																																	1	4	■	2	1	1									
E	MEP																																	1	4	5	■	1	1									
F	QSV																																	1	1	1	1	■	1									
G	RELV. OTHRS																																1						■									
A	Design criteria, standards & specifications																																							■								
B	Full ARCH designs																																							X	■	X	X	x				
C	Full STRUCT designs																																							X	X	■	X	x				
D	Full MEP designs																																							X	X	X	■	x				
E	Bills of quantities																																							X	X	X	X	■				
F	Full design report																																								X	X	X	X	■			
G	Approval of ARCH design by authorities																																													■		
H	Approval of STRUCT design by authorities																																														■	
J	Approval of MEP design by authorities																																															■

Figure 12.9: Detailed design MDM (Pre-BIM)

	Depends on	1	2	3	4	5	6	7	8	9	#	11	#	#	#	#	#	#	#	#	#	#	#	#	#	#	#	#	#	#	#	#	#	#	#	#	A	B	C	D	E	F	G	A	B	C	D	E	F	G	H	J	K
1	Invite potential suppliers to present samples for material and finishes selection	■							x																													x															
2	Provide samples of materials and finishes incl. BIM library items	x	■																																								x										
3	Select materials & finishes for MEP & prepare specs		x	■																																					x												
4	Select materials & finishes for STRUCT & prepare specs		x		■																																			x													
5	Select materials & finishes for ARCH & prepare specs		x			■																																	x														
6	Evaluate cost implications of material & finishes			x	x	x	■																																			x											
7	Present material & finishes to client			x	x	x	x	■																														x															
8	Assess the appropriateness of materials and finishes presented							x	■																												x																
9	Issue final design criteria & standards								x	■																												x						x									
#	Prepare full ARCH models (WIP)									x	■	x										x		x							x								x						x								
11	Check & approve full ARCH model for upload into SHARED										x	■																										x															
#	Move full ARCH model into SHARED section of CDE											x	■																										x														
#	Prepare full STRUCT models (WIP)												x	■	x							x																		x						x							
#	Check & approve full STRUCT model for upload into SHARED													x	■																							x															
#	Move full STRUCT model into SHARED section of CDE														x	■																								x													
#	Prepare full MEP models (WIP)												x			x	■	x				x																			x						x						
#	Check & approve full MEP model for upload into SHARED																x	■																				x															
#	Move full MEP model into SHARED section of CDE																	x	■																						x												
#	Review designs & specifications												x			x			x	■																						x											
#	Extract quantities, prepare bills of quantities & price																			x	■																					x						x					
#	Assess fit of designs with budget																				x	■																				x											
#	Coordinate/evaluate congruence of integrated design models; clash detection & resolution												x			x			x				■																x														
#	Check & approve coordinated full design models for upload into SHARED																						x	■														x															
#	PUBLISH & ARCHIVE all approved information on CDE																					x		x	■													x															
#	Discuss with authorities on feasibility & conformance of ARCH designs																								x	■													x														
#	Discuss with authorities on feasibility & conformance of STRUCT designs																								x		■													x													
#	Discuss with authorities on feasibility & conformance of MEP designs																								x			■													x												
#	Evaluate full design feasibility (case/scenario testing)																									x	x	x	■									x															
#	Prepare design report to client & organise presentations																												x	■								x												x				
#	Assess acceptability of full designs & budget																													x	■						x																
#	Approve all documents																														x	■					x																
#	Obtain approval of ARCH design by authorities																															x	■						x												x			
#	Obtain approval of STRUCT design by authorities																															x		■						x												x		
#	Obtain approval of MEP design by authorities																															x			■						x												x	
#	Extract COBie data, PUBLISH & ARCHIVE all approved information on CDE																															x				■		x																x
A	CLT																																				■	2															
B	PM/Information Manager																																				2	■	4	3	3	1											
C	ARCH																																				2	4	■	1	1	1	1										
D	STRUCT																																				1	3	1	■	1	1	1										
E	MEP																																				1	2	1	1	■	1	1										
F	QSV																																						1	1	1	■	1										
G	RELV. OTHRS																																					1					■										
A	Design criteria, standards & specifications																																											■									
B	Full ARCH design model																																											x	■	x	x	x					
C	Full STRUCT design model																																											x	x	■	x	x					
D	Full MEP design model																																											x	x	x	■	x					
E	Bills of quantities																																											x	x	x	x	■					
F	Full design report																																												x	x	x	x	■				
G	Approval of ARCH design by authorities																																																	■			
H	Approval of STRUCT design by authorities																																																		■		
J	Approval of MEP design by authorities																																																			■	
K	COBie data files																																											x	x	x	x	x	x	x	x	x	■

Figure 12.10: Detailed design MDM (BIM)

	Depends on	1	2	3	4	5	6	7	8	9	#	11	#	#	#	#	#	#	#	#	#	#	#	#	#	#	#	#	#	#	#	#	A	B	C	D	E	F	G	H	A	B	C	D	E	F	G	H	j	K	L	M	N	P
1	Review project programme																																	x																				
2	Advice on procurement strategy	x																																x																				
3	Approve procurement strategy		x																														x																					
4	Prepare procurement programme			x																														x							x													
5	Prepare tender ARCH drawings & specs				x																														x							x												
6	Prepare tender STRUCT drawings & specs				x																															x							x											
7	Prepare tender MEP drawings & specs				x																																x							x										
8	Prepare tender QS Bills & specs				x																																	x							x									
9	Collate all tender documents					x	x	x	x																									x																				
#	Invite tenders from contractors									x																								x																				
11	Prepare & explain tender evaluation criteria to all stakeholders										x																							x																				
#	Prepare & submit tender for the works										x																												x							x								
#	Open tenders & record tender figures											x	x																				x	x	x	x	x	x	x	x														
#	Evaluate technical ARCH submissions													x																					x												x							
#	Evaluate technical STRUCT submissions													x																						x												x						
#	Evaluate technical MEP submissions													x																							x												x					
#	Analyse bids against quoted prices, time & other relv. criteria													x																								x												x				
#	Prepare QS tender analysis report																	x																				x																
#	Prepare tender report for technical MEP submission																x																				x																	
#	Prepare tender report for technical STRUCT submission															x																				x																		
#	Prepare tender report for technical ARCH submission														x																				x																			
#	Evaluate technical & financial reports on tenders incl. negotiations																		x	x	x	x												x																				
#	Recommend contractor (s)																						x											x																				
#	Select preferred successful contractor (s)																							x									x																					
#	Issue letter (s) of intent stating conditions																								x									x																	x			
#	Accept offer																									x													x													x		
#	Issue letter(s) of award																										x							x																			x	
#	Define the format & procedure for project cost control																											x										x																
#	Assemble contract documents for signing by client & contractor(s)																												x									x																
#	Contractor signs contract for the works																													x									x															x
#	Client signs contract for the works																													x			x																					x
A	CLT																																	3					1	1														
B	PM																																3		3	3	3	3	2	1														
C	ARCH																																	2		1	1	1	1	1														
D	STRUCT																																	2	1		1	1	1	1														
E	MEP																																	2	1	1		1	1	1														
F	QSV																																	3	1	1	1		1	1														
G	CONTR.																																	3	1	1	1	2		1														
H	RELV. OTHRS																																1	1	1	1	1	1	1															
A	Procurement programme																																																					
B	ARCH tender documents																																																					
C	STRUCT tender documents																																																					
D	MEP tender documents																																																					
E	QS tender bills																																								x	x	x											
F	Contractor(s) tender																																								x	x	x											
G	Technical tender report - ARCH																																								x													
H	Technical tender report - STRUCT																																									x												
j	Technical tender report - MEP																																										x											
K	QS tender report - financial																																								x	x	x											
L	letter of intent																																													x	x	x	x	x				
M	letter of acceptance of offer																																													x	x	x	x	x	x			
N	Award letter(s)																																													x	x	x	x	x	x	x		
P	Signed contract																																													x	x	x	x	x	x	x	x	

Figure 12.11: Contractor procurement MDM (Pre-BIM)

Depends on →

		1	2	3	4	5	6	7	8	9	#	11	#	#	#	#	#	#	#	#	#	#	#	#	#	#	#	#	#	#	#	#	#	#	#
1	Review project programme	■																																	
2	Advice on procurement strategy	x	■																																
3	Approve procurement strategy		x	■																															
4	Prepare procurement programme			x	■																														
5	Prepare tender ARCH information & specifications ref. PUBLISHED section of CDE				x	■																													
6	Prepare tender STRUCT information & specifications ref. PUBLISHED section of CDE				x		■																												
7	Prepare tender MEP information & specifications ref. PUBLISHED section of CDE				x			■																											
8	Prepare tender QS Bills, information & specifications ref. PUBLISHED section of CDE				x				■																										
9	Collate all tender documents					x	x	x	x	■																									
#	Invite tenders from contractor(s) incorporating EIR									x	■																								
11	Prepare & explain evaluation criteria to all stakeholders										x	■																							
#	Prepare & submit tender fot the works including a PIIP											x	■																						
#	Open tenders and record tender figures												x	■																					
#	Analyse bids against quoted prices, time & other relv. criteria													x	■																				
#	Evaluate technical MEP services submissions													x		■																			
#	Evaluate technical STRUCT submissions													x			■																		
#	Evaluate technical ARCH services submissions													x				■																	
#	Prepare tender report for technical ARCH submission																	x	■																
#	Prepare tender report for technical STRUCT submission																x			■															
#	Prepare tender report for technicel MEP services submission															x					■														
#	Prepare financial tender analysis report														x							■													
#	Evaluate BIM, IT, resource capability & approach to information management																		x	x	x	x	■												
#	Evaluate technical and financial reports on tenders incl. negotiations																						x	■											
#	Recommend contractor(s)																							x	■										
#	Select preferred/ successful contractor(s)																								x	■									
#	Issue letter(s) of intent stating conditions																									x	■								
#	Accept offer																										x	■							
#	Issue letter(s) of award																											x	■						
#	Define the format & procedure for project cost control																												x	■					
#	Write in EIR into contractor's contract																													x	■				
#	Assemple contract for signature by client & contractor																														x	■			
#	Sign contract to deliver the project																															x	■		
#	Sign contract agreement engaging contractor																															x		■	
#	Extract COBie data, PUBLISH & ARCHIVE all approved information on CDE																																x	x	■

		A	B	C	D	E	F	G	H	A	B	C	D	E	F	G	H	j	K	L	M	N	P	Q
1	Review project programme		x																					
2	Advice on procurement strategy		x																					
3	Approve procurement strategy	x																						
4	Prepare procurement programme		x							x														
5	Prepare tender ARCH information & specifications ref. PUBLISHED section of CDE			x							x													
6	Prepare tender STRUCT information & specifications ref. PUBLISHED section of CDE				x							x												
7	Prepare tender MEP information & specifications ref. PUBLISHED section of CDE					x							x											
8	Prepare tender QS Bills, information & specifications ref. PUBLISHED section of CDE						x							x										
9	Collate all tender documents		x																					
#	Invite tenders from contractor(s) incorporating EIR		x																					
11	Prepare & explain evaluation criteria to all stakeholders		x																					
#	Prepare & submit tender fot the works including a PIIP							x							x									
#	Open tenders and record tender figures	x	x	x	x	x	x	x	x															
#	Analyse bids against quoted prices, time & other relv. criteria						x																	
#	Evaluate technical MEP services submissions					x																		
#	Evaluate technical STRUCT submissions				x																			
#	Evaluate technical ARCH services submissions			x																				
#	Prepare tender report for technical ARCH submission			x												x								
#	Prepare tender report for technical STRUCT submission				x												x							
#	Prepare tender report for technicel MEP services submission					x												x						
#	Prepare financial tender analysis report						x												x					
#	Evaluate BIM, IT, resource capability & approach to information management		x																					
#	Evaluate technical and financial reports on tenders incl. negotiations		x																					
#	Recommend contractor(s)		x																					
#	Select preferred/ successful contractor(s)	x																						
#	Issue letter(s) of intent stating conditions		x																	x				
#	Accept offer							x													x			
#	Issue letter(s) of award		x																			x		
#	Define the format & procedure for project cost control						x																	
#	Write in EIR into contractor's contract		x																					
#	Assemple contract for signature by client & contractor		x																					
#	Sign contract to deliver the project							x															x	
#	Sign contract agreement engaging contractor	x																					x	
#	Extract COBie data, PUBLISH & ARCHIVE all approved information on CDE		x																					x

		A	B	C	D	E	F	G	H
A	CLT	■	4	1	1	1	1	1	1
B	PM/Information Manager	4	■	3	3	3	4	3	1
C	ARCH	1	2	■	1	1	1	1	1
D	STRUCT	1	2	1	■	1	1	1	1
E	MEP	1	2	1	1	■	1	1	1
F	QSV	1	3	1	1	1	■	1	1
G	CONTR.	1	2	1	1	1	1	■	1
H	RELV. OTHRS	1	1	1	1	1	1	1	■

		A	B	C	D	E	F	G	H	j	K	L	M	N	P	Q
A	Procurement programme	■														
B	ARCH tender information/ documents		■													
C	STRUCT tender information/ documents			■												
D	MEP tender information/ documents				■											
E	QS tender bills		x	x	x	■										
F	Contractor(s) tender incl. PIIP		x	x	x		■									
G	Technical tender report - ARCH		x					■								
H	Technical tender report - STRUCT			x					■							
j	Technical tender report - MEP				x					■						
K	QS tender report - financial		x	x	x						■					
L	letter of intent						x	x	x	x	x	■				
M	letter of acceptance of offer						x	x	x	x	x	x	■			
N	Award letter(s)						x	x	x	x	x	x	x	■		
P	Signed contract						x	x	x	x	x	x	x	x	■	
Q	Cobie data files	x	x	x	x	x	x	x	x	x	x	x	x	x	x	■

Figure 12.12: Contractor procurement MDM (BIM)

13 APPENDIX 3

13.1 Research instruments

SCHOOL OF CONSTRUCTION ECONOMICS & MANAGEMENT

Date: dd-dd-yy

PARTICIPANT INFORMATION SHEET

PROJECT TITLE: Modelling a Collaborative Delivery Framework for BIM Projects in South Africa

SHORT TITLE: Understanding the Change Impact of BIM Implementation on Project Team Intra/Inter-organisational Work practices and Workflows in South Africa

Dear ___________________,

I am Adeyemi Akintola, a research student at the University of the Witwatersrand, Johannesburg. I am conducting a research study; its purpose is to help construction industry professionals like you understand the impact of implementing Building Information Modelling (BIM) on the work you do within your organisations, and as part of teams on construction projects. I would, therefore, like to speak with you (upon consent) about your experiences on projects where you have provided professional services and on which BIM was implemented. The essence is to contrast your experiences on such projects to those where delivery was not facilitated by implementing BIM.

I am therefore inviting you to take part in this research project. This is because you have been identified as one of the professionals that provide services on construction projects. Further, you have been chosen because of your involvement in projects where BIM has been implemented extensively. Your experience could, therefore, provide valuable insight into finding solutions to challenges that may be inherent in the implementation process. You may, therefore, be asked (upon consent) to contribute information in a face-to-face interview which might last between 30 to 90 minutes. For your convenience, this may take place in your offices, or any place of your choice. The interview will take place on a date that will be agreed with you, subsequent upon your acceptance to participate in this study.

Please note the following:

- Your participation is entirely voluntary, and your refusal to participate, or withdraw your participation (at any time) will involve no consequences.
- During the interview, you may refuse to answer any question(s) about which you do not feel comfortable
- Your participation is anonymous. Therefore, your name and identity will not be disclosed or contained in the final report of this study (pseudonyms/aliases will be used instead).
- All data will also be stored in a password protected digital form with all identifying features removed. Further, all information gathered through the interview will only be used for research purposes, and all raw data will be destroyed after five years.
- The results of this study will be reported to an academic and professional audience. Its dissemination will be through the thesis report, seminars, conferences and academic journals, all of which may be in print versions or electronic repositories accessible through the World Wide Web
- The summary of the research findings may be made available to you upon request

Please do not hesitate to contact me if there are any questions or clarifications you wish to make using the following contact details.

My contact details: Adeyemi Akintola
Email: adeyemi.akintola1@students.wits.ac.za
Phone number: 0735388583

My supervisors' contact details:
Prof. David Root
Email: david.root@.wits.ac.za
Phone number: 0827353491

Dr Senthilkumar Venkatachalam
Email: Senthilkumar.Venkatachalam@.wits.ac.za

CONSENT FORM

PROJECT TITLE: Modelling a Collaborative Delivery Framework for BIM Projects in South Africa

SHORT TITLE: Understanding the Change Impact of BIM Implementation on Project Team Intra/Inter-organisational Work practices and Workflows

NAME OF RESEARCHER: Adeyemi Akintola

Please tick the box after each statement to which you wish to consent

1	I confirm that I have read and understood the information sheet for the above-titled study and I have had the opportunity to consider the information contained therein	
2	I have been made aware of the purpose of the study	
3	I understand that my participation is voluntary and that I am free to withdraw it anytime	
4	I agree to take part in the study	
5	I agree to being interviewed	
6	I agree to the interview being audio recorded to ensure all information is captured	
7	I agree to take part in a follow-up interview if requested	
8	I would like to see a copy of the interview transcript	

______________	______________	______________
Name of participant	Date	Signature
______________	______________	______________
Name of person taking the consent	Date	Signature

SCHOOL OF CONSTRUCTION ECONOMICS & MANAGEMENT

UNIVERSITY OF THE WITWATERSRAND

A STUDY ON UNDERSTANDING THE CHANGE IMPACT OF BIM IMPLEMENTATION ON PROJECT TEAM INTRA/INTER ORGANISATIONAL WORK PRACTICES AND WORKFLOWS IN SOUTH AFRICA

INTERVIEW PROTOCOL

1. MATERIALS (Ensure that the items on the following checklist are available)
   - Audio recorder and charger ☐
   - Notepads and pens (make 3nr available for each interview) ☐
   - Copies of the 'script' (2nr) ☐
   - Watch or clock ☐
   - Notetaker ☐
   - Participant's contact information (email and phone numbers)
   - Bottles of water (3nr) ☐
2. PREPARATORY TASKS
   - Make firm arrangement for time and place of interview with participant
   - Contact the participant 7 days to agreed date for interview to confirm the date
   - 1 day to scheduled date
     - Ensure all materials as listed above are available
     - Ensure all electronic materials are working
     - Send an email reminder to participant
   - Plan at least 40 minutes setting up time before interview commences
3. MANAGING THE INTERVIEW SESSION
   - Arrive early according to schedule
   - Give a brief introduction as in the attached 'script'
   - Give consent forms to participant to read and complete
   - Begin the interview
4. CONCLUDING THE SESSION
   - Thank the participant
   - All notes and audio recordings should be checked. Thereafter, there should be a brief period of reflection on contextual information.

Time schedule

Task	**Estimated time required**
Setting up time	40 minutes
Actual interview	30 to 90 minutes
Rounding up	15 minutes
De-briefing (may not be at the venue for the interview)	60 minutes
Total	**145 to 205 minutes**

SCHOOL OF CONSTRUCTION ECONOMICS & MANAGEMENT

UNIVERSITY OF THE WITWATERSRAND

A STUDY ON UNDERSTANDING THE CHANGE IMPACT OF BIM IMPLEMENTATION ON PROJECT TEAM INTRA/INTER-ORGANISATIONAL WORK PRACTICES AND WORKFLOWS IN SOUTH AFRICA

INTERVIEW SCRIPT

PART I: PREAMBLE

Thank you for agreeing to meet with us for this conversation. I am Adeyemi Akintola, a research student at the University of the Witwatersrand, Johannesburg, South Africa. The purpose of this interview is to speak with construction industry professional service providers (consultants) who have participated in BIM projects in South Africa. We want to understand your experiences on such projects as compared to non-BIM projects. Particularly, the questioning will focus on how you have carried out their functions, challenges, constraints and specific changes you have had to make in your work practice and workflow. I will be audio-recording our conversation. The purpose of this is so that I can get all the details and at the same time be able to carry on an attentive conversation with you. My colleague here, ________________________________ is also present to take notes as a supplement to the audio recording.

Please base your answers to questions on a BIM project in which you participated or provided professional services. Your answers will be treated as confidential, and neither the transcript nor final report will carry any names or other identifying information

Before we get started, please take a few minutes to read and sign this consent form *(the interviewee is handed the consent form. After its read and signed the tape recorder is turned on if consented to).*

PART II:

Question 1

Background questions

Can you give a brief description of the organisation you work for?

How long have you been qualified to practice ______________? *(State the profession)*

Question 2

In your own words, could you briefly tell me of your understanding of what 'Building Information Modelling' is?

Question 3

Well, that's an interesting perspective. But could you tell me of what informed your decision to adopt and implement BIM?

Probe 1 – When was this?

Probe 2 – How easy was it, transitioning from CAD to BIM?

Probe 3 – Did you observe any benefits?

If so, were they incremental or one-of?

Question 4

What can you say about BIM use in South Africa construction industry, looking at the progression from 3D implementation to more advanced use, say for scheduling, estimating and project team collaboration?

Question 5

What would you say are the important concerns for the construction industry in implementing BIM?

Probe 1 – individuals, firms, project teams?

Question 6

Has BIM influenced how you think about, or visualise your work as a ________? (State profession)

Probe 1 – In what ways?.

Question 7
More to the point, how would you say implementing BIM has shaped your typical day at work in your offices?

Probe 1 – Could you expatiate?

Question 8
How has implementing BIM affected your firm's culture?

Probe 1 – could you expatiate?

At this point, it would be helpful for you to think back to a current or recently completed project on which you provided professional services, and BIM was implemented. I would discuss how your experience on that project differed from a project where you did not use BIM.

Question 9
Could you state the general characteristics of the project upon which you wish to base your responses to the rest of my questions? *(Delivery method, size, scope)*

Question 10
Was a formal plan developed for implementing BIM on the project?

Probe 1 – How was this plan initiated *(if there was one)*?
Probe 2 – How did this affect the project *(whether or not interviewee affirms)*?

Question 11
As a team, how much of BIM practices would you say was implemented on the project, what was the extent? *(Question is about BIM maturity)*

Probe 1 – Did every team member use BIM?
Probe 2 – Were there differences in the level of BIM use among project team members?
Probe 3 – How was project information coordinated? *(Check Question)*
Probe 4 – Did these affect the project in any way?

Question 12
Although we might have touched on similar issues already, but more to the point, did you carry out your tasks differently on the BIM project compared to non-BIM projects?

Probe 1 – Specifically, what were the things you did differently?
Probe 2 – Which aspect(s) of your work would you consider the most impacted?
Probe 3 – Did any of your usual project related activities (pre-BIM) become redundant?

Question 13
How did implementing BIM affect the sequence of activities and information flow within your firm?

Probe 1 – How about between your organisation and that of other team members?
Probe 2 – How did you adjust to accommodate these changes?

Question 14
Did any aspect of the implementation conflict with existing tools you used to employ in carrying out your work for non-BIM projects? E.g. other software or materials?

Probe 1 – Can you expatiate?

Question 15
Did any aspect of the implementation conflict with established guidelines for delivering projects *(contractual conditions, professional ethics, etiquette, conditions of engagement, remuneration etc.)*?

Question 16
How would you compare your roles and responsibilities on typical non-BIM projects to those roles that you took up on the BIM project?

Probe 1 – Did you see your roles on the BIM project as clearly defined?

Probe 2 – Were any new roles and responsibilities created as a result of BIM implementation?

Question 17
How much of an understanding of how your work fits in with that of other team members on an ideal BIM project do you have?

Question 18
We do know that BIM technologies and related tools have developed over the years, but are there any aspects of your work that BIM technologies do not support at all or do not support adequately?

Question 19
Do you have any additional comments, specific to the discussion or general in nature?

Thank you very much for your time.

CONCLUSION OF THE INTERVIEW

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

Table 13.1: Interview questions' structure based on Patton-Wengraf categories

Nr	Interview question (IQ)	Focus of questions							Theory question (TQ)	Analytic rationale
		Behaviours/experience	Feelings	Knowledge	Sensory events	Demography	Opinions	Values		
1	Could you give a brief description of the organisation you work for			x		x			TQ3, TQ4	Extent of BIM implementation will differ by organisation characteristics
2	In your own words, could you briefly tell me of your understanding of what 'Building Information Modelling is?			x			x	x	TQ2	This is basically to elicit participants' general opinions, values and knowledge about and around BIM
3	Well, that's an interesting perspective. But could you tell me of what informed your decision to adopt and implement BIM	x		x					TQ1	Why are organisations making the shift towards BIM?
3a	When was this?			x					TQ2	Organisations with a lot of BIM experience are expected to have better developed BIM protocols and practices than otherwise
3b	How easy was it, transitioning from CAD to BIM?	x	x	x					TQ3, TQ4	To elicit narratives about constraints and impediments to implementing BIM. These would eventually be associated with the changes made in their work practices.
3c	Did you observe any benefits from implementing BIM as a business entity? If so, were they incremental or one-off?	x		x				x	TQ3	To elicit narratives about enablement of benefits from implementing BIM. Specifically on their relationship to business objectives.
4	What can you say about BIM use in South Africa construction industry, looking at the progression from 3D implementation to more advanced use, say for scheduling, estimating and project team collaboration?			x			x		TQ1, TQ2	To elicit their knowledge and opinions about macro-level impediments to implementing BIM to high maturity levels.
5	You probably have a fair idea of how the BIM approach to design and construction works now, but	x	x				x		TQ3, TQ4	To elicit narratives about constraints to or benefits from implementing BIM

Nr	Interview question (IQ)	Focus of questions							Theory question (TQ)	Analytic rationale
		Behaviours/experience	Feelings	Knowledge	Sensory events	Demography	Opinions	Values		
	thinking back, how did it seem to you when you first adopted it?									
6	Keeping all that in mind, what would you say are the important concerns for the construction industry in implementing BIM?			x			x		TQ1 – 4	Participants' constructed ideas about how current BIM related industry challenges may be resolved or addressed.
6a	…for individuals, firms, project teams?			x			x		TQ1 – 4	See 6
7	Have you encountered any challenges in implementing BIM within your organisation?	x		x					TQ3	See 5
7a	How do you manage these challenges?	x		x					TQ3	See 5
8	Has there been any reassignment or creation of new roles and responsibilities within the organisation as a result of implementing BIM?	x		x					TQ3, TQ4	How do organisations respond the demands of implementing BIM?
8a	Which roles and job descriptions?	x		x					TQ3, TQ4	See 8
9	In what ways has implementing BIM shaped organisational procedures, structures and rules within your organisation? (Culture; effect on how things were normally done before BIM adoption)	x		x					TQ3, TQ4	
PROJECT SPECIFIC QUESTIONS										
10	Could you state the general characteristics of the project upon which you wish to base your responses to the rest of my questions? (Delivery method, size,			x					TQ3, TQ4	This is a basis for comparing findings. Further, BIM implementation may be well suited to projects of certain characteristics

Nr	Interview question (IQ)	Focus of questions: Behaviours/experience	Feelings	Knowledge	Sensory events	Demography	Opinions	Values	Theory question (TQ)	Analytic rationale
	scope)									
10a	Was a formal plan developed for implementing BIM on the project?	x		x					TQ3, TQ4	To elicit knowledge of the protocols or procedures through which BIM projects are delivered. Varying implementation protocols or methodologies will lead to non-interoperability or failure of the implementation
10b	How was this plan initiated (if there was one)? Information delivery schedules and execution plans?	x		x					TQ3, TQ4	See 10a
10c	How did this affect the project (whether or not interviewee affirms)?	x					x		TQ3, TQ4	The extent of implementation of BIM on the project will influence the amount of impact on workflows
11	As a team, how much of BIM practices would you say was implemented on the project, what was the extent? (Question is about BIM maturity; 3D object-based modelling, clash detection, concurrence and interactiveness of data sharing, document transfer on project closeout)	x		x					TQ1, TQ2	See 10a
11a	Did every team member use BIM?	x		x					TQ1, TQ2	To determine how integrated the BIM practices were on the project.
11b	Were there differences in the level of BIM use among project team members?	x		x					TQ1	To determine the level of integration and collaboration.
11c	How was project information exchanged and coordinated? (Check Question)	x		x					TQ1	

Nr	Interview question (IQ)	Focus of questions							Theory question (TQ)	Analytic rationale
		Behaviours/experience	Feelings	Knowledge	Sensory events	Demography	Opinions	Values		
11d	Did these affect the project in any way?	x					x		TQ1	To examine how the level of information exchange might have impacted project processes
11e	Which team member hosted and managed the data management system if any?			x					TQ3, TQ4	To determine project BIM leadership responsibility.
12	Although we might have touched on similar issues already, but more to the point, did you carry out your tasks differently on the BIM project compared to non-BIM projects?	x		x					TQ3, TQ4	To assess which changes have actually taken place in professional work practices.
12a	Specifically, what were the things you did differently?	x		x					TQ3, TQ4	To assess which changes have actually taken place in professional work practices.
12b	Which aspect of your work would you consider the most impacted?	x		x					TQ3, TQ4	To assess which changes have actually taken place in professional work practices.
13	How did implementing BIM affect the sequence of activities and information flow within the project team	x		x					TQ3, TQ4	To assess which changes have actually taken place in professional work practices.
13a	Your organisation and that of other team members?	x		x					TQ3, TQ4	
13b	How did you adjust to accommodate these changes	x		x					TQ3, TQ4	To assess challenge coping methods resorted to by the participants/organisations.
14	How would you compare your roles and responsibilities on typical non-BIM projects to those roles that you took up on the BIM project?						x		TQ3, TQ4	To assess which changes have actually taken place in professional work practices.

Nr	Interview question (IQ)	Focus of questions							Theory question (TQ)	Analytic rationale
		Behaviours/experience	Feelings	Knowledge	Sensory events	Demography	Opinions	Values		
14a	Did you see your roles on the BIM project as clearly defined?		x				x		TQ3, TQ4	To elicit impact of changing roles on role clarity and conflict and changing power dynamics.
14b	Were any new roles and responsibilities created as a result of BIM implementation?	x		x					TQ3, TQ4	To assess which changes have actually taken place in professional work practices.
15	What are your thoughts on the information delivery requirements of implementing BIM, were there challenges to meeting up with these requirements on the project?	x		x			x			To examine challenges experienced on multidisciplinary projects
16	Did any aspect of the implementation conflict with contractual provisions for delivering projects (contractual conditions, professional ethics, etiquette, conditions of engagement, remuneration etc.)? Especially considering the alteration of responsibilities.	x		x					TQ3, TQ4	Examination of potential constraints arising from implementing BIM
17	We do know that BIM technologies and related tools have developed over the years, but are there any aspects of your work that BIM technologies do not support at all or do not support adequately?						x			To elicit BIM authoring software tool deficiencies as experienced by the informants.
18	Would you say implementing BIM affected the balance of power, authority and structure among project team members?	x	x				x			Question on the impact of changing work practices on power authority and structure within teams.
19	Do you have any additional comments, specific to the discussion or general in nature?								TQ1 – 4	

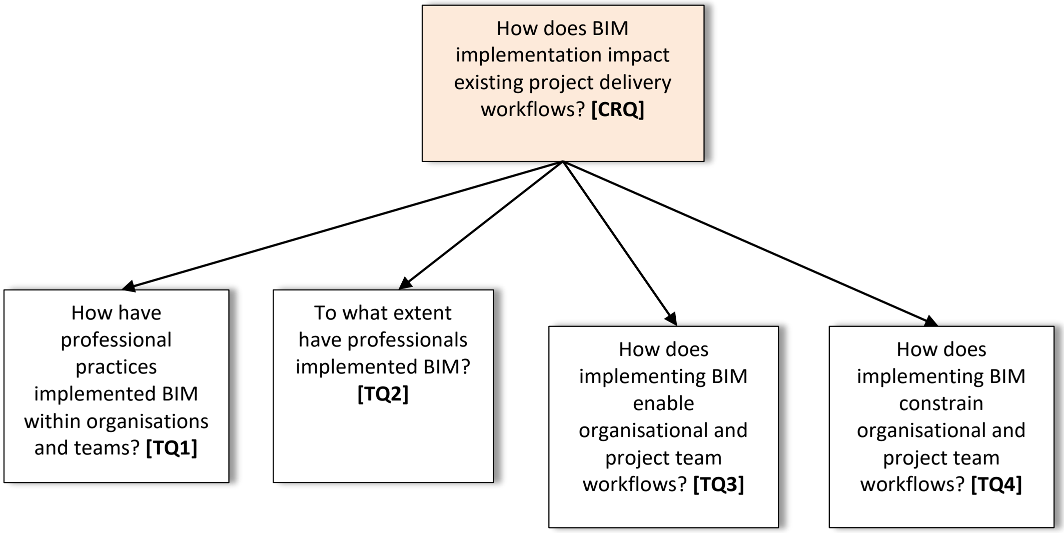

Figure 13.1: Relationship between the research question and the interview questions

SCHOOL OF CONSTRUCTION ECONOMICS & MANAGEMENT

Date: dd-dd-yy

PARTICIPANT INFORMATION SHEET

PROJECT TITLE: Modelling a Collaborative Delivery Framework for BIM Projects in South Africa

SHORT TITLE: Elicitation of Information on Existing (Pre-BIM) Project Delivery Work Practices of Professional Service Providers in the South African Construction Industry

Dear ___________________,

I am Adeyemi Akintola, a research student at the University of the Witwatersrand, Johannesburg. I am conducting a research study, the purpose of which is to help construction industry professionals like you understand the impact of implementing Building Information Modelling (BIM) on the work you do within your organisations, and as part of teams on construction projects. Before this can be achieved, however, it is important that we describe and understand how you currently carry out your functions on a typical construction project against which the impact of BIM will subsequently be evaluated. It will include information about interrelationships, dependencies and input/output of information within your workflow and as a team member on a typical construction project. This information will help to develop an understanding of how implementing Building Information Modelling will impact your work practices and workflows.

I am therefore inviting you to take part in this research project. This is because, as one of the professionals that provide services on construction projects, your experience could provide valuable insight into how you typically provide your services. You may, therefore, be asked (upon consent) to contribute information in a face-to-face interview which will last between 60 – 90 minutes. This will be to walk me through your work processes within your organisation and as part of a project team using a predesigned schedule. For your convenience, this may take place in your offices, or any place of your choice. The interview will take place on a date that will be agreed subsequent upon your acceptance to participate in this study.

Please note the following:

- Your participation is entirely voluntary, and your refusal to participate or withdraw your participation at any time will involve no consequences.
- During the interview, you may refuse to answer any question(s) about which you do not feel comfortable
- Your participation is anonymous. Therefore, your name and identity will not be disclosed or contained in the final report of this study (pseudonyms/aliases will be used instead).
- All data will also be stored in a password protected digital form with all identifying features removed. Further, all information gathered through the interview will only be used for research purposes, and raw data will be destroyed after 5 years.
- The results of this study will be reported to an academic and professional audience. Its dissemination will be through the thesis report, seminars, conferences and academic journals all of which may be in print versions or electronic repositories accessible through the World Wide Web
- The summary of the research findings may be made available to you upon request

Please do not hesitate to contact me if there are any questions or clarifications you wish to make using the following contact details.

My contact details: Adeyemi Akintola
Email: adeyemi.akintola1@students.wits.ac.za
Phone number: 0735388583

My supervisors' contact details:
Prof. David Root
Email: david.root@.wits.ac.za
Phone number: 0827353491

Dr Senthilkumar Venkatachalam
Email: Senthilkumar.Venkatachalam@.wits.ac.za

CONSENT FORM

PROJECT TITLE: Modelling a Collaborative Delivery Framework for BIM Projects in South Africa

SHORT TITLE: Elicitation of Information on Existing (Pre-BIM) Project Delivery Work Practices of Professional Service Providers in the South African Construction Industry

NAME OF RESEARCHER: Adeyemi Akintola

Please tick the box after each statement to which you wish to consent

1	I confirm that I have read and understood the information sheet for the above-titled study and I have had the opportunity to consider the information contained therein	
2	I have been made aware of the purpose of the study	
3	I understand that my participation is voluntary and that I am free to withdraw it anytime	
4	I agree to take part in the study	
5	I agree to be interviewed	
6	I agree to the interview being audio recorded to ensure all information is captured	
7	I agree to take part in a follow-up group brainstorming session on information provided if requested	
8	I would like to see a copy of the interview transcript	

______________________ ______________________ ______________________

Name of participant | Date | Signature

______________________ ______________________ ______________________

Name of person taking the consent | Date | Signature

SCHOOL OF CONSTRUCTION ECONOMICS & MANAGEMENT

UNIVERSITY OF THE WITWATERSRAND
ELICITATION OF INFORMATION ON EXISTING (PRE-BIM) PROJECT DELIVERY WORK PRACTICES OF PROFESSIONAL SERVICE PROVIDERS IN THE SOUTH AFRICAN CONSTRUCTION INDUSTRY

INTERVIEW PROTOCOL

1. MATERIALS (Ensure that the items on the following checklist are available)
   - Audio recorder and charger ☐
   - Notepads and pens (make 3nr available for each interview) ☐
   - Copies of the knowledge elicitation schedule (2nr) ☐
   - Watch or clock ☐
   - Notetaker ☐
   - Participant's contact information (email and phone numbers) ☐
   - Bottles of water (3nr) ☐
2. PREPARATORY TASKS
   - Make firm arrangement for time and place of interview with participant
   - Contact the participant 7 days to agreed date for interview to confirm the date
   - 1 day to scheduled date
     - ✦ Ensure all materials as listed above are available
     - ✦ Ensure all electronic materials are working
     - ✦ Send an email reminder to participant
   - Plan at least 40 minutes setting up time before interview commences
3. MANAGING THE INTERVIEW SESSION
   - Arrive early according to schedule
   - Give a brief introduction as in the attached script.
   - Give consent forms to participant to read and complete
   - Begin the interview
4. CONCLUDING THE SESSION
   - Thank the participant
   - All notes and audio recordings should be checked. Thereafter, there should be a brief period of reflection on contextual information.

Time schedule

Task	Estimated time required
Setting up time	40 minutes
Actual interview	60 to 90 minutes
Rounding up	15 minutes
De-briefing (may not be at the venue for the interview)	60 minutes
Total	**175 to 235 minutes**

SCHOOL OF CONSTRUCTION ECONOMICS & MANAGEMENT

	KNOWLEDGE ELICITATION SCHEDULE FOR COLLECTION OF INFORMATION ON EXISTING (PRE-BIM) PROJECT DELIVERY WORK PRACTICES OF PROFESSIONALS SERVICE PROVIDERS IN THE SOUTH AFRICAN CONSTRUCTION INDUSTRY
	INTRODUCTION AND EXPLANATION OF PURPOSE My name is Adeyemi Akintola, the purpose of this interview is to elicit information from professional services providers about the activities you perform on a typical construction project, i.e. your intra- and inter-organisational workflow in detail. It will include information about interrelationships, dependencies and input/output of information within your workflow. This information will help to develop an understanding of how Implementing Building Information Modelling will impact your work practices. I would like to you inform you that this conversation will be audio recorded. However, this conversation will remain confidential. Before we get started, please take a few minutes to read and sign this consent form *(The interviewee is handed the consent form. After it is read and signed, the interview may proceed).*
Q1	Which professional service does your organisation provide on construction projects?
Q2	The following schedule has been designed to collect or elicit from you, the tasks making up the steps with which you carry out your duties on a typical construction project. Please base your responses on one project you have recently provided professional services?
Q3	Which project delivery framework was used to for the project upon which you wish to base your responses?
Q4	Can you tell me the general characteristics of the project? *(Size, scope of works etc.)*

Label	What are the tasks that you perform, or steps that you take at these major stages of a typical construction project?	Tools used for the task (Software, materials, guides etc.)	This task requires information from which task or from whom (other team members, other task within your functions) – task dependence	Who carries out the task? (within your organisation)
A	**Preparation of strategic brief**			
A1				
A2	***Expandable***			
A3				

Label	What are the tasks that you perform, or steps that you take at these major stages of a typical construction project?	Tools used for the task (Software, materials, guides etc.)	This task requires information from which task or from whom (other team members, other task within your functions) – task dependence	Who carries out the task? (within your organisation)
B	**Investigate design alternatives**			
B1				
B2				
B3				
C	**Analysing design options**			
C1				
C2				
C3				
D	**Preparation of concept report**			
C1				
C2				
C3				
E	**Preparation of project implementation plans**			
E1				
E2				
E3				
F	**Approval of PED**			
F1				

Label	What are the tasks that you perform, or steps that you take at these major stages of a typical construction project?	Tools used for the task (Software, materials, guides etc.)	This task requires information from which task or from whom (other team members, other task within your functions) – task dependence	Who carries out the task? (within your organisation)
F2				
F3				
G	**Professional services procurement**			
G1				
G2				
G3				
H	**Approval of PSP award**			
H1				
H2				
H3				
J	**Design work schedule**			
J1				
J2				
J3				
K	**Architectural design dev.**			
K1				
K2				
K3				

Label	What are the tasks that you perform, or steps that you take at these major stages of a typical construction project?	Tools used for the task (Software, materials, guides etc.)	This task requires information from which task or from whom (other team members, other task within your functions) – task dependence	Who carries out the task? (within your organisation)
L	**MEP design dev.**			
L1				
L2				
L3				
M	**Structural design dev.**			
M1				
M2				
M3				
N	**Cost planning, estimation, and BOQ**			
N1				
N2				
N3				
P	**Approval of design**			
P1				
P2				
P3				
Q	**Approval of cost**			
Q1				
Q2				

Label	What are the tasks that you perform, or steps that you take at these major stages of a typical construction project?	Tools used for the task (Software, materials, guides etc.)	This task requires information from which task or from whom (other team members, other task within your functions) – task dependence	Who carries out the task? (within your organisation)
Q3				
R	**Production information**			
R1				
R2				
R3				
S	**Preparation of procurement doc.**			
S1				
S2				
S3				
T	**Request for tenders**			
T1				
T2				
T3				
U	**Review tenders and rec.**			
U1				
U2				
U3				
V	**Award of contract**			
V1				

Label	What are the tasks that you perform, or steps that you take at these major stages of a typical construction project?	Tools used for the task (Software, materials, guides etc.)	This task requires information from which task or from whom (other team members, other task within your functions) – task dependence	Who carries out the task? (within your organisation)
V2				
V3				
W	**Project execution stage**			
W1				
W2				
W3				

Table 13.2: Glossary of terms

TERM	DEFINITION
Action	Actions define the what actors do to achieve the purpose of their endeavour
Active sum/Active degree	Quantity of outgoing edges
Activity	Division of active sum by passive sum
Activity theory	A theory enables the analysis of emerging patterns of human activity in all its forms in terms of changing processes
BAST (BIM Authoring Software Tool)	A tool or application that is capable of modelling intelligent and parametric graphical information about facilities to produces defined outcomes
BIM process	A process that employs information derived from a BIM authoring tool for representing, analysing, and management of a building facility
Building Information Modelling (BIM)	BIM is a digital representation of the physical and functional characteristics of a facility such that it creates a shared knowledge resource for information about a facility among team members and also forms a reliable basis for their decisions throughout the facility's lifecycle (NIBS 2007 p. 12)
Business Process Re-engineering (BPR)	A process involving the analysis and redesign of intra- and inter-organisational workflows to improve or optimise them.
CDE (Common Data Environment/platform)	A single source of information for a project that assists in collection, management and dissemination of all verified and approved project documents for multi-disciplinary teams. This may employ a server or file transfer based system.
Collaboration/Collective work	Collective, motive-driven work between two or more actors directed towards a common object of interest that may be made up of individual goals
Contradiction	Contradictions within an activity system (dysfunctions) that require studying and analysis within the socio-cultural context
Criticality	Multiplication of active sum and passive sum
Data drop	Extraction of COBie data (graphical and non-graphical) about a facility for transfer to the owner and to aid the facility's management and operation. This is often in a spreadsheet format that will be used to supply data to the owner of facilities manager or operator
Dependency	A relationship between two elements of a system represented by a symbol or a number in a matrix cell
Design Structure Matrices (DSM)	A generic tool used to represent the constituent elements of a (complex) system and their interactions, in effect highlighting the system's structure or architecture in one domain of information
Document	Information for use throughout the whole building lifecycle
Domain	Represents the primary classification of elements in an MDM
Domain Mapping Matrices (DMM)	A generic representation of complex system information in two domains of information
EIR (Employer's Information Requirements)	Pre-tender document setting out the information to be delivered, and the standards and processes to be adopted by the supplier as part of the project delivery process (BSI 2013 p. 4)
Element	Single nodes of a complex system's structure that are aligned symmetrically on two sides of a square matrix
Evolution of work	Development of work practices
Industry Foundation Classes (IFC)	Internationally defined and accepted standard schema for representing building information
Interoperability (business process)	Congruence of different work practices of different organisations or entities in a collaborative project environment

TERM	DEFINITION
Interoperability (technical)	Ability to exchange and understand/read shared data between collaborating parties
MIDP (Master Information Delivery Plan)	primary plan for when project information is to be prepared, by whom and using what protocols and procedures, incorporating all relevant task information delivery plans (BSI 2013 p. 5)
Multi-Domain Mapping Matrices (MDM)	A generic representation of complex system information in more than two domains of information
Operation	Operations are the steps that define 'how' work is actually carried out.
Passive sum/Passive degree	Quantity of incoming edges
PIIP (Project Information Implementation Plan)	Statement of a potential suppliers' IT and human resources capability to deliver on the EIR
Project Information Model (PIM)	BIM design created by specific project team members to represent the whole or parts of a building facility
Strongly connected parts	An edge path can mutually reach all nodes
Theory	That which 'attempts to explain why things work the way that they do, by identifying and examining relationships among things' (Ravitch and Riggan 2017 p.22).
TIDP (Task Information Delivery Plan)	Federated lists of information deliverables by each task, including format, date and responsibilities (BSI 2013 p. 6)
Work practices	How work is done within a specific professional context or field
Workflow	A conceptual representation of tasks and information flow between persons or components within teams within organisations or project teams

Research Office

HUMAN RESEARCH ETHICS COMMITTEE (NON-MEDICAL)
R14/49 Akintola

CLEARANCE CERTIFICATE — **PROTOCOL NUMBER: H15/07/1**

PROJECT TITLE: Modelling a collaborative delivery framework for BIM projects in South Africa

INVESTIGATOR(S): Mr A Akintola

SCHOOL/DEPARTMENT: Construction, Economics & Management /

DATE CONSIDERED: 24 July 2015

DECISION OF THE COMMITTEE: Approved unconditionally

EXPIRY DATE: 13 August 2018

DATE 14 August 2015 **CHAIRPERSON** J. Knight
(Professor J Knight)

cc: Supervisor : Professor D Root

DECLARATION OF INVESTIGATOR(S)

To be completed in duplicate and **ONE COPY** returned to the Secretary at Room 10005, 10th Floor, Senate House, University.

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

____________________ **Signature**

____/____/____ **Date**

PLEASE QUOTE THE PROTOCOL NUMBER ON ALL ENQUIRIES

Figure 13.2: Ethics certificate